A study to evaluate the impact of a Numicon-based intervention on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in mathematics

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Word count: 43,331

Thesis submitted to the University of Nottingham
For the degree of Doctor of Applied Educational Psychology
September 2016

Abstract

"The evidence base on numeracy interventions is patchy" (DfE, 2012, p. 6), and in the majority of studies the statistical analysis of data is not without its limitations (Dowker, 2009). The purpose of this study is therefore to add to this evidence base.

A mixed methods explanatory sequential design was used to explore the efficacy of a Numicon-based intervention on the numeracy attainment and attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties.

Phase 1 implemented a pre-test post-test quasi-experimental design to explore the impact of a Numicon-based intervention across four primary schools. Twenty-five children aged 7 to 8, working at Levels 1C to 2B in numeracy, were allocated to the experimental condition (n = 15) and waiting list control (WLC) condition (n = 10). Interventions were delivered during the autumn term to children in the experimental condition by trained staff within school. The duration and content of sessions varied depending upon the needs of the children. The WLC condition received the intervention during the spring term.

The Sandwell Early Numeracy Test- Revised (SENT-R) was administered to investigate the impact of the intervention on numeracy attainment. At post-testing, no statistical significance was found between the experimental and WLC conditions. The null hypothesis was therefore accepted. The 'Maths and Me Survey' was used to measure children's attitudes towards numeracy. Again, at post-testing, no statistical significance was found between conditions, and so the null hypothesis was accepted.

During phase 2 of the study, interviews were conducted to obtain the facilitators perceptions of the intervention. Using thematic analysis, two overarching themes were identified: 'outcomes of the intervention' which focussed on affective factors and children's knowledge and understanding;

and ‘factors and underpinning mechanisms’, which considered the importance of a whole school ethos, the role of parents, features of Numicon, practicalities of implementing an intervention and theoretical underpinnings.

The findings of the current study are considered in light of previous research, as are the implications for Educational Psychologists and other professionals. Methodological issues that arose during the study are also discussed. Areas of future research are considered, focussing on the need for more research into the efficacy of Numicon-based interventions and on the development of attitudes towards numeracy.

Acknowledgements

There are many people who I would like to acknowledge and thank for their continuing support and advice during this research and the entire Doctoral training process:

- To the staff, parents and children who participated in this study. Without you all of this would not have been possible.
- To all of the tutor team at the University of Nottingham, especially Sarah Atkinson for all her support, guidance and advice; and for always reminding me that I could succeed.
- To my colleagues at Northamptonshire County Council Educational Psychology Service, especially my supervisor Helen Watson for her on going professional and emotional support, and to Marian Keenaghan (Senior Educational Psychologist) and team leader.
- To my fellow Trainee Educational Psychologists, both at the University of Nottingham and on placement. Thank you for all of your support and for being part of this journey.
- To my amazing friends. I cannot name you all individually, but you have all been there for me these past three years, and I value your friendship so much. I would especially like to thank Sarah for encouraging me when things were tough, and Linda and Nicole for all of your advice and support.
- To my wonderful parents, Joyce and Geoff. Thank you for always believing in me and encouraging me to follow my dreams. You have taught me so much and for that I will always be grateful.
- Finally to my partner Chris. The past three years have not always been easy, but there is no one else I would rather have had by my side throughout it. Thanks for always being there, for supporting me, believing in me, showing endless patience and just being you. Thank you also for being my proof reader and for helping me to use R-Studio.

Table of contents

Chapter 1 Introduction 1

1.1 The study 1

1.2 Personal and professional interest in the research 1

1.3 Professional relevance 2

1.4 Overview of the thesis 2

Chapter 2 Literature Review 4

2.1 Introduction 4

2.2 Definition of numeracy 4

2.3 Educational and political context 4

2.3.1 The importance of literacy and Numeracy within education 4

2.3.2 The current perspective towards numeracy 6

2.3.2.1 Policy and guidance 6

2.3.2.2 Criticisms of current policy 8

2.4 Why is numeracy important? 9

2.4.1 The importance of numeracy in the long term 9

2.4.2 The overemphasis on literacy 10

2.5 Mathematical difficulties 11

2.5.1 Terminology 11

2.5.2 Mathematical difficulties in children 12

2.5.3 The role of educational psychologists 13

2.6 Attitudes towards numeracy 14

2.6.1 Children's attitudes towards numeracy 15

2.6.2 The relationship between attitudes to numeracy and attainment 16

2.7 Numeracy interventions 17

2.7.1 The importance of intervention 17

2.7.2 What makes an effective numeracy intervention? 18

2.7.3 The role of support staff 20

2.7.4 Numeracy interventions in the UK 22

2.8 Numicon 26

2.8.1 What is Numicon? 26

2.8.2 Theoretical underpinning of Numicon 29
2.8.3 The role of manipulatives and representations in numeracy 29
2.8.3.1 Manipulatives and the mastery approach to mathematics . 32
2.8.4 The effectiveness of Numicon 33
2.8.5 The impact of Numicon on attitudes towards numeracy 35
2.9 Critical review of the evidence base for Numicon 35
2.9.1 Systematic literature review 35
2.9.2 Search terms and inclusion/ exclusion criteria 36
2.9.3 Frameworks of analysis 41
2.9.4 Data analyses 43
2.9.5 Data synthesis 49
2.9.5.1 Sample 49
2.9.5.2 Design 50
2.9.5.3 Intervention 51
2.9.5.4 Measures 55
2.9.5.5 Key findings 58
2.9.6 Conclusion of evidence base 61
2.10 The Research 61
2.10.1 Research questions 61
2.10.2 Unique contribution 62

Chapter 3 Methodology 63

3.1 Introduction 63
3.2 Science and Research 63
3.2.1 What is research? 63
3.2.2 Research and Educational Psychology 63
3.3 Philosophical Assumptions 64
3.3.1 Different paradigms 64
3.3.2 The post-positivist paradigm 67
3.3.3 The constructivist paradigm 67
3.3.4 The pragmatic paradigm 68
3.3.5 The philosophical assumptions underpinning the current study 69
3.4 Mixed Methods 69
3.4.1 Definition of mixed methods 69

3.4.2 Using mixed methods in the current study 70
3.5 Phase 1: The quantitative aspect of the study 71
3.5.1 Research questions and hypotheses 71
3.5.2 Independent and dependent variables 73
3.5.3 The Design Procedure 73
3.5.4 Sampling 73
3.5.4.1 Selection of schools 73
3.5.4.2 Selection of pupils 76
3.5.5 Conditions 79
3.5.5.1 Experimental condition 79
3.5.5.2 Waiting- list control (WLC) condition 79
3.5.6 Measures 80
3.5.6.1 Measures of numeracy attainment 80
3.5.6.2 Measures of attitudes towards numeracy 83
3.5.6.3 Administration of measures 85
3.5.7 Procedure 86
3.5.7.1 Information regarding facilitators 88
3.5.7.2 Completion of phase 1 89
3.6 Phase 2: The qualitative aspect of the study 94
3.6.1 Research question 94
3.6.2 The Design Procedure 94
3.6.2.1 Selection of facilitators 94
3.6.2.2 Interview with facilitators 94
3.6.3 Process of data analysis during phase 2 96
3.7 Design Considerations 98
3.7.1 Design considerations for phase 1 99
3.7.1.1 Threats to internal validity 99
3.7.1.2 Threats to external validity 102
3.7.1.3 Additional threats 105
3.7.2 Design considerations for phase 2 106
3.8 Ethical Considerations 108
3.9 Summary 111

Chapter 4 Data Analyses 112
4.1 Introduction 112
4.2 Phase 1: Quantitative data analyses 112
4.2.1 Types of data analyses 112
4.2.2 Parametric and non-parametric tests 113
4.2.2.1 Parametric tests 113
4.2.2.2 Non parametric tests 114
4.2.2.3 Limitations of statistical significance testing 114
4.2.3 Meeting parametric assumptions 115
4.2.3.1 Assessing whether data is normally distributed 115
4.2.3.1a Visual representations 115
4.2.3.1b Skewness and kurtosis 116
4.2.3.1c Tests of normality 116
4.2.3.2 Testing for homogeneity of variance 117
4.2.4 Data analysed from phase 1 117
4.2.5 Statistical testing used in phase 1 analyses 118
4.2.6 Data analyses for research question 1 118
4.2.6.1 Descriptive statistics 119
4.2.6.2 Does the data meet parametric assumptions? 120
4.2.6.2a Visual analyses of data 120
4.2.6.2b Test of normality 123
4.2.6.2c Homogeneity of variance 124
4.2.6.3 Inferential statistics 124
4.2.6.3a Preliminary analyses for ANCOVA 124
4.2.6.3b ANCOVA 125
4.2.6.3c Gains within both conditions 126
4.2.6.4 Conclusion 127
4.2.7 Data analyses for research question 2 127
4.2.7.1 Descriptive statistics 128
4.2.7.2 Inferential statistics 130
4.2.7.2a Gains within both conditions 131
4.2.7.3 Conclusions 133
4.3 Phase 2: Data analyses 133
4.3.1 Familiarising oneself with data 133

4.3.2 Generating initial codes 134
4.3.3 Searching for themes 134
4.3.4 Reviewing themes 135
4.3.4.1 Inter-rater reliability checks 135
4.3.4.2 Member checks 136
4.3.5 Defining and naming themes 137
4.3.5.1 Overarching theme 1 139
4.3.5.1a Theme 1: Impact on affective factors 139
4.3.5.1b Theme 2: Impact on knowledge and understanding 139
4.3.5.2 Overarching theme 2 140
4.3.5.2a Theme 1: Theoretical underpinnings 140
4.3.5.2b Theme 2: Whole school ethos 142
4.3.5.2c Theme 3: Practicalities 142
4.3.5.2d Theme 4: The role of the Numicon equipment 143
4.3.5.2e Theme 5: The role of parents 144
4.3.6 The overall story 144
4.4 Summary 146

Chapter 5 Discussion 147

5.1 Introduction 147
5.2 Research findings 147
5.2.1 Research question 1 147
5.2.1.1 The use of SENT-R 148
5.2.1.2 Numicon as a confounding variable 151
5.2.1.3 The Numicon-based intervention 152
5.2.1.4 Individual differences 155
5.2.2 Research question 2 157
5.2.3 Research question 3 160
5.3 Methodological limitations of the current study 165
5.3.1 Limitations of phase 1 166
5.3.1.1 Internal validity 166
5.3.1.2 External validity 167
5.3.2 Limitations of Phase 2 168
5.4 Ethical considerations 170

5.5 Implications of the current study 172
5.5.1 Professional implications for EPs 172
5.5.2 Implications for other professionals 174
5.5.3 Implications for future research 175
5.6 Author's reflections 179

Chapter 6 Conclusion 181

References 182

Primary References 182
Secondary References 208

Appendices 209

Table of Tables

Table 2.1 Numeracy interventions used in primary schools to support pupils with mathematical difficulties (Dowker, 2009) 23

Table 2.2 The impact of Numicon on the attainment of pupils in primary schools..... 33

Table 2.3 Inclusion and exclusion criteria for Systematic Literature Review 38

Table 2.4 The Weight of Evidence Framework (Gough, 2007) 42

Table 2.5 An analysis of the key studies identified using the WoE Framework (see Appendix 5 for more details) 43

Table 2.6 Key features of interventions evaluated in individual studies 52

Table 2.7 Key features of the attainment measures..... 55

Table 3.1 The Four Paradigms Used in Educational and Psychological Research (Adapted from Mertens 2005)..... 65

Table 3.2 The research questions and hypotheses for phase 1 72

Table 3.3 Demographic features of the schools participating in the current study 76

Table 3.4 Information about Parent/ Carers Meetings 77

Table 3.5 Demographic Features of Pupils Participating in the Numicon-Based Intervention Groups 78

Table 3.6 National Curriculum Levels of Pupils Participating in the Numicon-based Intervention Groups at the End of KS1 in July 2015..... 78

Table 3.7 Measures of numeracy skills considered to assess attainment.... 81

Table 3.8 Key features of 'The Mathematics Anxiety Questionnaire' and 'The Maths and Me Survey' 83

Table 3.9 Delivery of the Numicon-based intervention for the experimental condition in each school..... 87

Table 3.10 Objectives taught during the Numicon-based intervention in each school 91

Table 3.11 Threats to internal validity and management of identified threats (Based upon Campbell & Stanley, 1963, from Mertens, 2005, p. 121-124; Cohen, et al., 2007) 100

Table 3.12 Threats to External Validity and management of identified threats (Based upon Bracht & Glass, 1968, from Mertens, 2005 p.125-126)..... 103

Table 3.13 Treatment fidelity checks of the Numicon-based interventions 105

Table 3.14 Processes implemented to ensure credible qualitative research in the current study 107

Table 3.15 Ethical principles and considerations relevant to the current research (Based on BPS, 2009; BPS, 2014; HCPC, 2012; UoN, 2015) For details of references to specific guidance see Appendix 22..... 109

Table 4.1 The four levels of data from Robson (2011, p. 420)..... 113

Table 4.2 Effect sizes identified by Cohen (1988) taken from Howell (2013) 115

Table 4.3 Descriptive statistics of the SENT-R for the experimental and WLC conditions at T1 and T2 119

Table 4.4 Results for the Shapiro-Wilk test of normality for the T1 scores of the experimental and WLC conditions 123

Table 4.5 The mean raw score gains in attainment made per school for children in both conditions as measured by the SENT-R..... 126

Table 4.6 Descriptive statistics of the ‘Maths and Me Survey’ for the experimental and WLC conditions at T1 and T2 128

Table 4.7 The mean Likert rating score for an individual statement on each subscale at T1 and T2 for the experimental and the WLC condition..... 129

Table 4.8 The mean raw score gains in attitudes towards numeracy made per school for children in both conditions as measured by the subscales of the ‘Maths and Me Survey’ 132

Table 5.1 The percentage of questions used to assess each sublevel of the National Curriculum on the SENT-R 149

Table 5.2 Ideas for future research 176

Table of figures

Figure 2.1 Numicon shapes and number line 28

Figure 2.2 Numicon shapes showing number bonds to 10 28

Figure 2.3 Numicon shapes representing division calculations..... 28

Figure 2.4 A diagram to show the flow of information through the different phases of the systematic review (Based on Moher, Liberati, Tetzlaff, Atman and the PRISMA Group 2009) 40

Figure 3.1 An illustration of the explanatory sequential design current study71

Figure 3.2 An illustration of the design procedure for phase 1 of the current study 93

Figure 4.1 A histogram to show the distribution of scores for children in the experimental condition at T1 121

Figure 4.2 A histogram to show the distribution of scores for children in the WLC condition at T1 121

Figure 4.3 A Q-Q Plot to show the distribution of scores for children in the experimental condition at T1 122

Figure 4.4 A Q-Q Plot to show the distribution of scores for children in the WLC condition at T1 123

Figure 4.5 A scatterplot to show the relationship between the covariate and the dependent variable with regression lines 125

Figure 4.6 A hierarchical overview of the overarching themes, themes and subthemes identified through TA 138

Table of appendices

Appendix 1 Summary of articles excluded following title scan 209

Appendix 2 Records from systematic search rejected based upon inclusion and exclusion criteria following article screening 210

Appendix 3 Articles identified for systematic literature review..... 214

Appendix 4 Criteria for each of the Weight of Evidence strands 215

Appendix 5 Weight of Evidence analyses of the key studies identified for the systematic literature review..... 216

Appendix 6 Expression of interest letter..... 219

Appendix 7 Confirmation of ethical approval received from the University of Nottingham Ethics Committee Review..... 222

Appendix 8 Stakeholders' responsibilities sheet 223

Appendix 9 Presentation shown at parents/ carers research meeting 228

Appendix 10 Information sheet for parents/ carers 231

Appendix 11 Information sheet for children..... 234

Appendix 12 Prompt cards to support completion of the 'Maths and Me Survey' 238

Appendix 13 Script for administration of SENT-R and the 'Maths and Me Survey' 240

Appendix 14 Questions asked to provide a pen portrait of facilitators..... 241

Appendix 15 Example session plan from school B 242

Appendix 16 Example session plan from school D 243

Appendix 17 Information sheet for facilitators 244

Appendix 18 Semi-structured interview for facilitators 247

Appendix 19 Treatment fidelity checklist..... 248

Appendix 20 Ethical guidance from the British Psychological Society, the Health and Care Professions Council and the University of Nottingham ... 249

Appendix 21 Raw data collected at T1 251
Appendix 22 Raw data collected at T2 255
Appendix 23 Notation system used for orthographic transcripts 259
Appendix 24 Author's summary of initial impressions of interviews with the facilitators 260
Appendix 25 Example of codes identified for data extracts 263
Appendix 26 Codes identified at stage 1 of TA 267
Appendix 27 The initial sorting of codes into candidate themes 269
Appendix 28 Grouping of codes into candidate themes 272
Appendix 29 Codes and themes that were disregarded at stage 4 of TA .. 275
Appendix 30 Inter-rater reliability for coding of data extracts 276
Appendix 31 Inter-rater reliability for themes 279
Appendix 32 Debrief statements for parents/ carers 280
Appendix 33 Debrief statement for facilitators 282
Appendix 34 Summary of research for schools 284
Appendix 35 Summary of research for parents/ carers 287

Table of data disc appendices

Appendix 1 R-Studio output: Experimental group attainment data (pre- and post-test)- Descriptive statistics

Appendix 2 R-Studio output: Waiting list control group attainment data (pre- and post-test)- Descriptive statistics

Appendix 3 R-Studio output: Levene's test- Pre-test attainment data for experimental and waiting list control group

Appendix 4 R-Studio output: Homogeneity of regression line for attainment data

Appendix 5 R-Studio output: ANCOVA for attainment data

Appendix 6 R-Studio output: Experimental group attitudes data (pre- and post-test)- Descriptive statistics

Appendix 7 R-Studio output: Waiting list control group attitudes data (pre- and post-test)- Descriptive statistics

Appendix 8 R-Studio output: Wilcoxon rank-sum test of attitudes (Pre- and post-test data)

Appendix 9 Transcript for interview with Amy

Appendix 10 Transcript for interview with Beth

Appendix 11 Transcript for interview with Clare

Appendix 12 Transcript for interview with Debbie

Appendix 13 Author's summary/ paraphrasing of each data extract

Appendix 14 Codes identified for data extracts

Glossary of abbreviations

ABBREVIATION	EXPLANATION
ANCOVA	Analysis of covariance
BPS	British Psychological Society
CPA	Concrete – Pictorial – Abstract
CUN	Catch Up Numeracy
DfE	Department for Education
DfES	Department for Education and Skills
DV	Dependent variable
EAL	English as an Additional Language
EC	Exclusion Criteria
ECC	Every Child Counts
EHC Plans	Educational and Health Care Plans
EPs	Educational Psychologists
EPS	Educational Psychology Service
FSM	Free school meals
HCPC	Health Care Practitioners Council
IQR	Interquartile ranges
IV	Independent variable
KS1	Key Stage 1: Children aged 5 to 7 years old
KS2	Key Stage 2: Children aged 7 to 11 years old
LA	Local Authority
LSAs	Learning Support Assistants
LST	Learning Support Team
MBC	Metropolitan Borough Council
NC	National Curriculum
NCETM	National Centre for Excellence in the Teaching of Mathematics
NLS	National Literacy Strategy
NNS	National Numeracy Strategy
NSAs	Numeracy Support Assistants
NVQ	National Vocational Qualification

ABBREVIATION	EXPLANATION
OECD	The Organisation for Economic Co-operation and Development
Ofqual	The Office of Qualifications and Examinations Regulation
OFSTED	Office for Standards in Education
OSI	Oxford School Improvement
OUP	Oxford University Press
PISA	Programme for International Student Assessment
RCT	Randomised control trials
SATS	Standard Attainment Tests (National Curriculum Tests)
SEN	Special Educational Needs
SCED	Single Case Experimental Design
SENCo	Special Educational Needs Coordinator
SENT-R	Sandwell Early Numeracy Test- Revised
SLR	Systematic Literature Review
SLTs	Senior Leadership Teams
T1	Time 1
T2	Time 2
TA	Thematic analysis
TEP	Trainee Educational Psychologist
TSA	Teaching School Alliances
UoN	University of Nottingham
WLC	Waiting-list control
WoE	Weight of Evidence

Chapter 1 Introduction

1.1 The study

Numicon is a multi-sensory teaching approach that can be used in whole class learning or as an intervention to support children experiencing mathematical difficulties. The purpose of this study is to investigate the impact of a Numicon-based intervention on the numeracy attainment, which shall be referred to as attainment, and attitudes towards numeracy of Year 3 children experiencing mathematical difficulties.

1.2 Personal and professional interest in the research

I am a Trainee Educational Psychologist (TEP) currently on a two year placement in a Local Authority (LA) Educational Psychology Service (EPS), as part of my Doctoral training. My interest in numeracy stems from when I undertook a Primary Postgraduate Certificate in Education with a mathematics and Key Stage 2 (KS2) specialism. Recently, through discussions with other educational psychologists (EPs), I have become aware that more and more schools are asking for advice and support when working with children experiencing mathematical difficulties, many of which use Numicon to support children experiencing such difficulties. These observations are consistent with findings from a survey of 457 teachers, in which 50 per cent reported that they used Numicon in numeracy (Gifford, Back & Griffiths, 2015). Whilst Numicon appears to be used in many schools, the evidence-base is limited. As an evidence-based practitioner, the purpose of the current study is therefore to investigate the efficacy of a Numicon-based intervention.

I chose to focus on Year 3 children who were experiencing mathematical difficulties, as I had previous experience of teaching in KS2. I was also aware that the majority of previous research into the effectiveness of Numicon had been conducted in Key Stage 1 (KS1). Not only was I interested in the impact the intervention had on attainment, but I was also interested in the impact

participation had on attitudes towards numeracy. As a teacher I had seen many children who displayed negative attitudes towards numeracy, especially those who found the subject difficult. This view was supported through discussions with teachers and parents that I have met since becoming a TEP.

1.3 Professional relevance

The study has professional relevance for EPs as it investigates whether a published numeracy scheme used as an intervention, is an effective way for schools to support children with mathematical difficulties, thus promoting evidence-based practice. Factors that impact on the success of the intervention are also explored, with the intention of enabling EPs to provide more support to schools when delivering such interventions.

1.4 Overview of the thesis

In the next chapter, the educational and political contexts, which have impacted upon the teaching of numeracy in England, are discussed. Consideration is given to the long term impact of mathematical difficulties, and what such difficulties entail. The relationship between numeracy difficulties and attitudes towards numeracy is also considered. Numeracy interventions currently used in primary education are then discussed, with a focus on Numicon and the use of manipulations in numeracy. A systematic review of research evaluating the effectiveness of Numicon is completed, and the current study introduced.

Chapter 3 highlights the importance of research for EPs and philosophical assumptions underpinning such research. The author's epistemological and ontological stance and the rationale for using a mixed methods design are shared. Methodological details about phase 1 and 2 of the study, and information about ethical and design considerations are discussed.

In chapter 4 the process of data analyses undertaken during phases 1 and 2 in order to explore the research questions is described. Data is analysed using both quantitative and qualitative methods of analyses.

The findings of the current study are discussed in chapter 5. Limitations are considered, as is the value of the current study. Implications for EPs and other professionals, as well as opportunities for future research, are also considered.

In the final chapter the findings of the current study are summarised. The limitations are acknowledged, but the author also identifies why the research is of value.

Chapter 2 Literature Review

2.1 Introduction

In this chapter the educational and political contexts, which have impacted upon the teaching of numeracy in England are discussed. Consideration is given to the importance of numeracy, particularly the long term impact of mathematical difficulties. Mathematical difficulties are discussed, as is the relationship between such difficulties and attitudes towards numeracy. Information on numeracy interventions currently used in primary education is provided, focussing on Numicon. The chapter concludes with a systematic review of research evaluating the effectiveness of Numicon, and the introduction of the current research.

2.2 Definition of numeracy

It is important to provide a clear definition of the term 'numeracy'. Numeracy is often used in primary schools instead of the term mathematics, and is a contraction of 'numerical literacy' (Compton, Fielding & Scott, 2007).

The National Numeracy Strategy (1999) defined numeracy as:

> *"A proficiency which involves confidence and competence with numbers and measures. It requires an understanding of the number system, a repertoire of computational skills and an inclination and ability to solve number problems in a variety of contexts. Numeracy also demands practical understanding of the ways in which information is gathered by counting and measuring, and is presented in graphs, diagrams, charts and tables.* (DfEE, 1999, p. 4)"

2.3 Educational and political context

2.3.1 The importance of literacy and Numeracy within education

Since the passing of the 1870 Elementary Education Act, in which education became compulsory for all children aged 5 to 13, there has been an

emphasis on the teaching of the '3Rs' (reading, 'riting and 'rithmetic). This emphasis continued throughout the 20th century (Galton, Simon & Croll, 1980).

Following the introduction of the National Curriculum in the 1988 Education Reform Act, literacy and numeracy, alongside science, became core subjects that all children and young people of compulsory school age should be taught. The introduction of the mathematics National Curriculum was *"undoubtedly the most significant statutory intervention in primary mathematics for over a hundred years."* (Askew, Millett, Brown, Rhodes & Bibby, 2001, p. 5-6).

Despite the introduction of the National Curriculum, standards in literacy and numeracy continued to fall during the late 1980s and early 1990s (Alexander, Rose & Woodhead, 1992). In 1995, at the end of KS2, 49 per cent of pupils achieved the expected Level 4 in literacy and 47 per cent in numeracy (DfE, 2011a).

Following the election of the Labour Government in 1997 the 'National Literacy Strategy' (NLS) and the 'National Numeracy Strategy' (NNS) were introduced in 1998 and 1999 respectively. Although the strategies were non-statutory documents, having an advisory status, schools were expected to implement them (Webb, 2010). The NLS aimed to raise standards in literacy by providing teachers with a framework for teaching with detailed termly objectives and advice on how these could be met (Beard, 1999). Whilst the NNS aimed to raise standards in numeracy by changing the teaching approaches used within schools (Jones, 2002).

The introduction of these strategies resulted in some improvements in literacy and numeracy (DfE, 2011a), but in the mid-noughties, nearly 25 per cent of children were still not achieving a Level 4 in numeracy, and there was still room for improvements in writing (DfES, 2006). This lead to the introduction of the 'Primary Framework for Literacy and Mathematics' in 2006 which, by providing guidance on *"planning, teaching and assessment"* (DfES,

2006, p. 3), aimed to, *"support and increase all children's access to excellent teaching, leading to exciting and successful learning."* (DfES, 2006, p.1).

In 2009 however, The House of Commons Children, Schools and Families Committee concluded there was no evidence to suggest that one way of teaching literacy and numeracy was best, and that the implementation of strategies such as the Primary Framework had deskilled many teachers. They therefore recommended schools should continue to deliver a broad and balanced curriculum, but this should be less prescriptive than the current National Curriculum with *"a basic entitlement for literacy and numeracy and offering general guidelines on breadth and balance to be interpreted by schools and teachers themselves."* (p. 23).

In 2010 the Conservative- Liberal Democrats Coalition Government came into government. This resulted in the development of a new Curriculum Framework consisting of a School Curriculum and a National Curriculum (DfE, 2013). This states that all state-funded schools must offer the School Curriculum, which is a balanced and broad curriculum. Schools maintained by Local Authorities (LAs) are also legally required to follow the National Curriculum programme of study (DfE, 2013).

2.3.2 The current perspective towards numeracy

2.3.2.1 *Policy and guidance*

Following the introduction of the Curriculum Framework (DfE, 2013), numeracy continues to be taught in all schools, whether academies, free or maintained (DfE, 2014a). Government guidance emphasises the importance of developing numeracy across all subjects in order to highlight its importance, and a range of skills are taught (DfE, 2013).

The concept of mastery is central to the current mathematics curriculum (NCETM, 2014). This emphasises the importance of all children developing a deep understanding of mathematics (Askew et al., 2015), and is underpinned by the following principles and features:

- All children have the potential to understand and achieve.
- All children are taught the same mathematical concepts. Those who are not secure in such concepts received additional support. Whilst those who grasp new concepts quickly, should not move onto learning new concepts, but should be challenged through "*enrichment and deepening on content"* (Askew et al., 2015, p. 6).
- Children need to have a secure understanding of basic mathematical concepts in order to progress in their learning. Over time this understanding develops so they are able to apply a range of concepts and procedures to various problems.
- Practice and consolidation are vital in order to develop fluency and understanding of mathematical concepts.

(Askew et al., 2015; NCETM, 2014)

In July 2016, Nick Gibb (Minister of State at the Department of Education) announced that schools would receive £41 million to support the implementation of the 'mastery' approach to mathematics which is used in China, Singapore and Hong Kong (DfE, 2016). To coincide with this announcement, Boylan et al. (2016) published their interim research report, evaluating the implementation of the mastery approach to teaching mathematics in 48 primary schools. Initial findings suggested that the implementation of such an approach had had a positive impact on pupil outcomes.

Recent guidance has also highlighted the role of teachers and the importance of them having secure subject knowledge (Vorderman, Porkess, Budd, Dunne, & Rahman-Hart, 2011). It has been recommended that there be mathematics specialists in all primary schools who have *"deep subject knowledge and deep knowledge of how to teach mathematics"* (NCETM, 2014). A further recommendation is that all schools should have access to an 'external consultant' (or 'knowledgeable other') who is able to support them in enhancing their mathematics curriculum so that all children are able to become mathematically confident (Burghes et al., 2012).

2.3.2.2 *Criticisms of current policy*

Despite a new curriculum, there are some criticisms of current policy and the current curriculum.

The current mathematics curriculum reflects the content and principles of those found in internationally high performing education systems, especially those in East and South-East Asia (NCETM, 2014). Whilst data from the Programme for International Student Assessment (PISA) suggests that 15 year olds in these areas are top-performers in mathematics (OCED, 2014) there are concerns that evidence was selected in order to support the Government's review of the National Curriculum, without considering the wider cultural, economic and social contexts (Alexander, 2012). It has also been argued that wider research regarding the teaching and learning of mathematics has been ignored (Thompson, 2012).

Thompson (2012) highlighted the following additional concerns:

- The new curriculum is too prescriptive, with teachers being told the exact procedures they should use in order to teach formal addition and subtraction.
- Some of the content such as teaching children to read Roman numerals or learning the 12 times table are not relevant.
- The new curriculum is too demanding; topics that research suggests Year 4 children find difficult have now been moved into the Year 3 programme of study.

There are concerns that a significant proportion of Year 6 teachers will continue to teach to the SATS (Alexander, 2012). This has previously been found to have a negative impact on pupils, reducing their opportunities to learn about, and develop a wider range of mathematical concepts (OFSTED, 2008).

A final criticism is raised by Boaler (Montague & Boaler, 2014) who argues that children are currently taught a narrow and impoverished version of what

mathematics really is. She believes that real mathematics of the world needs to be brought into the classroom.

2.4 Why is numeracy important?

2.4.1 The importance of numeracy in the long term

The above highlights the role numeracy plays in education, but why is it important for children and young people to be taught such skills?

Not only are numeracy skills essential for everyday tasks such as budgeting and data-handling (Norris, 2012), but the changing nature of the international economic climate, in which the fields of Science, Technology, Engineering and Mathematics are starting to take a central role, has resulted in a greater demand for numeracy skills and knowledge. If the UK economy is to continue to grow and young people are to compete in the international job market, they need to be taught such skills and knowledge (The Royal Society, 2011).

Currently 30 per cent of young people do not achieve a grade C or above in GCSE mathematics (Ofqual, 2015). Whilst in primary schools, 13 per cent of children leave without achieving the expected attainment of a Level 4. This does not include children working below a Level 3, as they do not take the SATs (DfE, 2015). National data also suggests children are less likely to achieve a Level 4 at the end of KS2 and a good GCSE grade if they fail to achieve a Level 2C at the end of KS1 (The National Strategies, 2010).

The long term impact of literacy and numeracy difficulties were investigated using data from two longitudinal studies; the 1958 National Child Development Study and the 1970 British Cohort Study (Parson & Bynner, 2005). Data, from 17,000 adults born in the respective years, were collected until 2004. They found that a higher percentage of men and women with poor literacy and numeracy skills left school at 16 compared to those who were competent in these areas. This resulted in them having fewer qualifications,

and less likely to be working in full time employment. In addition, men with poor numeracy and literacy skills were likely to be on lower wages, working in semi-skilled or unskilled jobs, and have fewer opportunities for training and promotion, whilst 40 per cent of women with poor skills were in manual work.

There was a stronger association between poor numeracy skills and low-economic wellbeing in adults at the age of 30, than poor literacy skills and low-economic wellbeing. In women, the impact of poor numeracy skills was greater than that of poor literacy skills, with such women reporting lower self-esteem. Whilst in men, poor numeracy had the equivalent impact of poor numeracy and literacy skills combined. Men with poor numeracy skills were also more likely to be at risk of depression, compared to those with poor literacy skills.

The authors concluded that poor numeracy skills were associated with negative effects on life outcomes, although the combination of poor literacy and numeracy skills had the greatest negative impact on an individual's economic, social and emotional outcomes.

Following a review of the research into the long term costs of numeracy difficulties, Gross (2009) identified that such difficulties resulted in additional provision needed within school, a greater risk of truancy or exclusion from school, fewer employment opportunities, increased health risks and an increased risk in criminal activities. The report concluded that a child, who failed to master basic numeracy skills during primary school, was likely to cost the 'public purse' between £4000 and £67000 over their lifetime. Martin and Hodgson (2014) also reported that low levels of adult numeracy cost the UK economy £20.2 billion in 2012.

2.4.2 The overemphasis on literacy

Despite research suggesting numeracy difficulties can have a long term negative impact on individual opportunities, and financial implications for

society, it has been argued that there is an assumption that numeracy is less important than literacy (Parson & Bynner, 2005).

In England there has previously been an emphasis on literacy difficulties. Greg Brookes' paper, 'What Works for Children with Literacy Difficulties' was originally published in 1998, and is now on its fourth edition (Brookes, 2013), but it was not until 2004 that the Department for Education and Skills commissioned a similar report into numeracy difficulties (Dowker, 2004). This is consistent with the views of Gersten, Jordan and Flojo (2005) who commented that research into the assessment of numeracy difficulties was within its infancy, whilst assessment into literacy difficulties had long been established. Dowker (2004) highlighted that despite there being an increased interest in numeracy difficulties over the past 20 years, the research into such difficulties was significantly smaller than that into literacy difficulties.

2.5 Mathematical difficulties

2.5.1 Terminology

Various terms can be used to describe numeracy difficulties including mathematical difficulties, mathematical disabilities, mathematical learning disabilities and dyscalculia (Mazzocco, 2007). Whilst the terms 'disability' and 'dyscalculia' suggest a biologically driven difficulty, the term 'mathematical difficulties' acknowledges the impact of socio-cultural factors on such difficulties (Mazzocco, 2009). The term 'mathematical difficulty' includes children working at the low average range; below the 35th percentile (Gersten et al., 2005), whilst those working below the 25th percentile are described as having 'mathematical disabilities' (Geary, 2004). Not all children identified as having a 'mathematical disability' however, actually have an underpinning cognitive or memory deficit (Geary, 2004).

According to Gifford and Rockliffe (2012), dyscalculia is believed to be caused by a *"dysfunctional 'number module' in the brain"* (p.2), although the nature and function of this 'number module' is disputed, as is the prevalence

of dyscalculia (Gifford & Rockliffe, 2012). Dyscalculia has also been used to refer to individuals experiencing specific and severe difficulties in mathematics, without considering the possible causes of such difficulties (Dowker, 2009).

Due to these discrepancies and uncertainties, the term 'mathematical difficulties' is used in this study to describe any child experiencing difficulties within numeracy.

2.5.2 Mathematical difficulties in children

According to Dowker (2009), between 15 and 20 per cent of the UK population experience mathematical difficulties, which result in *"significant, practical and educational problems for the individual"* (p. 4), with 6 per cent experiencing severe specific difficulties, or 'dyscalculia'.

Children with mathematical difficulties can experience difficulties in one or more arithmetical abilities (Dowker, 2012), including counting, memorising arithmetical facts, understanding number concepts, and following procedures (Dowker, 2008). Significant characteristics of children with mathematical difficulties include difficulties in rapid fact retrieval and calculation fluency (Jordan, Hanich & Kaplan, 2003), resulting in difficulties with counting procedures and number knowledge (Jordan, 2007). Children with comorbid mathematics and reading difficulties can also experience difficulties in understanding the principles of calculations, and in their ability to solve mathematical based story problems (Jordan et al., 2003).

In a two year longitudinal study, Ostad (1997, 1999, 2008) investigated the mathematical strategies used by Norwegian children aged 7 to 11. Children were observed solving different calculations, and asked to explain how they had solved them. Reported and observed strategies were then classified as backup strategies (using apparatus, pencil and paper methods or verbally counting on/back) or retrieval strategies in which *"answers are retrieved directly from long-term memory" (Ostad, 1999, p.22)*. At the end of the study,

children with mathematical difficulties were found to still rely upon backup strategies, whereas those without showed a decreased reliance upon such strategies, instead using a range of different retrieval strategies. It is important to note however that this study is subject to potential bias, as the researcher defined and classified all of the strategies used. Furthermore, some of the children may have had difficulties articulating how they solved certain calculations, and thus not provided an accurate description of the strategies they used.

Children with language difficulties have been found to experience difficulties with activities such as verbal counting, problem solving and reasoning due to the language demands of such tasks (Arvedson, 2002). They can also experience difficulties in learning and understanding mathematical symbols (Alt, Arizmendi, & Beal, 2014).

The DfE (2012) highlighted that certain groups, including boys, pupils eligible for ‘free school meals’, some ethnic minority groups, pupils with ‘English as an additional language’, those with ‘special educational needs’ (SEN), pupils with high rates of mobility, and ‘Looked After Children’, are most at risk of low attainment in numeracy.

2.5.3 The role of educational psychologists

EPs play a vital role when working with children and young people with SEN, a group which can include those with mathematical difficulties (Farrell et al., 2006). Such work involves assessment of the individual needs, and consultation with parents and staff, as well as providing training and advice about SEN (Farrell et al., 2006).

There is evidence to suggest that although interventions to support children and young people with SEN are generally managed and delivered within schools, there is a need for more support from EPs in such areas (Scottish Executive, 2002). This highlights the importance of EPs having knowledge

and understanding of effective interventions, including numeracy interventions that are available to support children with a range of needs.

With regards to numeracy, one of the key roles of EPs is to formulate and explore possible hypotheses as to why a child is experiencing mathematical difficulties, in order for appropriate intervention and teaching to be implemented (McKensie, 2007). This involves completing detailed assessments, with EPs playing a particular role in diagnostic assessments (Gillam, 2014).

According to Orton (2004) teachers need to be knowledgeable about the learning and theoretical frameworks that underpin the teaching and learning of mathematics, as well as the difficulties experienced by some children with regards to learning basic number concepts. Such information can be provided by EPs.

2.6 Attitudes towards numeracy

According to Dowker, Bennett and Smith (2012) emotional factors and attitudes impact on an individual's performance in numeracy. In secondary aged students and adults, performance in numeracy has been found to be related to a liking of numeracy; high self-efficacy in the subject and low mathematics anxiety (Ho et al., 2000; Ashcraft & Krause, 2007). Those who hold negative attitudes towards numeracy are likely to display a lack of willingness to persist when solving mathematical based problems, which in turn can result in a lack of development in numeracy (Ashby, 2009). Such research highlights the importance of promoting positive attitudes towards numeracy and in exploring children's attitudes towards numeracy.

Attitudes towards numeracy are often assessed using Likert-scales, where respondents have to identify to what extent they agree or disagree with the statement, choosing from a continuum of responses (Adelson & McCoach, 2010). Likert-scales, however, are not without their limitations- respondents generally tend to agree with the statements or will be prone to giving socially

desirable responses (Robson, 2011). Respondents will also often avoid giving extreme responses (Bertram, 2007). A final limitation is that it can be difficult to demonstrate that the scale is valid and is actually measuring what it is intended to measure (Bertram, 2007).

2.6.1 Children's attitudes towards numeracy

As the current study focuses on the attitudes of primary aged children towards numeracy, it is important to discuss these in more detail. Current research has highlighted inconsistencies into the development of attitudes towards numeracy in younger children.

According to Eccles, Wigfield, Harold and Blumenfeld (1993), children as young as 6 develop differentiated self- and task-related perceptions to different domains including numeracy. Whilst Adelson and McCoach (2011) concluded that children as young as 8 hold two types of attitudes towards numeracy:

- Mathematical Self-Perceptions: How the individual perceives themselves as a learner, and whether they believe they are able to perform well in mathematics.
- Enjoyment of mathematics: How much enjoyment the individual gets from mathematics.

Dowker, Ashcraft and Krinzinger (2012) however, drew attention to the fact that there has been limited, and conflicting, research into the attitudes of younger children. This conflict is highlighted by the following studies.

In a study of 89 children from Years 3 and 5, Dowker, Bennett and Smith (2012) concluded that the majority of children under 9 years of age tend to have positive attitudes towards numeracy. Using the 'Mathematics Attitudes and Anxiety Questionnaire', they found that all attitude scores were rated higher than the neutral score of '3', as measured on a 5-point Likert scale, except for the attitudinal measure of 'unhappiness at poor performance'. One could argue however that the use of such a measure limited the children's

choices and did not allow for spontaneity (Smith, Duncan & Marshall, 2005). As the participants were from two primary schools and predominantly white middle class, issues of generalisability need to be considered.

In another study, Mazzocco, Hanich and Noeder (2012) reported that children aged between 7 and 9 years of age generally perceived numeracy in a more negative light than reading. Two hundred and seven children were asked to provide definitions for mathematics and reading, which were coded on three dimensions: likeability; difficulty and specificity. Codes rated from - 2 (negative) to + 2 (positive). They concluded that:

> *"Children in our study expressed relative flat affect with regard to their enjoyment of maths, did not hold very elaborate conceptions regarding the usefulness of mathematics, and attributed more difficulty to maths than reading." (p. 10)*

As the definitions were coded by the researchers, one cannot be sure that they interpreted the views of the children correctly as no member checks were completed. Furthermore, only two researchers were involved in the coding process, which could result in bias.

2.6.2 The relationship between attitudes to numeracy and attainment

Although there appear to be inconsistencies in general research about attitudes in younger children, there is evidence to suggest that a relationship exists between attitudes towards, and performance in, numeracy.

Thomas and Dowker (2000) found strong correlations between liking for numeracy, self-ratings and actual performance. This study did however have a small sample of twenty 6 year olds. Similar findings were reported by Krinzinger, Kaufmann, & Willmes (2009) in an 18 month longitudinal study of 140 children with a mean age of 7 years 6 months. They found that a positive correlation existed between a child's mathematical ability and their related

attitudes towards numeracy. These children however, were asked to complete self-report measures, and could have provided socially desirable responses.

In another study Ashby (2009) explored the attitudes of twelve Year 3 children, identified as low, middle or high achievers, who displayed strong positive or negative feelings towards mathematics. Children were asked to complete four questions and then participate in a focus group. Ashby concluded that children who experienced difficulties in mathematics were more likely to lack self-belief and resign themselves to failure. This however was based upon the researcher's interpretation of the data; no formal qualitative analysis was undertaken.

Finally, Mazzocco et al. (2012) reported that although all children held 'flat' attitudes towards numeracy, those with mathematical learning difficulties, and to some extent low achievers, reported lower likeability ratings towards numeracy than their peers. Whilst this study had a large sample of 207 pupils, only a small proportion had mathematical learning difficulties, which raises questions about the generalisability of the findings.

Dowker (2012) concluded that research from around the world suggests that numeracy performance is positively related to a liking for numeracy and perceived ability in numeracy, although the direction of this relationship is not clear. Do children view numeracy more favourably because they are good at it, or are children who view maths positively more likely to engage, thus resulting in better performance?

2.7 Numeracy interventions

2.7.1 The importance of intervention

Since the introduction of the NNS approximately 6 per cent of children have consistently failed to achieve a Level 2C in numeracy at the end of KS1

(Williams, 2008). This highlights the importance of early intervention for those children experiencing mathematical difficulties.

The intended outcome of early intervention is to reduce the number of children requiring intervention during KS2 and beyond (Williams, 2008). It also aims to reduce the possibility of children experiencing mathematics anxiety and developing negative attitudes towards numeracy (Dowker, 2004).

2.7.2 What makes an effective numeracy intervention?

Since the mid-noughties, three key reviews have been published drawing attention to the importance of numeracy within primary education, and identifying ways to support children experiencing mathematical difficulties; 'What Works for Children with Mathematical Difficulties' (Dowker 2004; 2009) and 'Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools' (Williams, 2008).

All have emphasised the importance of receiving early intervention, personalised to the individual needs of the child, as evidence suggests no single intervention meets the needs of all children experiencing mathematical difficulties (Dowker, 2009). Baseline assessment is crucial in order to identify these needs, as well as a child's areas of strength and potential barriers towards learning. Although early intervention is crucial, some children may continue to experience difficulties, whilst some difficulties may not become apparent until a child is older (Dowker, 2009).

Evidence suggests that interventions are most effective when facilitated by a qualified teacher who has secure mathematical knowledge (Williams, 2008). Due to underpinning cost implications however, support staff, who shall be referred to as learning support assistants (LSAs) may be a more economical way of delivering interventions to small groups of children with moderate difficulties (Williams, 2008), so long as they are suitably trained (Dowker, 2004). Children with severe difficulties should receive one to one

interventions delivered by qualified teachers (Williams, 2008). The role of LSAs is discussed in more detail in section 2.7.3.

According to Williams (2008), interventions should be delivered one to one over a period of 12 weeks. Dowker (2009) argued that working in small groups can also be beneficial as it enables children to share and discuss strategies they have used. She also argued there is a lack of evidence as to the impact of the duration of interventions on children's attainment.

Manipulatives and multisensory approaches are important components of an effective intervention, especially for children with language difficulties, or those struggling to understand the concept of number (Dowker, 2009). The use of such resources does however come with a caveat, which is discussed in section 2.8.3.

Senior Leadership Teams (SLTs) also play an important role in ensuring intervention programmes are successful. This includes arranging appropriate training for staff, having adequate time to manage and deliver the intervention, and giving appropriate support and guidance (Dowker, 2009).

Based upon the outcomes of two numeracy interventions delivered to children in grade 3 identified as having 'mathematical disabilities', Fuchs et al. (2008) proposed that if numeracy interventions are to be effective, information should be shared both explicitly and didactically and instructions given in a structured way and misconceptions explained. Children also need regular opportunities to practise and consolidate basic number concepts, upon which other skills can be built. Skills that have previously been taught need to be reviewed and linked into current learning, in order to assess whether such skills have been mastered. The progress of each child should be monitored as, although research may identify successful interventions, they are not guaranteed to be successful for all children. If a child continues to experience mathematical difficulties, and does not respond positively to an intervention, it is important to use the data collected to develop a personalised intervention programme, which meets their needs. Finally

motivators should be provided in order to promote student engagement and success.

Although some research has been conducted into what makes an effective numeracy intervention, it is important to note that such research is still in its infancy (Dowker, 2009) and the evidence has been described as patchy (DfE, 2012). More research needs to be conducted in order to compare the impact of different interventions (DfE, 2012); investigate the impact of interventions that address mathematical difficulties in areas other than arithmetic; and evaluate interventions aimed at older children (Dowker, 2009).

2.7.3 The role of support staff

Since the late 1990s there has been an increase in the number of LSAs, and other support staff, working in mainstream education (Farrell, Alborz, Howes & Pearson, 2010). Such staff predominantly support low-ability children or those with SEN through small group work, or one to one work, both in and out of the class (Blatchford et al., 2009).

The DISS Project (Blatchford et al., 2009), a major report on the deployment and impact of LSAs, used both qualitative and quantitative methods, to investigate the impact that LSAs had on a range of factors within the school setting, including the impact on pupils' academic progress. The researchers concluded that primary aged pupils who received additional support within the classroom during literacy and numeracy, made less progress than peers who did not receive such support. They did not however, investigate the impact that LSA support has on pupils who receive particular interventions.

Farrell et al. (2010) carried out a systematic literature review (SLR) of the impact of LSAs on pupil attainment. Studies were split into two groups, those that focused on specific targeted interventions and those where LSAs provided support within the classroom. Findings from eight of the nine studies, all of which focused on literacy interventions, suggested that children

who receive targeted intervention from trained and supported LSAs make significantly more progress compared to children of similar ability who do not receive such support. The final study (Muijs & Reynolds 2003) however, did not support this conclusion.

Muijs and Reynolds (2003) evaluated the role of LSAs, known as Numeracy Support Assistants (NSAs) in the Gatsby NSAs Project. NSAs received three days training before working with children who were low achievers in numeracy. During numeracy lesson they worked with a group of children providing additional explanations, modelling how to complete tasks, asking questions and providing support and encouragement. Children in Years 1 and 2 were allocated to the experimental group, or control group, with 180 children in each. Pre- and post-test data were collected using a standardised numeracy assessment. The researchers concluded that children who had received additional support from the NSAs did not make more progress than those in the control group.

Whilst this study suggests that LSAs may not be effective at delivering numeracy interventions it is important to acknowledge that the Gatsby Project was not a typical intervention as it was delivered within the main classroom with all children accessing the same lesson, rather than following a personalised numeracy programme. The children also received less additional time with the NSA compared to that given in most interventions (Farrell et al., 2010). Other factors that may have impacted upon the children's progress such as children's individual differences, as well as differences in teaching styles within whole class learning and also during group work with the NSA, were not considered. Furthermore, questions are raised about the generalisability of results, as only two LAs were involved in the research.

Recent guidance produced by Sharples, Webster and Blatchford (2015) concluded that where LSAs were delivering targeted interventions on a one-to-one basis or in small groups, there was a consistent impact on attainment. This impact was only observed in situations where LSAs were receiving high

quality support and training, and delivering structured interventions. Where LSAs were delivering more informal interventions, there was evidence to suggest that such interventions could impact negatively on pupil outcomes.

Blatchford, Webster and Russell (2012) evaluated the impact of the 'Effective Deployment of Teaching Assistants' project. Based upon data from ten schools, they concluded that if LSAs were specifically trained in the delivery of interventions and received support and guidance from teachers on how to plan, prepare and implement the intervention, the LSAs had a positive impact on pupil attainment. These findings however predominantly focused on literacy interventions and so one cannot conclude that the same would necessarily be true for numeracy interventions.

To conclude, the evidence considering the role of LSAs in supporting children with learning difficulties appears inconclusive. LSAs however continue to play a role in supporting such children, especially in the delivery of interventions.

2.7.4 Numeracy interventions in the UK

To date the most recent and comprehensive review of numeracy interventions used in primary schools in England and Wales is 'What Works for Children with Mathematical Difficulties' (Dowker, 2009). As part of this review, numeracy advisors within LAs, and other organisations that produce numeracy interventions, were contacted and asked to provide information about interventions schools used to support children with mathematical difficulties.

In total information was provided for sixteen interventions, of which nine were used in KS2.

A summary of KS2 interventions reviewed by Dowker (2009) is presented in Table 2.1. Numicon is not included as this will be reviewed in depth in section 2.8.

Table 2.1 Numeracy interventions used in primary schools to support pupils with mathematical difficulties (Dowker, 2009)

Name of intervention	*Target group*	*Intervention details*	*Sample*	*Key findings*
Snap on 2 Maths (Surrey)	KS1/2 pupils working significantly below expectation	1 year, daily for 10-15 minutes Facilitator: LSA Group size: 4 max.	27 schools 162 Y2 / 3 pupils Boys = 90	50% moved at least 2 NC sublevels 11% made more progress
West Sussex Wave 3 Mathematics Project	Wave 3 intervention for pupils in KS2/3.	Facilitator: Trained LSA	18 schools Majority of pupils in Y4 Some from Y3, 5 + 8	24 made > 1 NC sublevel progress 10 made ≤ 1 NC sublevel progress
Moving on in Maths (Luton)	Y6 pupils needing support to achieve Level 4.		12 schools Y6 pupils	Increase in number of pupils achieving Levels 4/ 5 in Y6 SATs
Mathematics Recovery (Cumbria)	Pupils working at NC Level 1 or below.	1:1 3-4 sessions/ wk: 20-30 mins Facilitator: Trained teacher/ LSA	33 Y1 pupils 27 Y2 pupils	Y1: 70% achieved at least NC Level 2c, and 27% achieved at least NC Level 2b Y2: 50% achieved at least NC Level 2c, and 14% achieved at least NC Level 2b

Name of intervention	*Target group*	*Intervention details*	*Sample*	*Key findings*
Mind the Gap (Devon)	Y6 pupils at risk of not achieving NC Level 4	Small group/ 1:1 Weekly session (20-30 mins) for 10 weeks		Raw data not analysed
Catch Up Numeracy (CUN)	Pupils in Y2-6 with moderate mathematical difficulties.	1:1 2x 15 min sessions/ wk Facilitator: Teacher / LSA (Trained)	CUN: 154 pupils Comparison: 50 pupils Control: 42 pupils	Mean ratio gain of mathematics age: CUN: 2.2 (p = 0.01l) Comparison: 1.47 Control: 1.25
Addacus Activity Packs	Children experiencing difficulties in grasping early number concepts	1:1/ small groups Sessions: 30-45 mins (2/ wk or daily) Facilitator: Trained adult		Evaluation not completed. Qualitative feedback: Pupils making good progress
The Harrow Dyscalculia project	KS2 + 3 pupils with dyscalculia.	1:1 Facilitator: Trained teacher/ LSA	9 schools Pupils aged 8-14	Evaluation not completed Positive teacher feedback
The Jump Project (Lambeth)	Pupils in Y5 + 6 not expected to achieve NC Level 4 at end of KS2	1:1/ small groups 30 days: 1 hour/ day Facilitator: Trained teacher/ LSA	30 schools 454 children	33% achieved Level 4 NC sublevels progress made: 50% ≥ 2 and 35% ≥ 3

Name of intervention	*Target group*	*Intervention details*	*Sample*	*Key findings*
Talking Maths (Liverpool)	Underperforming pupils in Y1-3	Group size: 3 max. 3x 30 min sessions/ wk Facilitator: Trained LSA	32 pupils	NC sublevels gains made in yr.: 3 sublevels = 7 pupils; 2 = 12 pupils; 1 = 11 pupils

Although a diverse range of interventions have been evaluated, there are various methodological limitations including small samples, and a lack of comparison or control groups. It is therefore important that systematic research is completed on the various interventions (Dowker, 2009).

2.8 Numicon

2.8.1 What is Numicon?

Numicon was originally developed in 1996 as part of a Teacher Training Agency Teacher Research Project. The aim was to develop a programme of multisensory based activities to develop the arithmetic skills of children in Reception and Year 1 (Tacon, 2005).

Numicon is a teaching approach based upon multisensory teaching activities that uses *"structured imagery and apparatus within an image/symbolic-rich classroom environment"* (Tacon, Atkinson & Wing, 2004, p. 3). It can be used in whole class teaching, or as an intervention. Oxford University Press, who publish Numicon, provide a two day training course for schools in delivering the Numicon Intervention Programme which is specifically for children who are experiencing difficulties in numeracy.

Central to the Numicon programme are apparatus including Numicon plates and number lines. These enable children to *"develop a systematic mental imagery of number, to develop mathematical language and to apply their arithmetic to real-life problems"* (Tacon et al., 2004, p. 3). The Numicon plates (Figure 2.1) represent numbers up to 10 using arrays of two. They form a 'staircase pattern' where the odd numbers provide a 'step up' (Haseler, 2008). They can be combined to visually represent abstract concepts including simple calculations (Figure 2.2 & Figure 2.3). By physically doing and seeing these calculations, children begin to understand number and to feel more confident about it (Wing & Tacon, 2007). They also begin to learn simple number facts (Haseler, 2008). Children are able to develop a mental image of the Numicon plates through the use of 'feely

bags', which also encourage the use of mathematical language (Tacon, 2005).

Scaffolding is central to Numicon with skills being built upon and extended in each session (Tacon, 2005). Children initially learn about the patterns of Numicon plates, before beginning to order them and understand how they relate to number. These plates are used to develop children's understanding of arithmetic, and of place value (Tacon, 2005). This approach provides children with opportunities to practise and rehearse what they have previously taught (Tacon et al., 2004).

Figure 2.1 Numicon shapes and number line

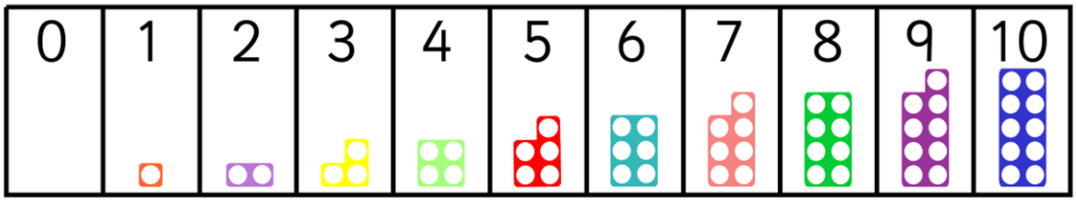


Figure 2.2 Numicon shapes showing number bonds to 10

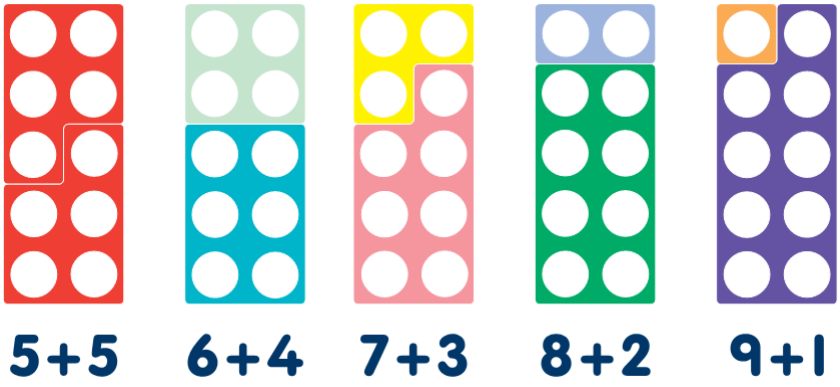
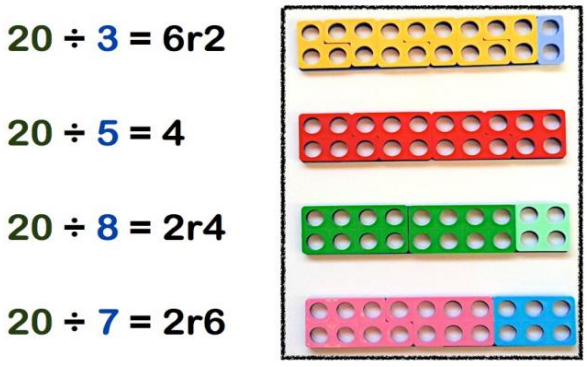


Figure 2.3 Numicon shapes representing division calculations



2.8.2 Theoretical underpinning of Numicon

Numicon was influenced by the work of Catherine Stern (Neumark, 1999). Stern developed an approach that used clear structures to show children the relationship between the different numbers in the number system, and to help them understand the structure of this system (Stern, 1949). Children followed a fixed sequence, which began with the introduction of number concepts and worked through various stages until addition and subtraction were introduced (Stern, 1949).

One of the key aims was for children to develop number sense which is concerned with the counting, comparison and composition of numbers (Gifford et al., 2015). Concrete apparatus, where numbers were represented using blocks of different lengths which measured 1 to 10 units, were used to enable children to understand the number system, and identify patterns which represented different numbers (Stern, 1949). It is these number patterns upon which the Numicon resources are based (Haseler, 2008).

2.8.3 The role of manipulatives and representations in numeracy

According to Boggan, Harper and Whitmire (2010), manipulatives can be defined as, *"physical objects that are used as teaching tools to engage students in the hands-on learning of mathematics"* (p.1). They play an important role in the development and understanding of abstract mathematical concepts, enabling young children to make links with representations and abstract ideas (Toptas, Celik & Karaca, 2012; Uttal, O'Doherty, Newland, Hand & DeLoache, 2009), and to talk about and reflect upon their thought processes, thus enhancing their mathematical knowledge (Ross & Kurtz, 1993). They also support the development of visual images of numbers and an understanding of how numbers relate to each other (Haseler, 2008).

Recently the English government has become interested in the Singaporean approach which advocates a concrete- pictorial- abstract (CPA) approach to

learning mathematics (Gifford et al., 2015). In this approach, manipulatives are used to teach a mathematical process (concrete stage). The same process is then taught using pictures and drawings (representational/ pictorial). Finally numbers and symbols are used to complete a mathematical based process (Flores, 2010).

This approach is based upon Bruner's theory of "enactive-iconic-symbolic" modes of representation (Hoong, Kin & Pien, 2015). Bruner (1966) proposed that knowledge could be represented in one of three ways:
Stage 1- Enactive: Children learn through manipulation and action
Stage 2- Iconic: Perceptual organisation and imagery enable children to learn.
Stage 3- Symbolic: Children learn through language.

The 'optimum sequence' of learning is enactive, iconic and symbolic, but this is dependent upon various factors including individual differences, past learning and stages of development, as well as the knowledge that is being taught; some knowledge is learned best if it is presented in a symbolic format, whilst other knowledge may need to be presented in an iconic or enactive format (Bruner, 1966). Furthermore, children do not need to be at a certain age to understand abstract concepts, nor progress through the three stages of learning at specific times; as long as the instruction and context is meaningful to the child, they will be able to understand some abstract mathematical concepts from a young age (Merttens, 2012).

Bruner's theory has been criticised as providing a simplified view of instruction, and does not consider the role of socio-cultural factors (Hoong et al., 2015). However, central to Bruner's theory is the notion of 'scaffolding', in which the learner is assisted by another person in order to achieve a goal that they would be unlikely to achieve independently (Smith, Cowie & Blades, 1998). This highlights that social interaction is central to Bruner's theory of instruction and raises questions about the above criticism. Furthermore, Hoong et al. (2015) argue that Bruner's theory of instruction has sound

theoretical assumptions, which can be applied when teaching mathematical concepts within the classroom.

Various American studies (Flores, 2010; Flores, Hinton & Strozier, 2014; Fyfe, McNeil & Borjas, 2015; Hughes, 2011) have concluded that CPA is an effective approach for teaching mathematical concepts. In the UK, Dowker, (2009) reported that *"the use of apparatus and multisensory teaching can be helpful and effective in interventions"* (Dowker, 2009, p. 18). Wilson (2014) reported on good practice that was occurring in twelve 'teaching school alliances' (TSA), two of which had implemented interventions that used manipulatives to support children who were not confident at basic number and calculation skills. In the first, TSA staff reported that, although children had not met their overall targets, they had made progress in some areas of numeracy. Whilst in the second school, children were reported to be more confident about numeracy and their ability to carry out number calculations had improved. Whilst these studies suggest that multisensory approaches to learning are part of effective interventions, they do have limitations including a lack of control or comparison group. The positive effects may therefore be due to other factors such as maturation or additional support rather than the actual apparatus.

Although some research suggests that manipulatives are an effective resource for teaching mathematical concepts, the effectiveness of such resources is inconclusive (Gifford et al., 2015). It has been argued that using manipulatives does not guarantee that children will acquire mathematical concepts (Brown, McNeil & Glenberg, 2009). Furthermore, as manipulatives have a dual purpose, representing abstract concepts and actual objects, children can be distracted by the superficial information conveyed by the object (Kaminski, Sloutsky & Heckler, 2009), rather than focusing on understanding the abstract concept (Uttal et al., 2009). Therefore manipulatives that appear plain and simple in design, rather than those which represent actual objects e.g. 'compare bears' may be more effective at supporting children in the development and understanding of abstract mathematical concepts.

Children need to be taught how to use such materials, and receive enough guidance to enable them to learn the desired concept (Brown et al., 2009). They need support in understanding that the purpose of the materials is to enable them to develop knowledge and understanding of the mathematics system, so that they can transfer learning from concrete to more abstract concepts (Kaminski et al., 2009).

When using concrete materials and multisensory approaches to teach mathematical concepts, educators need to take a balanced approach and consider both the advantages and disadvantages of such approaches (Uttal et al., 2009). They need to ensure that manipulatives are not just seen as a fun activity, but actually support and scaffold children's learning (Toptas et al., 2012), and that the manipulatives chosen are carefully matched to the concept being taught (Gifford et al., 2015).

2.8.3.1 *Manipulatives and the mastery approach to mathematics*

As has already been discussed in section 2.3.2.1, the mastery approach to mathematics is now central to the teaching of mathematics in primary school. Boylan et al. (2016) compared this approach to traditional approaches used within primary schools. One of the differences that they drew attention to was the difference in the type of resources used when teaching the mastery approach. Traditionally they highlighted how manipulatives had been used to support younger children in mathematics, whereas the mastery approach tends to focus more upon the use of textbooks and visual imagery. This raises questions about the future use of manipulatives in the teaching of mathematics.

According to the NCETM (2014) however, as part of the mastery approach to teaching mathematics, *"concrete and pictorial representations of mathematics are chosen carefully to help build procedural and conceptual knowledge together"* (p. 2). This suggests that manipulatives continue to play a role in the teaching of mathematics. This view is further supported by OUP (2016) who state that the *"concrete-pictorial-abstract approach is at the heart of Numicon"* (p. 4) and thus enables children to *"develop conceptual*

understanding and fluent recall" (p.4) through the use of visual and practical based activities using Numicon.

2.8.4 The effectiveness of Numicon

Oxford University Press (OUP) which publishes Numicon states that, *"Numicon is proven to raise attainment in mathematics and sustain it over time"* (OUP, 2014, p. 1). It is used within many LAs and schools across the country, some of whom have reported the effectiveness of the programme on OUP's website (Table 2.2)

Table 2.2 The impact of Numicon on the attainment of pupils in primary schools

School	*Numicon*		*Findings*
	Whole class	*Intervention*	
Francis Askew Primary School (Oxford School Improvement-OSI, 2014a)	Yes	Yes	Increase in % of pupils achieving Levels 2 and 3 at end of KS1. Intervention: Age gains of 9 to 36 months
SS Aidan & Oswald RC Primary School (OSI, 2014c)	Yes	Yes	Increase in % of pupils achieving Levels 2 and 3 at end of KS1 and Level 5 at end of KS2. Intervention: Attained 2 sublevels after 12 week intervention.
St Joseph's RC Primary School (OSI, 2014d)	Yes	No	Increase in % of pupils achieving Levels 4 and 5 at the end of KS2.

Whilst the above suggests Numicon is effective in raising pupils' attainment, it is important to note that these case studies are not formal evaluations of the programme. The effectiveness of Numicon in these cases is based solely

upon the SATs results, which may be influenced by a range of factors including the content of the SATs paper, the individual abilities of pupils in each year, and the teaching staff and their methods of teaching. Furthermore no comparison or control groups are provided, so one is unable to conclude whether the increases in attainment are in fact due to Numicon alone.

Evaluations by Doncaster Metropolitan Borough Council- MBC (2008) and Leicester LA (2009) also suggest that Numicon is an effective intervention. In Doncaster, key findings from five case studies suggested that Numicon, used for both whole class learning and as an intervention, had a positive impact on children's mathematical knowledge, skills and understanding, as well as on their confidence and enjoyment in numeracy. It is not clear however how these conclusions were reached, or what data was used to support them. Whilst in Leicester, of 42 children who accessed the Numicon intervention group, 88 per cent made progress, with 29 children moving 3 National Curriculum sublevels upon completion of the intervention. Like the school based case studies, this evaluation does not consider the impact of external factors, nor is a comparison or control group provided.

Schools in Devon participated in a project where Foundation Stage and Year 1 teachers kept a reflective journal about their experiences of using Numicon within the classroom (Devon Primary Mathematics Team, 2006). Reflections included:

- Numicon supports children in the understanding of mathematical language.
- It enables children to recognise the numerosity of numbers.
- Children are more confident at working with bigger numbers and completing a range of calculations.
- Numicon enables children to see the relationships between different numbers.

Whilst this study highlights reasons why Numicon is perceived as being effective, it is not clear how these findings were identified as no formal qualitative analysis was completed of the journals.

2.8.5 The impact of Numicon on attitudes towards numeracy

There is limited research into the impact of Numicon on attitudes towards numeracy. In the Numicon Impact Report (OUP, 2011) 91 per cent teachers (n=137) reported that Numicon had a significant or very significant impact on children's enjoyment of maths. Whilst various case studies have also suggested that Numicon has a positive impact on attitudes (OSI, 2013a; OSI, 2013b; OSI, 2014a; OSI, 2014b). Such findings however are based on teacher opinion and not an objective measure of attitude. Bias is also a potential issue, as respondents chose to complete the survey or the case studies.

2.9 Critical review of the evidence base for Numicon

In order to objectively evaluate the effectiveness of Numicon, a SLR was completed, investigating the following question:

What impact does Numicon have on the attitude and numeracy attainment of children in KS2 experiencing mathematical difficulties?

2.9.1 Systematic literature review

The purpose of a SLR is to *"to review and synthesise existing research in order to answer specific research/review questions"* (Andrews, 2005, p. 399) providing a "*comprehensive and stronger picture* [about an area] *based on many studies"* (Gough, Oliver & Thomas, 2012, p.3). It also enables researchers to identify where there are gaps within this research (Davies, 2004). By searching all of the available research literature using a systematic, transparent and replicable methodology (Hammerstorm, Wade & Jorgensen, 2010) the aim is to examine the same phenomenon in different contexts, resulting in greater confidence and reliability, and reducing the risk of bias (Brunton, Stansfield & Thomas, 2012).

Such reviews can also inform policy and decision making (Gough et al., 2012), and support professionals in the development of evidence-based

practice (Petticrew & Roberts, 2006). Such practice enables EPs to provide professional evidence-based advice resulting in successful outcomes for children (Frederickson, 2002).

SLRs are not without their critics as they take a positivist stance towards research, focusing upon quantitative and experimental designs. This provides statistical evidence, rather than interpretative (Andrews, 2005). It has been argued that such research does not account for the complexities within real world research (Gersten, Baker & Lloyd, 2000).

Critics also argue that whilst SLRs aim to reduce bias, they can in fact be selective and partial, as they are often written in response to a particular research question with the researcher bringing their own bias to the search terms and the data synthesis (Andrews, 2005).

Despite these limitations, SLRs are still considered the gold standard for evaluating evidence and informing decision-making (Pettigrew & Roberts, 2006).

2.9.2 Search terms and inclusion/ exclusion criteria

On the 29th June 2015, using the search term 'Numicon', eight electronic databases were searched for relevant records: EBSCO HOST Education database and Psychology/Sociology database; Educational Evidence Portal; EMBASE; PsycINFO; Researchgate; Scopus; Web of Science and Zetoc. Databases from education and psychology were chosen as it was felt that relevant research may have been conducted in both fields. Including duplicate records, 27 articles were found.

A search was undertaken on 'Google Scholar' and 197 records were found. Twenty records were also accessed from the 'Numicon Case Studies and Research' section of the Oxford University Press.

Finally a search was undertaken of the ‘Etheses’ websites for the twelve universities which provide training in the ‘Doctorate of Educational Psychology’ and of the British Library EThOS website. No records were found. The author however was aware that a previous student at the University of Nottingham had undertaken research into the impact of Numicon. The Course Coordinator therefore contacted this individual requesting a copy of their thesis to be shared with the author.

The above searches were undertaken again on the 3rd March 2016, to see if any relevant research had been completed over the past eight months, but no additional records were found. The search was also undertaken in July 2016, and one additional paper was found.

In order to identify relevant articles inclusion and exclusion criteria were applied (Table 2.3).

Table 2.3 Inclusion and exclusion criteria for Systematic Literature Review

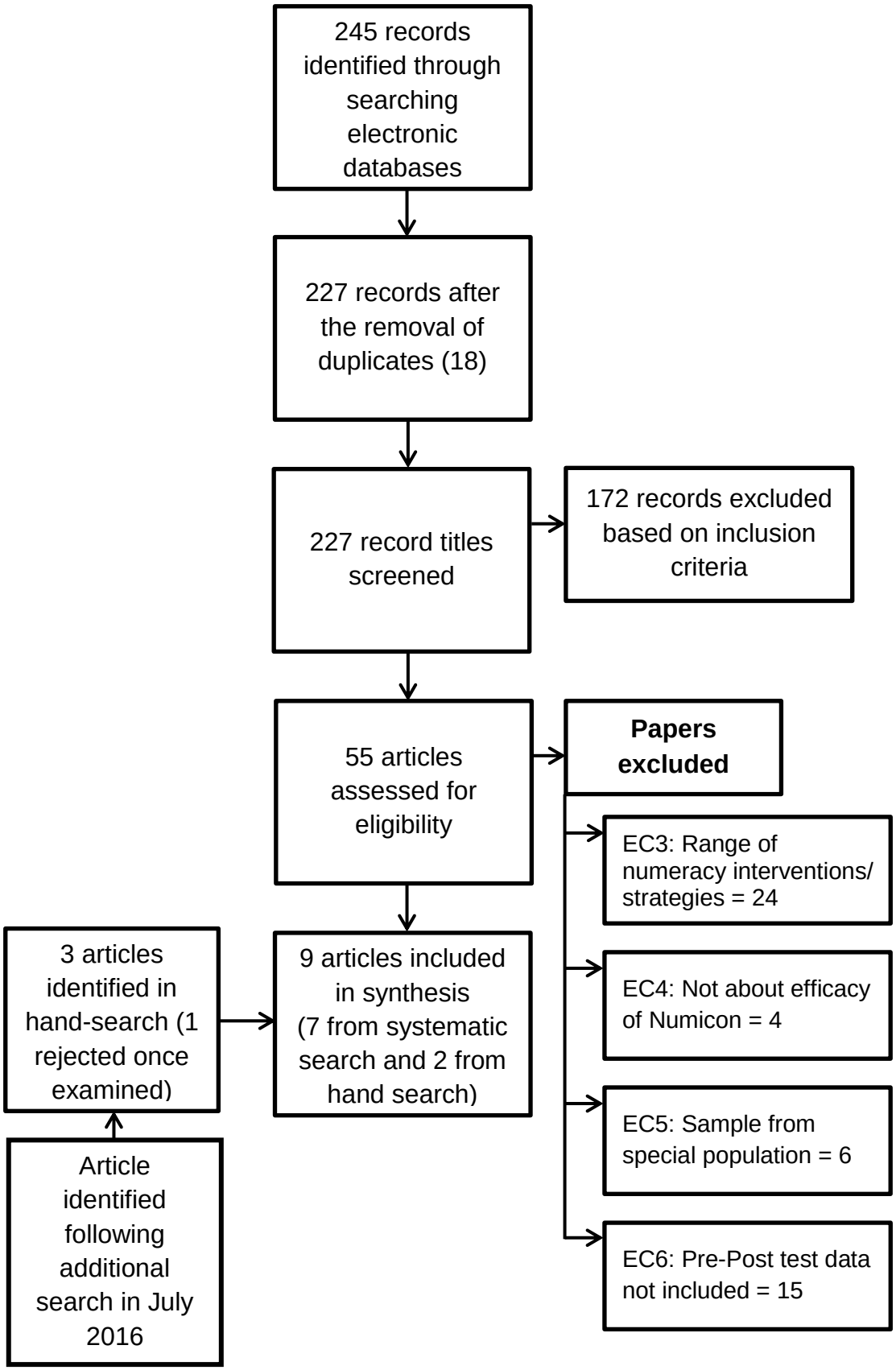
Inclusion criteria	*Exclusion criteria*
1. Article published between 1996-current	1. Articles published before 1996
2. Article accessible in English, including abstracts	2. Articles not accessible in English
3. Article focuses on Numicon-based intervention	3. Article provides information about a range of interventions/ strategies for teaching numeracy
4. Article reports efficacy of Numicon-based intervention	4. Article does not report the efficacy of Numicon-based intervention
5. Sample are not from a special population	5. Sample are from a special population e.g. Down Syndrome
6. Quantitative data using measures of attainment other than National Curriculum levels is provided	6. Quantitative data is not used or only National Curriculum levels are reported

Following the removal of 18 duplicate records, 227 records were screened by title. This resulted in 172 records being rejected based on the inclusion/ exclusion criteria (Appendix 1). The remaining 55 articles were screened using the inclusion/ exclusion criteria and 48 further records were rejected (Appendix 2).

Reference lists from the seven identified articles and 'What Works for Children with Mathematical Difficulties' (Dowker, 2009) were hand-searched, resulting in the identification of two additional articles, but one article was rejected as it was qualitative (EC6). The thesis by the University of Nottingham student was also included at this stage.

In order to obtain the article by Bury Learning Support Team- LST (2008) the LA were contacted directly. The article by Advisory Service Kent (ND) was obtained from another researcher who had completed a study of Numicon. Nine articles were reviewed for the SLR (Appendix 3). Additional information about the Every Child Counts Project- ECC (2008) was provided in Dowker (2009), which was reviewed in conjunction with the project report.

Figure 2.4 A diagram to show the flow of information through the different phases of the systematic review (Based on Moher, Liberati, Tetzlaff, Atman and the PRISMA Group 2009)



2.9.3 Frameworks of analysis

According to Harden and Gough (2012), *"Assessing the quality and relevance of individual studies within a review is a crucial part of the review process and contributes to the quality and credibility of the review itself". (*p. 154). Various tools have therefore been developed (Harden & Gough, 2012) with this intended purpose. These include the 'Cochrane Collaboration Handbook' (Higgins & Green, 2011), the TAPUPAS (Pawson, Boaz, Grayson, Long & Barnes, 2003) and the 'Weight of Evidence' (Gough, 2007) frameworks.

The 'Cochrane Collaboration Handbook' provides guidance on preparing a Cochrane Intervention Review, including the use of meta-analyses, which inform healthcare decisions (Higgins & Green, 2011). As such analysis was not being completed, and nor was a health based intervention being reviewed, it was concluded this was not an appropriate tool to use in this systematic review.

The TAPUPAS Framework focuses on six generic standards (Transparency, Accuracy, Purposivity, Utility, Propriety, Accessibility and Specificity) that need to be asked about any piece of knowledge. It was developed in order to provide a framework for judging knowledge within the social care community (Pawson et al., 2003). As this framework was developed for use within social care, and does not focus solely on research, it was concluded that this was not an appropriate framework to use.

The final framework considered was the Weight of Evidence (WoE) Framework. This framework enables the researcher to consider all relevant research and not just randomised control trials- RCT (Gough, 2007). This is of particular relevance in real world research where RCT are rarely possible.

The WoE framework consists of four strands, which are summarised in Table 2.4.

Table 2.4 The Weight of Evidence Framework (Gough, 2007)

Strand	*Description*
A	A non-review specific judgement that examines the quality of the design of the individual study
B	A review-specific judgement, examining the appropriateness of the individual study for answering the review question
C	A review-specific judgement which considers whether the focus of the individual study is relevant to the review question
D	An overall assessment of the individual study based upon the judgements given for strands A to C. The purpose is to consider *"the extent that a study contributes evidence to answering a review question"* (Gough, 2007, p. 225)

As this framework does not explain how judgements should be made (Gough, 2007), and can be used for a range of research designs, the author concluded this was the most appropriate framework for the current systematic review. Criteria were developed for each of the WoE strands (Appendix 4), which were used to analyse the relevance of the identified studies to the current research question.

2.9.4 Data analyses

Table 2.5 An analysis of the key studies identified using the WoE Framework (see Appendix 5 for more details)

Study and location	*Purpose*	*Participants*	*Design*	*Measures*	*Key findings*	*WoE rating*
Bury Learning Support Team (2008) England	*To explore the use of Numicon and other multi-sensory materials as a Wave 3 intervention (p. 1)*	12 Y1 pupils working below L1	Quasi-experimental design Pre-post-test data	VMISS[1] Score (n = 10)	• Average pre-test score: 16.4 points • Average post-test score: 31.1 points • Average gain: 14.7 points Qualitative: • +ve impact on pupil's confidence/ motivation • Progress easy to see	A: Low B: Low C: Med D: Low
Cambridgeshire LA (2007) England	To evaluate the impact of Numicon on children's number skills	8 schools	Quasi-experimental design Pre-post-test data	Assessment of various number skills. Measure used not named.	• +ve gains made in various number skills • Reported improved mathematical self-confidence/ felt better at maths	A: Low B: Low C: Med D: Low

[1] VMISS: Visual Models and Images Supported by Signs and Symbols Assessment Tool- Part of the Brighton and Hove LEA 'Wave 3' Programme: Visual Models and Images Supported by Signs and Symbols.

Study and location	*Purpose*	*Participants*	*Design*	*Measures*	*Key findings*	*WoE rating*
Churches (2016a/b) England	To trial and evaluate the statistical effects of seven numeracy interventions including Numicon simultaneously	Year 2 pupils Trial 1: N = 875 (E = 504 C = 371) Trial 2: N = 529 (E = 251 C = 278)	Collaborative RCT Pre-post-test data	• Progress In Maths Test	Trial 1: No sig. difference between post-test scores for pupils in experimental group compared to control. Trial 2: • Sig. difference (p<.001) for pupils in experimental group, compared to control group who also made substantial gains. Effect size, d = 0.38 • Significant gain (p<.01) for FSM pupils in experimental group. Effect size, d = 0.51	A: Med B: High C: Med D: Med
Education Leeds (2005) England	To develop and evaluate a Wave 3 intervention for children experiencing mathematical difficulties	8 schools (27 KS2 pupils) 1 specialist setting (2 KS3 pupils)	Quasi-experimental design Pre-post-test data	• British Ability Scales 2 • Wechsler Operational Number Test • Basic Number Screening Test • Questionnaire: Pupils' views	Pre- Post-test scores: • BAS2: Sig. difference for visual memory and quantitative reasoning • BNS: Sig. difference (p<.02) • WOND: No sig. difference • Average progress on PIVATS: 7.1 points • Pupils more confident	A: Low B: Med C: Med D: Med

Study and location	*Purpose*	*Participants*	*Design*	*Measures*	*Key findings*	*WoE rating*
Every Child Counts (2008) [Dowker, 2009] England	To evaluate the effectiveness of Numicon for children experiencing mathematical difficulties	40 Y2 children from 10 schools in one LA	Quasi-experimental design Pre-post-test data Comparison groups	NFER Test (standardised)	• Average pre-test score: 77.08 points • Average post-test score: 94.89 points • Average gain: 17.82 points	A: Low B: Med C: Low D: Low
Herbert (2011) England	To measure the impact of Numicon on children experiencing mathematical difficulties	23 children from 9 schools. On average maths age was 25.83 months (range: 10-40) behind CA	Quasi-experimental design Pre-post-test data	• Sandwell Early Numeracy Test • Questionnaire: Child's opinion of numeracy • LSA questionnaire about confidence	Data for 20 children: Average ratio gains: 2.21 (accelerated progress) 13 children made at least modest progress 5 children were falling behind Happy/ confident about maths: Pre- 7/11 (happy); 5/11 (confident) Post- 7/11 and 7/11	A: Low B: Med C: Med D: Med

Study and location	*Purpose*	*Participants*	*Design/ Methodology*	*Measures*	*Key Findings*	*WoE Rating*
Jenkins (2013) USA	To investigate the effects of Numicon on the development of number sense skills for children experiencing mathematical difficulties	9 kindergarten children who performed below 25th percentile in numeracy. Age range 5:04 to 6:02	SCED with multiple baseline	• The Number Sense Brief (NSB) • 2 probes: Quantity discrimination & Quantity-numeral correspondence • Teacher/ pupil questionnaires	Quantity discrimination (n = 8) PND: 100% --> intervention v. effective Quantity-numeral correspondence (n = 7) PND: 55% --> questionable effectiveness NSB: Post-test significantly higher than pre-test (p = .008). Effect size = 1.02	A: High B: Med C: Low D: Med
Jones (2014) England	To evaluate the impact of Numicon on: • Attainment • Metacognition • Maths enjoyment • Maths anxiety for children with mathematical difficulties	2 schools 51 children KS1	True-experimental design (RCT): Experimental comparison and waiting-list control groups.	Sandwell Early Numeracy Test-Revised Junior Metacognitive Awareness Inventory Maths Anxiety Questionnaire	• Significant difference between attainment for children in experimental (d= 0.31) and comparison (d=0.52) conditions compared to control (p < .005). • No significant difference between attainment for children in experimental and comparison conditions	A: High B: High C: Med D: High

Study and location	*Purpose*	*Participants*	*Design/ Methodology*	*Measures*	*Key Findings*	*WoE Rating*
Jones (2014) cont.					• Significant gains for metacognition of children in experimental group ($p < 0.05$), but no significant difference between conditions • No significant differences between conditions for enjoyment. Significant difference ($p<0.05$) within conditions for Numicon (-ve) and WLC group (+ve). • Levels of anxiety, relatively stable	
Lane (2009) Republic of Ireland	To investigate impact of Numicon as early intervention programme for children experiencing mathematical delays	1 senior infant class 24 children, many with delays	Quasi-experimental design Pre-Post-test data Action Research	Number Diagnostic Test	• Post-test results showed increase in attainment across all abilities • Observed growth in confidence	A: Low B: Med C: Low D: Low

Study and location	*Purpose*	*Participants*	*Design/ Methodology*	*Measures*	*Key Findings*	*WoE Rating*
Saunders (2005) [Dowker, 2009] England	To develop/ evaluate an intervention for children in Y2, 3 + 4 attaining significantly below expectations	5 schools Children in Y3 who achieved L1 or below in KS1 SATS	Quasi-experimental design Pre-post-test data	Attitudinal questionnaire Early Maths Diagnostic Kit	• Average pre-test score: 38/53 points • Average post-test score: 48/53 points • Pre-test range: 28 • Post-test range: 15 • Change in attitudes towards numeracy	A: Low B: Med C: Med D: Med

2.9.5 Data synthesis

In order to complete data synthesis, based upon the WoE framework, key themes were identified that were relevant to the review question. These were sample, design, intervention, measures and key findings. Using these themes, each study was critically analysed to investigate to what extent it answered the review question.

2.9.5.1 *Sample*

The majority of studies had sample sizes of less than fifty (Bury LST, 2008; ECC, 2008; Herbert, 2011; Jenkins, 2013; Lane, 2009; Education Leeds, 2005). Two studies had a sample greater than 50 (Churches, 2016b; Jones, 2014), whilst two studies did not report sample size (Cambridgeshire, 2007; Saunders, 2005).

The review question focused on children in KS2. Only two studies had samples from this age range (Education Leeds, 2005; Saunders, 2005), with five studies focusing on children aged 5 to 7 years. Two studies did not identify the age of the children (Cambridgeshire, 2007; Herbert, 2011)

Limited information was provided regarding the additional characteristics of the samples. Only one study provided information regarding gender and ethnicity (Jenkins, 2013). ECC (2008) completed data analysis based upon gender, but the number of male and females were not reported. The remaining studies did not provide any information regarding gender of participants. Churches (2016b) provided information about the number of participants who were eligible for FSM.

All of the children who participated were identified as experiencing mathematical difficulties, apart from in Lane (2009), although the majority of children in this study had mathematical delays.

The majority of the studies were conducted in the UK with one being conducted in the USA (Jenkins, 2013) and one in the Republic of Ireland (Lane, 2009).

In general sample sizes were relatively small, with a bias towards KS1 participants. Both of these factors are limitations as the current review question is concerned with children in KS2.

The fact that all of the studies focused on children with mathematical difficulties and the majority were conducted in the UK does however enable findings to be generalised to children of similar populations within the UK. However, only limited data were provided about these populations.

A final limitation is sample selection bias. Opportunity sampling was used in three of the studies (Bury LST, 2008; Herbert, 2011; Saunders, 2011). Whilst in two of the studies schools were specifically selected by the researcher (Education Leeds, 2005; Jones, 2014). Churches (2016a) used volunteer sampling. Three studies (Cambridgeshire, 2007; ECC, 2008; Jenkins, 2013) did not make it clear how schools were selected, and Lane (2009) conducted the research in the school where she taught.

2.9.5.2 *Design*

The majority of studies used quasi-experimental designs using pre-test post-test single group designs (Robson, 2011). Such studies should be avoided as they are at-risk of many threats to validity, and one cannot be sure if any differences at post-test are due to the intervention or other factors (Robson, 2011). Two studies used a RCT (Churches, 2016a; Jones, 2014) which is a true-experimental design (Robson, 2011) and is defined as the 'gold standard' in research (Coe, Fitz-Gibbon & Tymms, 2000). Jenkins (2013) used a Single Case Experimental Design (SCED) with multiple baselines.

Follow-up measures were only collected by Jenkins (2013), although these were collected one week after the intervention had finished. The lack of follow-up data raises questions about the long term impact of the

interventions. It would have been beneficial for other researchers to have collected such data, and for Jenkins (2013) to have collected this data at a later date.

Due to design limitations in the majority of studies, only two studies (Jenkins, 2013; Jones, 2014) were given a 'high' weighting for strand A of the WoE model. This suggests that the design of the majority of studies was of poor quality in terms of causal inference. Findings therefore need to be considered with care.

2.9.5.3 *Intervention*

In all of the studies Numicon was used as an intervention for children experiencing mathematical difficulties or working below national expectations. Although Lane (2009) described the programme as an intervention, it was delivered to a class of 24 children, suggesting it was actually used as a whole class teaching tool. The schools in Saunders (2005) study also used Numicon in whole class teaching.

Table 2.6 Key features of interventions evaluated in individual studies

Study	*Details of intervention*	*Facilitator*	*Example plans provided*	*Evidence of treatment fidelity*
Bury LST (2008)	12 week intervention	Trained LSA	No	Yes: Monitoring visits
Cambridgeshire LA (2007)	10 week intervention	No details	No	No
Education Leeds (2005)	Delivered from January to May	Trained staff	No	No
Every Child Counts (2008)	Delivered over summer term Daily sessions 2 x paired and 3 x 1:1 per week Children received up to 35 sessions ($\bar{x}$ = 29)	No details	No	No
Herbert (2011)	$\bar{x}$= 16 sessions (range: 8-42) 1:1 (15) or in pairs	LSA	No	No
Jenkins (2013)	Ability based intervention groups (n = 3 per group) 10 x 20 mins sessions over 6 week period Focus: counting and number sense	Certified special education teacher	Yes	Yes

Study	*Details of intervention*	*Facilitator*	*Example plans provided*	*Evidence of treatment fidelity*
Jones (2014)	3 x 30 min sessions per week over 10 weeks.	Trained staff (head teacher and LSAs)	Yes	Yes
Lane (2009)	Whole class approach Duration: 12 weeks	Teacher	No	No
Saunders (2005)	3 x 20 min sessions per week over 10 weeks Maximum of 4 children per group	LSA	No	No

NB: No information was provided about the intervention in Churches (2016a) study, but schools were reported to have followed the 'Numicon Intervention Programme'.

In the majority of studies, Numicon was delivered by a LSA (Bury LST, 2008; Herbert, 2011; Jones, 2014; Saunders, 2005). It was also delivered by a certified special needs teacher (Jenkins, 2013), a qualified teacher (Lane, 2009) and a head teacher (Jones, 2014). Four studies did not provide information about who delivered the intervention (Cambridgeshire, 2007; Churches, 2016a; Education Leeds, 2005; ECC, 2008). Staff were trained to deliver Numicon in four of the studies (Bury LST, 2008; Education Leeds, 2005; ECC, 2008; Jones, 2014).

The duration of the intervention varied in each study, as did the number of sessions received. In Bury LST (2008) children received the intervention daily

for 12 weeks, but the length of each session was not provided. Lane (2008) also delivered Numicon over a 12 week period, but no reference was made to the number of sessions or duration of each one. Three studies delivered the intervention over a 10 week period (Cambridgeshire, 2007; Jones, 2014; Saunders, 2005). In both Jones (2014) and Saunders (2005), children received three sessions per week lasting 30 and 20 minutes respectively. No additional information was provided in Cambridgeshire (2007). In Jenkins (2013) the intervention was delivered over a six week period, with children receiving ten 20 minute sessions during this time. Children in the ECC (2008) received on average 27 sessions, daily during the summer term. Whilst in Education Leeds (2005) sessions were delivered from January to May, and children in Herbert (2011) received an average of 16 sessions. No additional information was provided for either of these studies. No information about the number and duration of sessions was provided in Churches (2016).

Numicon was delivered in groups (Jenkins, 2013; Jones, 2014; Saunders, 2005) and on a one to one basis (Herbert, 2011). Those in ECC (2008) received Numicon both individually and in pairs. Such information was not provided in four studies (Bury LST, 2008; Cambridgeshire, 2007; Churches, 2016; Education Leeds, 2005).

Although Numicon was delivered differently in all of the studies, multisensory approaches to learning and concrete apparatus were used to help children develop number skills, suggesting that the studies are appropriate for evaluating the effectiveness of Numicon for children with mathematical difficulties. Due to variations in the delivery of Numicon however, it is difficult to make generalisations about the effectiveness of Numicon, and to conclude that these studies provide evidence for the research question.

Further limitations include the lack of detail about the intervention sessions, with example lesson plans only being provided in two of the studies (Jenkins, 2013; Jones, 2014), making replication of the other studies especially difficult. Furthermore fidelity checks were only completed in three of the studies (Bury LST, 2008; Jenkins, 2013; Jones, 2014). One cannot therefore

be certain that the intervention the majority of children received was actually Numicon.

2.9.5.4 *Measures*

Pre- and post-test data of attainment was collected in all of the studies, with Jenkins (2013) collecting additional data as part of the SCED, in order to analyse progress made throughout the intervention. Various measures were used to assess attainment, with one study (Cambridgeshire 2007) not naming the measure used (Table 2.7).

Table 2.7 Key features of the attainment measures

Name of Measure	*Studies used in*	*Standardised*	*Other Information*
Basic Number Screening Test-BNS (Gillham & Hesse, 2001)	Education Leeds (2005)	Yes	None provided
British Ability Scales 2- BAS2 (Elliott, 1996)	Education Leeds (2005)	Yes	4 subtests (Quantitative Reasoning, Visual and Auditory Memory, Speed of Processing)
Early Maths Diagnostic Kit-EMDK	Saunders (2005) Named in Dowker (2009)	Yes	None provided
NFER Test	ECC (2008)	Yes	Provides NC levels
Number Diagnostic Test-NDT (Gillham & Knight, 2001)	Lane (2009)	Information not provided	Assesses number Age appropriate Provides number age

Name of Measure	*Studies used in*	*Standardised*	*Other Information*
The Number Sense Brief- NSB (Jordan, Glutting & Ramineni, 2008)	Jenkins (2013)	Information not provided	Validated screening measure Identifies children at-risk of mathematics failure 33 items: Aspects of number sense Retest reliability: .81 - .86
Progress in Maths (PiM) Test (Clausen-May & Vappula, 2006/ 2009)	Churches (2016a)	Yes	Age appropriate (6-14) Assesses mathematical skills and concepts Can be administered digitally
Sandwell Early Numeracy Test-SENT (Arnold, Bowden, & Waldon, 2007) Revised: (Arnold, Bowden, Talents, & Walden, 2011)	Herbert (2011) Revised: Jones (2014)	Yes	Age appropriate Two parallel forms Individual administration
VMISS	Bury LST (2008)	Information not provided	None provided
Wechsler Operational Number test-WOND (Wechsler, 2005)	Education Leeds (2005)	Yes	None provided

Whilst standardised measures were used in six studies, it is difficult to conclude whether any of the measures used were appropriate as limited information has been provided. Numicon focuses on number, and no other areas of numeracy. Of the measures used only one is described as focusing solely on number (Jenkins, 2013). The others may measure other skills, and therefore may not be valid measures. Since the measures were used for pre- and post-test data collection, there is also the risk of practice effects. Only one study (Jones, 2014) reports using parallel forms. This suggests that any improvements in post-test scores in the remaining studies could in part be attributed to practice effects. A further limitation is that the majority of the studies have not reported the validity or reliability of the measures used.

For the majority of studies the measures are clearly identified, so whilst limited information is provided it would be possible to replicate studies using these measures. Two measures however are not clearly defined, VMISS (Bury LST, 2008) and NFER test (ECC, 2008), making it difficult for other researchers to replicate studies using these measures.

Some studies (Bury LST, 2008; Cambridgeshire LA, 2007; Education Leeds, 2005; Herbert, 2011; Jenkins, 2013; Saunders, 2011) collected qualitative data from either staff or children in the form of interviews or questionnaires. Whilst this data was not analysed and samples were generally small, it does provide limited additional insights into the effectiveness of Numicon and the impact that it has upon children's confidence and attitudes towards numeracy.

Jones (2014) used published questionnaires to measure 'maths anxiety' and 'metacognition', both of which used a Likert scale to measure the two concepts. Whilst this enabled the measures to be statistically analysed, one does need to be aware of the possibility of social desirability bias, as the measures were self-reported.

2.9.5.5 *Key findings*

Only four of the studies (Churches, 2016a/b; Education Leeds, 2005; Jenkins, 2013; Jones, 2014) analysed the data using tests of statistical significance. Churches (2016a/b) used ANCOVAs to identify if there was an improvement in post-test scores for pupils who had participated in the intervention compared to pupils allocated to the control group. In trial 1, no significant differences were found, but the results were significant ($p<.001$) in trial 2. ANCOVAs were also used to identify if there was an improvement in the progress rate for pupils who had participated in the intervention compared to the control group. Again results were found to be non-significant in trial 1, but significant in trial 2 ($p<.001$). Education Leeds (2005) used t-tests to identify if significant differences occurred between pre- and post-test findings. Such differences occurred on the 'quantitative reasoning' and 'visual memory' subtests of the BAS 2, as well as the BNS ($p<.02$). As 'quantitative reasoning' and 'visual memory' are not measures of numeracy attainment, these findings are not relevant to the current review question. Using the Wilcoxon Signed-Rank test, Jenkins (2013) found that post-test results from the NSB were significantly higher than pre-test results ($p = .008$). Jones (2014) used ANCOVAs to investigate if attainment, as measured by the SENT-R was statistically higher for children in the Numicon group compared to those in the control and comparison groups. She found that it was significant compared to the control group ($p<.005$), but not compared to the comparison group. Although this suggests that Numicon is an effective intervention, it also highlights the effectiveness of a comparable intervention. Jones (2014) also investigated the impact that Numicon had on meta-cognition. Using the Wilcoxon Signed-Rank test, a significant difference ($p<.05$) was found between the pre- and post-test scores of metacognition of children who had received the Numicon intervention, but not for those who were in the control or comparison group.

Whilst Churches (2016a/b), Jenkins (2013) and Jones (2014) all suggest that Numicon had a significant impact on attainment, it is important to note that Jenkins (2013) used a non-parametric test. Such tests are less 'powerful' than parametric tests, and are less likely to find differences between

populations or two variables (Dancey & Reidy, 2007). All three did however report effect sizes, which provide information about the magnitude of the relationship or difference between two groups, and therefore enable the reader to understand the practical significance of the findings (Rockinson-Szapkiw, 2013).

Average gains were reported by Bury LST (2008), ECC (2008), and Herbert (2011). Although these results suggest that Numicon had a positive impact on attainment, as no statistical analysis was completed one cannot be certain whether these gains were purely due to chance.

Data from the remaining three studies (Cambridgeshire, 2007; Lane, 2009; Sanders, 2005) all reported that post-test scores for children receiving the Numicon intervention were higher than at pre-test. Due to lack of statistical analysis however, such outcomes may be the result of chance.

The above findings suggest that there is some evidence that Numicon has a positive impact on the attainment for children experiencing mathematical difficulties. This evidence is however weak due to the range of different measures used, some of which were not standardised, the lack of statistical analysis and design limitations which have previously been discussed.

When considering the impact of Numicon on attitudes towards numeracy, seven of the studies (Bury LST, 2008; Cambridgeshire LA, 2007; Education Leeds, 2005; Herbert, 2011; Jones, 2014; Lane, 2009; Saunders, 2005) reported that participation in the intervention had had a positive impact on children's confidence in numeracy and their attitudes towards numeracy.

In three of the studies (Bury LST, 2008; Education Leeds, 2005; Lane, 2009) these conclusions were based upon feedback from staff or observations by staff. Whilst in Herbert (2011), Jones (2014) and Saunders (2005), children completed questionnaires to obtain their views about numeracy.

Herbert, using a questionnaire written especially for the study, asked children how happy and confident they felt about maths at both pre- and post-testing. At post-testing there was an increase in the number of children who reported that they felt confident about numeracy (pre: 5/11 and post: 7/11), whilst the number of children (n=7) who reported they felt happy about numeracy remained the same.

In Jones' study, children completed The Mathematics Anxiety Questionnaire (Dowker & Thomas, 2000) at pre- and post-testing. This questionnaire uses a Likert scale to obtain information regarding a child's enjoyment of numeracy and their levels of anxiety towards the subject. Jones (2014) found that there was a significant reduction ($p<.05$) for levels of enjoyment at post-testing compared to pre-testing for children in the Numicon group. For children in the WLC group there was a significant increase ($p<.05$) in enjoyment at post-testing, compared to pre-testing. There weren't however any significant differences within groups at pre- and post-testing in self-perception of numeracy proficiency.

Using an attitudinal questionnaire, Saunders (2005) found that at post-testing there was a change in attitudes reflected in children's comments which provided more information about what they had learnt, as well as showing a greater enjoyment in numeracy. Children also reported that they wanted numeracy "to get harder". It is not clear however what questionnaire was used to obtain these views or how the data had been analysed.

In the Cambridgeshire study (Cambridgeshire LA, 2007), it was reported that children had greatly improved mathematical self-confidence, but no data was provided to show how the researchers had reached such a conclusion.

Whilst the above suggests that Numicon generally has a positive impact on children's attitudes and confidence towards numeracy this conclusion needs to be interpreted with care due to a lack of information regarding how the data was obtained. Furthermore, nearly 50% of the findings are based upon

teachers' perceptions and observations rather than the direct views of the children.

2.9.6 Conclusion of evidence base

In conclusion there is a weak evidence base to support the review question based upon the various limitations highlighted above and the WoE framework. When considering the WoE framework, only two of the studies (Jenkins, 2013; Jones, 2014) received a 'high' weighting for strand A. The remaining designs were of low quality, based on this framework, with a range of limitations that impacted on validity and reliability. Furthermore, only two studies (Churches 2016a/b; Jones, 2014) received a 'high' weighting for strand B, suggesting that the majority of studies were not overall appropriate for answering the review question due again to design limitations. Finally as none of the studies received a 'high' weighting for strand C, it was concluded that the focus of the identified studies was not entirely appropriate for answering the review question.

Therefore, based upon these limitations one cannot conclude that Numicon is an effective intervention for children in KS2 experiencing mathematical difficulties.

2.10 The Research

The above has highlighted the lack of an evidence base for numeracy interventions within primary education, especially in KS2. Where evidence does exist, there are often a range of methodological issues, which have been particularly highlighted with regards to Numicon.

2.10.1 Research questions

Due to these limitations and the fact that Numicon is used in many schools within the LA where the author is on placement as a TEP, the author investigated the following:

1. Does participation in a Numicon-based intervention have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties?
2. Does participation in a Numicon-based intervention have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?
3. According to the facilitators of the Numicon-based intervention, what are the outcomes for the children who have participated in the intervention, and what factors impact on these outcomes?

2.10.2 Unique contribution

This study provided a unique contribution as only two studies have previously investigated the impact of Numicon on children in Year 3 experiencing mathematical difficulties. With regards to attitudes, previous studies have provided qualitative data, but this study provided quantitative analysis of attitudinal measures. Furthermore qualitative analysis was completed to identify what factors impacted on the outcomes of the intervention. To the author's knowledge, such analysis had not been completed before.

Chapter 3 Methodology

3.1 Introduction

In this chapter, the importance of research in the field of Educational Psychology and the role of EPs as scientist-practitioners is discussed. The different research paradigms are explored, with a focus on the pragmatic approach and mixed methods. Methodological details about the current study are then provided.

3.2 Science and Research

3.2.1 What is research?

Research is a way of knowing and understanding that uses a process of systematic enquiry- data are collected, analysed and interpreted in order to *"understand, describe, predict or control an educational or psychological phenomenon"* (Mertens, 2005, p.2). According to Robson (2011), real world research can also have the additional purpose of facilitating or helping change, making improvements, and influencing policy and practice.

3.2.2 Research and Educational Psychology

Research is of particular importance in educational psychology as EPs are scientist-practitioners (Frederickson, Miller & Cline, 2008), who should be knowledgeable about both research and applied practice (Jones & Mehr, 2007). Their work should be *"grounded in scientific psychology… and [a] commitment to evidence-based practice and scientific research methods"* (Lunt, 2002, p. 182). Evidence-based practice should contribute to EPs' knowledge base, enabling them to apply such knowledge to their individual practice in order to help others (Kazdin, 2008).

In the context of the current study, the intended outcome was to contribute to the evidence base for a numeracy intervention which is used in primary education, as well as exploring how such an intervention is used in practice.

3.3 Philosophical Assumptions

3.3.1 Different paradigms

A researcher's actions and thinking are directed by certain philosophical assumptions known as paradigms, which are defined by the ontological, epistemological and methodological stances the researcher takes (Mertens, 2005). In any research, such stances need to be defined and the researcher needs to identify the paradigm that most closely aligns with their world view (Mertens, 2005).

In order to define each paradigm, three questions can be asked:

- *The ontological question: What is the nature of reality?*
- *The epistemological question: What is the nature of knowledge and the relationship between the knower and the would-be known?*
- *The methodological question: How can the knower go about obtaining the desired knowledge and understanding?*

(Mertens, 2005, p. 8)

Within psychological and educational research, Mertens (2005) identified four main paradigms, which are summarised in Table 3.1.

Table 3.1 The Four Paradigms Used in Educational and Psychological Research (Adapted from Mertens 2005)

	Positivism/ Post-positivism	*Constructivist*	*Transformative*	*Pragmatic*
Ontology	One reality exists. The researcher aims to discover this reality.	Reality is socially constructed. The researcher aims to understand these constructs.	Multiple realities exist and are influenced by the social, political, cultural, economic, ethnic, gender and disability values. Historical factors also influence perceptions of reality.	Value of research is due to its effectiveness. Truth is determined by what is useful.
Epistemology	Objectivity should be strived for. The researcher should remain neutral and not be influenced by their own values and biases.	The researcher and participants influence each other and the study. Values that influence the researcher are made explicit. Importance of confirmability.	Interactive relationship between the researcher and participants. The researcher should aim to empower participants, by identifying ways in which the research is beneficial.	The relationship between the researcher and the participants is dependent upon what the researcher perceives as appropriate to their study.

	Positivism/ Post-positivism	*Constructivist*	*Transformative*	*Pragmatic*
Methodology	Experimental and quasi-experimental methods. Usually data are quantitative.	Qualitative methods including interviews, observations and document reviews. Interaction between the researcher and participants is key.	Predominantly qualitative, but mixed methods and quantitative methods can be used.	Quantitative or qualitative methods are appropriate. Mixed methods are often used. Methods are matched to the specific purpose of the research.

3.3.2 The post-positivist paradigm

Post-positivist researchers usually conduct confirmatory research using experimental (randomised controlled trials- RCTs) or quasi-experimental designs. They emphasise the use of scientific approaches in order to strive for general laws and theories which provide an understanding of the social world (Robson, 2011).

Traditionally it has been argued that RCTs are the gold standard of research when researching the efficacy of an intervention, and play an essential role in evidence-based practice (Frederickson, 2002). Since the 1960s however, researchers have acknowledged that traditional experimental methods are not appropriate in educational and psychological research, resulting in the development of quasi-experimental designs, which allow the modifications of experimental designs so that they can be applied to people within a real world setting (Mertens, 2005). It has been argued however that such designs, whilst identifying whether an intervention may be effective, do not explain how an intervention actually works (Hughes, 2000). Furthermore, in real world research a post-positivist researcher can experience many challenges including difficulties in controlling extraneous variables and in fulfilling certain design requirements such as random allocation of participants (Robson, 2011). A final criticism is that post-positivist research is driven by the researcher and therefore provides little understanding of the individual context of each participant (Creswell, 2015).

3.3.3 The constructivist paradigm

Researchers who take a constructivist stance are concerned with how individuals construct and make sense of the world (Robson, 2011), and tend to use qualitative approaches to research (Mertens, 2005). They do not believe in an objective reality, but rather that there are many realities, constructed by each individual participant (Robson, 2011). It is the interactions between these individuals that results in the construction of social properties (Robson, 2011). Constructivists believe that the aim of research is to *“understand the multiple social constructs of meaning and*

knowledge" (Robson, 2011, p. 24) by searching for patterns; looking for interactions; and looking at stories (Braun & Clarke, 2013).

Like the post-positivist paradigm, the constructivist approach has been criticised. Some researchers argue that as the researcher plays a role in constructing the reality being explored, this approach is subjective and promotes bias. It has been claimed, that this subjectivity, alongside the exploratory nature of such an approach, results in unscientific research (Denzin & Lincoln, 2011). It has also been argued that such research has limited generalisability (Creswell, 2015).

3.3.4 The pragmatic paradigm

The pragmatic approach is the most recent paradigm (Mertens, 2005), which aims to draw upon the strengths of both the post-positivist and constructivist paradigms (Johnson & Onwuegbuzie, 2004). It arose from the belief that *"important paradigm differences should be respectfully and intentionally used together"* (Greene, 2007, p. 69, cited in Teddlie & Tashakkori, 2010, p. 15).

Pragmatists believe that the value of the research is dependent upon its effectiveness (Mertens, 2005), and that methodological approaches should be guided by the research question (Johnson & Onwuegbuzie, 2004). They argue that reality is complex and exists in multiple forms (Johnson & Onwuegbuzie, 2004), and that knowledge is neither subjective nor objective, but rather on a continuum (Teddlie & Tashakkori, 2009). In their view, knowledge is based upon the reality of the world that an individual lives in and experiences, as well as the individual constructs one holds (Johnson & Onwuegbuzie, 2004).

Although pragmatism aims to reconcile the constructivist and post-positivist approaches, it is not without its weaknesses. Scott (2007) argues that methodological decisions should be based upon the researcher's epistemological and ontological stances rather than the research question. Whilst researchers who take a transformative stance have questioned "For

whom is a pragmatic solution useful?" (Mertens, 2003). Pragmatism has also been rejected by many philosophers, as it provides a practical, rather than a logical solution, to current philosophical debates (Johnson & Onwuegbuzie, 2004).

3.3.5 The philosophical assumptions underpinning the current study

In this study a pragmatic stance was taken, thus enabling methodological decisions to be guided by the research questions. A mixed method approach was chosen, and thus, by being pragmatic, a theoretical base was provided for this approach (Mertens, 2005).

Consistent with Teddlie and Tashakkori (2010) concept of 'paradigm pluralism', it was acknowledged that whilst the research question guided the methodology, the author's underlying philosophical assumptions were influenced by the post-positivist and the constructivist paradigms. By incorporating both paradigms, the intention was to provide a greater insight and understanding into the phenomenon being investigated.

3.4 Mixed Methods

3.4.1 Definition of mixed methods

Johnson, Onwuegbuzie and Turner (2007), analysed nineteen definitions of mixed methods, resulting in the following definition:

> *"Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration."* (p. 123)

According to Gorard (2010), no research uses purely quantitative or qualitative methods, but rather good research should use various types of

data collection in order to explore whether or not an intervention works, as well as identifying possible reasons for this. He further argues that *"Mixed methods, in the sense of having a variety of tools in the toolbox, and using them as appropriate, is the only sensible way to approach research" (p. 247)*

From an epistemological perspective, mixed methods enable researchers to explore the complexities of reality by providing opportunities to explore both subjective experiences through the use of qualitative methods of data collection, as well as enabling the objective testing of hypotheses through the use of quantitative methods of data collection (Teddlie & Tashakkori, 2009).

Creswell (2015) identified three mixed methods designs:

1. Convergent design: Both quantitative and qualitative data are collected and analysed. The data are then merged in order to compare and validate the findings.
2. Explanatory sequential design: Quantitative data are collected first. Qualitative data are then collected in order to explain the quantitative findings in more detail.
3. Exploratory sequential design: Qualitative methods are used to explore an understudied area. The researcher then develops a quantitative phases in response to the qualitative findings with the intention of developing an instrument to measure a specific variable or developing an intervention. In the final phase, the instrument or intervention that has been developed is investigated using a quantitative data collection and analysis approach.

3.4.2 Using mixed methods in the current study

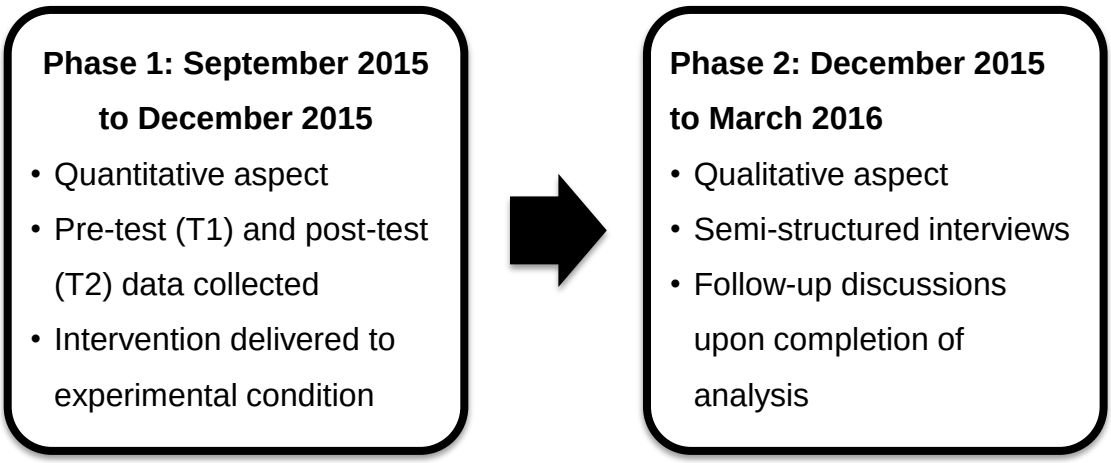
In the current study, a mixed methods approach was used in order to explore both exploratory and confirmatory questions (Teddlie & Tashakkori, 2010). The purpose of such a methodology was not solely to combine quantitative and qualitative methods thus addressing the weaknesses of each approach, but rather to select the best methods required in order to address the research questions being investigated.

An explanatory sequential design was used. This is illustrated in Figure 3.1.

During phase 1, a pre-test post-test quasi-experimental design was used to explore the impact of a Numicon-based intervention on the attainment and attitudes towards numeracy of Year 3 children experiencing mathematical difficulties.

In phase 2, a qualitative approach was used to explore the facilitators' views about the outcomes of the intervention and any underpinning mechanisms.

Figure 3.1 An illustration of the explanatory sequential design current study



3.5 Phase 1: The quantitative aspect of the study

3.5.1 Research questions and hypotheses

The purpose of phase 1 was to investigate the research questions and hypotheses that are outlined in Table 3.2

Table 3.2 The research questions and hypotheses for phase 1

Research question	*Null hypothesis*	*Experimental hypothesis*
Does participation in a Numicon-based intervention have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties?	Participation in a Numicon-based intervention will not have an impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties.	Participation in a Numicon-based intervention will have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties.
Does participation in a Numicon-based intervention have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?	Participation in a Numicon-based intervention will not impact on the attitudes towards numeracy, of children in Year 3 experiencing mathematical difficulties.	Participation in a Numicon-based intervention will have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties.

3.5.2 Independent and dependent variables

In research the independent variable (IV) is the variable that is being manipulated by the researcher that is not dependent upon any other factors (Field, Miles & Field, 2012). In the current study, the IV was the Numicon-based intervention that children in the experimental condition received.

The dependent variables (DV) are those variables that are dependent upon the IV. In this study, the DVs were attainment in numeracy, and attitudes towards numeracy, as it was hypothesised that involvement in the Numicon-based intervention would have a positive impact on these variables.

3.5.3 The Design Procedure

The purpose of this section is to explain the methodology used, identifying the procedures undertaken in order to complete phase 1 of the study. Information is provided about sampling, the intervention received by the experimental condition and the process of data collection, including information on the measures used.

3.5.4 Sampling

3.5.4.1 *Selection of schools*

At the time of the study, the author was a TEP on placement at an EPS in a county LA. The EPS consisted of four locality based teams. The author was a member of the team located in the principal town within the LA.

Four primary schools were recruited to take part in the study who all met the following selection criteria:

- Numicon had been used in Year 3 for at least one academic year prior to the study commencing.
- Numicon was used in both whole class learning and for intervention groups in Year 3.
- Training on the implementation of Numicon had been provided to staff either in-house or by an external provider.

- Facilitators of the intervention were experienced at using Numicon in an intervention group.
- Pupils had used Numicon in KS1: The author felt it was important that children had experience of using Numicon in KS1, as previous research has suggested that a lack of knowledge on how to use Numicon may impact negatively on the outcomes of any Numicon-based intervention (Jones, 2014).

Using a 'sample size calculator'[2] the author identified that in order to achieve a power level of 0.8, which is generally seen as acceptable (Robson, 2011) a sample size of 42 would be required, with 21 participants in each condition. The author therefore aimed to recruit at least five schools, with ten participants in each school.

In order to invite schools to participate in the research an initial letter asking for an 'expression of interest' (Appendix 6) was sent to every primary school (n=46) in the principal town in January 2015. This resulted in a response rate of 22 schools (47.8%) of which three were not using Numicon and seven were not interested in participating in the research. The author contacted the remaining twelve schools via phone to explain the proposed research in more details. Three schools did not meet the criteria for research, and two schools decided they did not wish to take part.

Following approval from the Ethics Committee Review (Appendix 7), the author met with the remaining seven schools, between May and June 2015, to discuss how Numicon was used in Year 3 and whether schools would like to participate in the research. It was decided that three schools were not suitable as they had previously not used Numicon in Year 3, whilst one school was unable to commit due to other commitments. Three schools however, confirmed that they were able to take part in the research.
Due to the small sample, the author emailed all of EPs in the LA in July 2015 asking if they knew of any schools that may be interested in participating in

[2] Yager, N. (2016) Sample size calculator
https://www.ai-therapy.com/psychology-statistics/sample-size-calculator

the research. Expressions of interests were received from three schools and the author contacted these via email, providing some additional information about the research. In September 2015 the author contacted the three schools again. Two were still interested in taking part in the research, but following further conversations, it was decided that they were not suitable as one was starting to use Numicon that academic year, and the other was a small school that used Numicon for 1:1 interventions rather than group interventions.

In September 2015 the author also spoke to a Numeracy Consultant who worked with primary schools in the principal town. The consultant provided contact details for six primary schools that used Numicon. The author contacted these schools and one school expressed an interest in participating in the research. Following an additional meeting the school (School D) confirmed that they would like to participate in the research.

The ‘Stakeholders’ Responsibilities’ sheet (Appendix 8) was signed by the four schools that had met the selection criteria and confirmed they were able to take part in the study. This was fewer schools than originally intended, but other schools did not meet the selection criteria or were unable to commit to the study.

Demographic data about each school is presented in Table 3.3.

Table 3.3 Demographic features of the schools participating in the current study[3]

School	Type of school	Pupils on roll	% of FSM[4]	% of statements/ EHC plans[5]	% of EAL[6]
A	Academy	504	31.1	0.4	64
B	Academy	408	10	2.7	18.7
C	Academy	587	43.1	0.9	14.8
D	Community School	508	7.7	0.6	11.7

3.5.4.2 *Selection of pupils*

Once schools had confirmed their participation in the study, they were asked to select up to ten pupils to participate in the Numicon-based intervention who, at the end of Year 2, had achieved Level 2C or below in numeracy, but were not working below a Level 1C. In some schools staff requested that some children who had achieved a Level 2B be included in the intervention groups, as they felt they would benefit from additional support in numeracy. The author trusted the staff's professional judgement and therefore agreed to this. Children with Statements of SEN, and those who spoke English as an Additional Language (EAL) were included in the sample, if schools felt they were able to access the intervention.

Following the selection of pupils, their parents/ carers (who shall be referred to as parents) were invited to a meeting at each school. The purpose of which was to provide information about the study and an opportunity to ask any questions thus enabling them to provide informed consent. Table 3.4 provides additional information about each meeting.

[3] DfE (2016) School and College Performance Tables http://www.education.gov.uk/schools/performance/ (accessed: 16/02/2016)
[4] FSM: Free School Meals
[5] EHC Plans: Education and Health Care Plans
[6] EAL: English as an additional language

Table 3.4 Information about Parent/ Carers Meetings

School	*Date of meeting*	*No. of parents invited*	*No. of parents attended*
A	1st October 2015	9	3
B	6th July 2015	10	1
C	14th July 2015	6	3
D	8th October 2015	7	1

Those parents who were unable to attend the meeting were given copies of the presentation (Appendix 9) and the 'Information Sheet for Parents/ Carers' (Appendix 10) by the school Special Educational Needs Coordinator (SENCo)/ Numeracy Coordinator. Parents were also given the author's contact details.

Informed parental consent was received from the following number of parents:

- School A: 4 parents
- School B: 10 parents
- School C: 6 parents
- School D: 6 parents

Upon obtaining parental consent, the author then met with the pupils to obtain child consent. This was done on a one to one basis with a member of school staff available if required. The 'Information Sheet for Children' (Appendix 11) was read to each pupil, and clarification provided if the pupil was unsure about anything. Each pupil then completed a consent form. Consent was obtained from all of the pupils.

Information about the pupils participating in the study is provided in Table 3.5 and Table 3.6.

Table 3.5 Demographic Features of Pupils Participating in the Numicon-Based Intervention Groups

No of children	*Experimental condition*	*WLC condition*	*Total*
Female	5	5	10
Male	11	5	16
Receive FSM	4	6	10
EAL	6	3	9
Have a SEN	4	2	6
Ethnic group	White British: 11 Other white b/ground: 3 White/ black Caribbean: 1 Pakistani: 1	White British: 6 Other white b/ground: 2 African: 1 Indian: 1	White British: 17 Other white b/ground: 5 Pakistani: 1 African:1 Indian: 1

Table 3.6 National Curriculum Levels of Pupils Participating in the Numicon-based Intervention Groups at the End of KS1 in July 2015

National Curriculum Level	*No. of children*		
	Experimental condition	*WLC condition*	*Total*
1C	5	0	5
1B	1	1	2
1A	4	2	6
2C	3	5	8
2B	2	2	4

NB: The NC level for one child in the experimental condition was not provided.

The above suggests that there were a disproportionate number of children in the experimental group working at a level 1C compared to those in the WLC condition. This is because three of the children working at a 1C attended school A, who did not provide a WLC condition. If school A had of provided such a condition one would have expected the distribution of children achieving a level 1C to be more evenly spread across the two conditions.

3.5.5 Conditions

3.5.5.1 *Experimental condition*

All of the pupils in the experimental condition received the Numicon-based intervention during the autumn term, as well as daily numeracy lessons as part of whole-class learning. During these lessons, pupils were able to access additional adult support, and use the Numicon apparatus if required.

The purpose of the Numicon-based intervention was to further develop pupil's understanding of number including the recognition of number and calculation skills, by using the Numicon apparatus. Children were introduced to, and used language specific to Numicon such as 'Numicon staircase'.

As Numicon is not a scripted intervention, consistent with guidance from Dowker (2004, 2009) and Williams (2008) individual schools identified what objectives should be taught in order to personalise the interventions to the needs of their pupils (see table 3.10 for details). This resulted in a divergent curricula being taught across the four schools, but some common objectives and features were identified across interventions (see tables 3.10 and 3.13 for details).

3.5.5.2 *Waiting- list control (WLC) condition*

The WLC condition did not receive any intervention input during the autumn term, but received daily teaching in numeracy as part of whole-class teaching. This included additional adult support and the use of Numicon apparatus when required. Although the author acknowledges that this could be seen as an extraneous variable which may impact on the numeracy

attainment of children in the WLC condition, it is important to note that whilst children were accessing Numicon in whole class learning this was not done in a standardised way, but rather children were able to choose whether they wished to use such equipment. On occasions, staff may demonstrate how Numicon could be used to support the children's learning, but this was not done daily as part of a structured programme.

Upon completion of phase 1 of the study, pupils in the WLC condition received the Numicon-based intervention following the same procedure used for the experimental condition in each school. This ensured that the WLC condition were not disadvantaged in any way, and received appropriate support in numeracy.

3.5.6 Measures

3.5.6.1 *Measures of numeracy attainment*

When considering research question 1 which aimed to investigate the impact of the Numicon-based intervention (IV) on numeracy attainment (DV), various measures of numeracy skills that were appropriate for assessing attainment, and had been used in previous Numicon-based research (Table 3.7), were considered.

Table 3.7 Measures of numeracy skills considered to assess attainment

Name of measure	*Description*	*Limitations in relation to current study*
Sandwell Early Numeracy Test-Revised (Arnold, et al., 2011)	Focus: Basic numeracy skills Age range: 4:00 to 8:00 68 items Parallel forms A/B Individual administration: 10 – 30 mins	Time to administer Not standardised for children over 7:11
Basic Number Screening Test (Gillham, McCarty & Hesse, 2012)	Focus: Understanding of number and number operations Age range: 5:00 to 12:08 30 items Parallel forms A/B Group administration: < 30 minutes	Time to administer Group administration: Pupils may not ask for additional support or may copy others
Wechsler Individual Achievement Test - Second UK Edition (Wechsler, 2005)	Focus: Numerical Operations and Mathematical Reasoning Age range: 4:00 to 16:11 years Numerical Operations: 54 items Mathematical Reasoning: 67 items Individual administration	One form: Risk of practice effects Risk of ceiling effect, as limited items focus on basic number skills Mathematical Reasoning assesses a range of mathematical skills including shape and space, fractions and data collection
British Ability Scales 3: Achievement Scale-Number Skills (Elliott & Smith, 2011)	Focus: Basic number skills and numerical operations using whole number, decimals, fractions and percentages Age range: 3:00 to 17:11 years 51 items Individual administration	Risk of ceiling effect, as limited items focus on basic number skills

All of the measures had some limitations; a decision was therefore taken to use the 'Sandwell Early Numeracy Test- Revised' (SENT-R). The rationale underpinning this was:

- Numicon is used to teach and reinforce basic number skills. The SENT-R assesses the five basic numeracy skills of: identification, oral counting, value, object counting and language.
- It is specifically for assessing the number skills of children working between National Curriculum levels P6 and 2A.
- There are two parallel forms enabling participants to be assessed using alternative forms at T1 and T2.
- According to the authors the measure has established *"a finely graded scale to measure progress, particularly for children with SEN in KS2"* (Arnold et al., 2011, p. 23).
- In previous studies (Herbert, 2011; Jones, 2014) the SENT and SENT-R have been shown to measure progress in numeracy over a short period of time for children experiencing mathematical difficulties who have participated in interventions, suggesting that it is a sensitive measure.
- It is recommended by the 'Every Child Counts Programme' and the DfE (Imaginative Minds 2014).
- The correlation between forms A and B is significant at the 0.01 level (2 tailed)

The SENT-R has been standardised on a sample of 1568 students aged between 4 and 7 years old from seventeen schools in the UK. Concurrent validity has been measured compared to KS1 SATS results and scores from the 'Mathematical Reasoning' and 'Numerical Operation' subscales of the Wechsler Individual Achievement Test. On all three measures, Pearson's Correlation was found to be significant at the 0.01 level.

An analysis of 96 sample test papers from the standardised sample resulted in a Cronbach Reliability Coefficient of 0.965 where $p<.01$ and $R= .962$.

3.5.6.2 *Measures of attitudes towards numeracy*

Research question 2 was concerned with the impact the Numicon-based intervention (IV) had on the children's attitudes towards numeracy (DV).

According to Adelson and McCoach (2011), although attitudes towards mathematics have long been of interest to researchers, the majority of measures have focused on young people aged 12 and over. Two measures however, were identified that were suitable for assessing the DV of attitudes towards numeracy in the current study. These were 'The Mathematics Anxiety Questionnaire' (Thomas & Dowker, 2000) and 'The Maths and Me Survey' (Adelson, 2006), which were compared in order to identify the most suitable measure (Table 3.8).

Table 3.8 Key features of 'The Mathematics Anxiety Questionnaire' and 'The Maths and Me Survey'

Feature	*The Mathematics Anxiety Questionnaire*	*The Maths and Me Survey*
Age range	6:00 to 9:00 years	5:00 to 12:00 years (Elementary pupils)
No. of items	28	18
Focus	Maths related attitudes and maths anxiety	Mathematical self-perceptions and enjoyment of mathematics
Administration	Self-report measure: 5-point Likert scale	Self-report measure: 5-point Likert scale

Based upon the above information, 'The Maths and Me Survey'[7] was selected for the current study. The rationale underpinning this decision was:

- It does not measure mathematical anxiety.
- It is a psychometrically valid instrument.

'The Maths and Me Survey' was developed in the United States of America. It was standardised on a sample of 1504 students from nine schools aged 8 to 12 years old. The mean score for the 'mathematical self-perception'

[7] A copy of 'The Maths and Me Survey' is available from the author Dr. Jill Adelson.

subscale was 3.79 (SD= 0.82, range= 1-5), and for the 'enjoyment of mathematics' was 3.59 (SD= 1.00, range= 1-5).

Analysis of the internal consistency reliability of statements within each subscale was conducted by Adelson and McCoach (2011). Cronbach's alpha for the 'mathematical self-perception' subscale was found to be .917, and for 'enjoyment of mathematics' .939.

In order to assess the content validity of 'The Maths and Me Survey', Adelson and McCoach (2011) asked 14 'experts' in mathematics to complete a 'content validity questionnaire' asking them to identify in which subscale they would place each of the items. All statements were placed in the correct subscale by at least 86 per cent of the experts. External validity was analysed using student data from 'The Maths and Me' surveys and teacher ratings of mathematical ability (Adelson & McCoach, 2011). The correlations between both subscales and teacher ratings were found to be significant at the $p < .001$ level.

'The Maths and Me Survey' consists of eighteen statements which measures two types of attitude towards mathematics:

- 'Mathematical self-perception': *"A person's perceptions of self as a mathematical learner including beliefs about his or her ability to perform and do well in maths"* (Adelson & McCoach, 2011, p. 226).
- 'Enjoyment of mathematics': *"The degree to which a person takes pleasure in doing and learning mathematics".* (Adelson & McCoach, 2011, p. 226)

Examples of statements from the 'mathematical self-perception' subscale include:

- I am really good at maths
- Maths is very hard for me

Examples of statements from the ‘enjoyment of mathematics’ subscale include:

- I look forward to learning new maths
- Solving maths problems is fun

Children respond to each statement using a 5-point Likert scale with response ranging from ‘strongly disagree’ to ‘strongly agree’.

As the measure is not published, a copy was obtained directly from the author Dr. Adelson.

It is important to measure ‘Mathematical self-perception’ as research from around the world has found a positive relationship between mathematical performance and *“high self-ratings in mathematics”* (Dowker, 2012, p. 249). Therefore, one would expect children with high ‘mathematical self-perceptions’ to perform better in mathematics.

In order to make the administration of the measure simpler, when completing the Likert scale, visual prompts were provided to help the pupils select an appropriate response. These were in the form of ‘thumbs up/ down’ or different faces (Appendix 12). Pupils were asked which they would prefer to use.

3.5.6.3 *Administration of measures*

Pre-test data collection was completed for all pupils one week prior to the implementation of the intervention for pupils in the experimental condition in schools B, C and D. In school A, the pupils received three intervention sessions prior to pre-testing. Pupils in schools B and C completed the pre-test in September 2015, whilst schools A and D completed it in October 2015. This was known as the time 1 (T1) data collection.

T1 data were collected by the author and another TEP. Pupils worked with them on a one to one basis, so that additional explanations could be provided if the pupils struggled to understand elements of ‘The Maths and Me Survey’.

When administering the measures a script was followed to ensure consistency (Appendix 13). Pupils were reminded that they had the right to withdraw and at the end of the data collection they were informed what would happen to their data. They were also provided with opportunities to take breaks, and there was a member of school staff available should any pupil become upset or anxious.

With regards to the SENT-R, pupils were administered either form A or B in order to reduce the risk of order effects and to enable two pupils to be assessed concurrently.

3.5.7 Procedure

Following T1 data collection, pupils were allocated to either the experimental condition or the WLC condition. In school C each pupil was given a numerical identifier and then randomly assigned to the experimental or WLC condition using an online random number generator. School B was two-form entry and so requested that children in the experimental condition be from class 1 and those in the WLC condition from class 2, thus reducing the impact of the intervention on classroom routine. Whilst in school D, staff requested that they allocate the pupils to the two conditions due to personal characteristics of the children such as confidence. Both of these requests were agreed to.

Due to a change in staffing structure, School A was able to provide the intervention to two groups of pupils simultaneously and so all pupils from this school were allocated to the experimental condition.

In schools A, B and C the Numicon-based intervention commenced in September 2015, whilst in school D it commenced in October 2015. The delivery of the Numicon-based intervention in each school is summarised in Table 3.9.

Table 3.9 Delivery of the Numicon-based intervention for the experimental condition in each school

School	*Duration*	*No. of sessions per week*	*Length of each session*	*Total no. of sessions*	*No. of children in group*	*Facilitator*
A	PM sessions: 10 weeks AM sessions: 5 weeks	3 (Tues & Thurs PM, and Tues AM from 4/11)	AM: 20 mins PM: 10 mins	25 (20 PM sessions & 5 AM sessions)	2 groups of 3 to 4 children	Teaching Assistant (PM sessions) SENCo- Amy (AM sessions)
B	8 weeks	3 (Mon & Thurs PM; Weds AM)	15 mins	24	5	Teaching Assistant-Beth
C	10 weeks	2 (Mon & Weds AM)	20 mins	20	3	Teaching Assistant-Clare
D	8 weeks	2 (Weds & Fri AM)	20 mins	16	4	Teaching Assistant-Debbie

3.5.7.1 *Information regarding facilitators*

Facilitators of the intervention were chosen by the school SENCo or Numeracy Coordinator. The author requested that the facilitators have had at least one year's experience of delivering Numicon as an intervention, and that they have received appropriate training either externally or within school.

All five facilitators had received some form of training on the delivery of Numicon:

- Amy, Beth and Clare had received training from an external numeracy consultant on using Numicon to support the understanding of number. This training however, did not focus on supporting children with mathematical difficulties, although some of the ideas discussed would be suitable for use in interventions.
- Debbie and the teaching assistant from school A had received in-house training from the numeracy coordinator on using Numicon in numeracy to support the understanding of number. Again this training did not focus on supporting children with mathematical difficulties, although some of the ideas discussed would be suitable for use in interventions.

In order to obtain more information about the facilitators' background and experience, during phase 2 of the study, as part of the semi-structured interview, facilitators were asked to provide some background information using standardised questions (Appendix 14). This resulted in the following pen-portraits.

Amy: Amy is a qualified teacher who has 10 years teaching experience. She has been a SENCo for 1 year and 3 months, and has the SENCo qualification. Amy has been delivering Numicon-based interventions for three years, and has previously delivered numeracy interventions developed within school. She has received training in Numicon from an external provider. Amy is female, aged 35 to 44, and Black Caribbean.

Beth: Beth is a teaching assistant, who has an NVQ in Support Teaching and Learning. She has held her current role for two years, and has been delivering Numicon-based interventions for one year prior to this academic year. Beth has also delivered interventions that support SEN children in understanding number sense, and has received Numicon training from an external provider, although this did not focus on supporting children with mathematical needs. Beth is female, aged 25 to 34, and White British.

Clare: Clare has been a SEN teaching assistant for two and a half years, and has worked in primary education for four years. She previously worked in secondary education for two years. Clare has been delivering Numicon-based interventions for two and a half years, and has received training in Numicon from an external provider. Clare is female, aged 35 to 44 and White British.

Debbie: Debbie is teaching assistant and has worked in primary education for 10 years, including two years in her current role. Previously she worked as a Nursery Nurse and has a NVQ in Childcare. Debbie has been delivering Numicon-based interventions for two years, and received Numicon training within school from a member of staff who had received training from an external provider. Debbie is female, aged 35 to 44 and White British.

As the teaching assistant who delivered the intervention in school A did not wish to participate in the research, the author could not obtain such information about her.

3.5.7.2 *Completion of phase 1*

Upon completion of phase 1 of the study, an audit of session plans used within each school was completed to identify session objectives. Schools A and C had used and adapted published plans from the Numicon scheme. In school B, sessions were planned by the Year 3 teachers, whilst in school D sessions were planned by the facilitator of the intervention.

School A provided some examples of plans, but did not provide plans for all sessions. The objectives taught during the intervention are shown in Table 3.10, and example lesson plans for schools B and D are provided in Appendix 15 andAppendix 16.

Table 3.10 Objectives taught during the Numicon-based intervention in each school

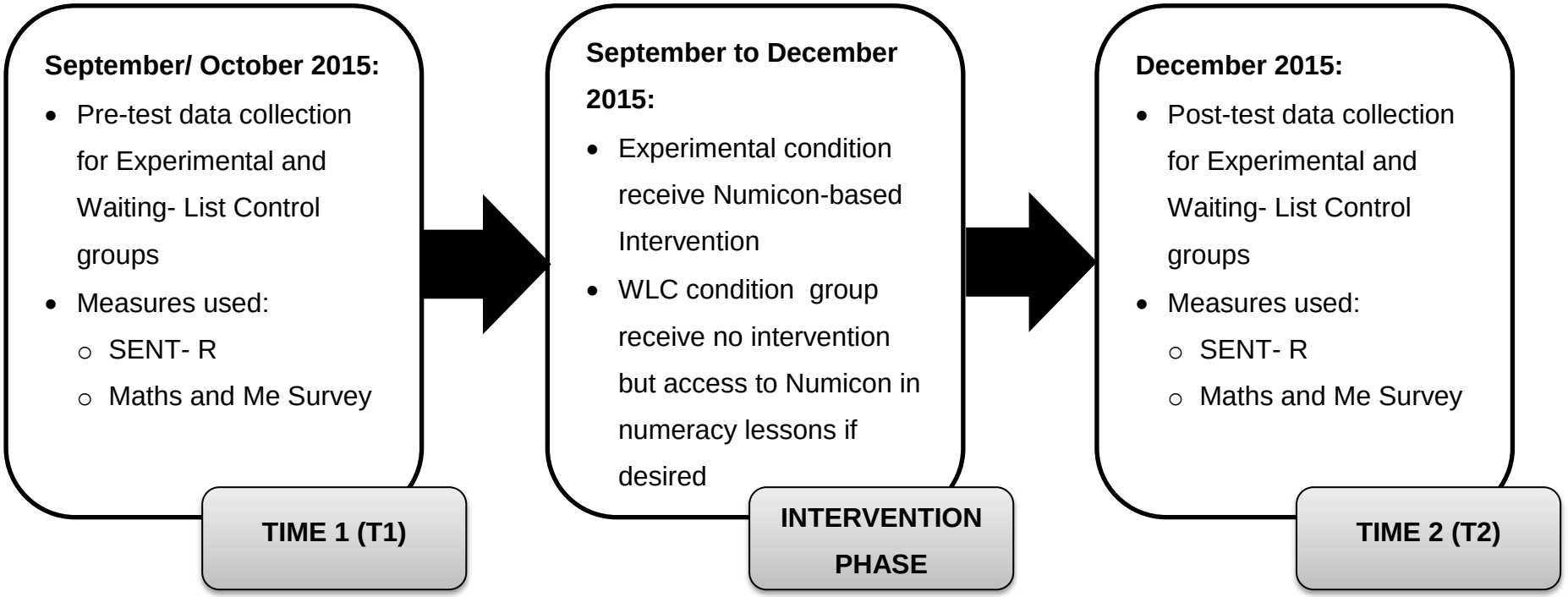
Objective	*School A*	*School B*	*School C*	*School D*
To know and order Numicon shape	✓	✓	✓	✓
To recognise 1 more and 1 less		✓	✓	✓
To be able to count on and back from a given number				✓
To make number pairs to 10	✓	✓	✓	✓
To make number pairs to 20		✓	✓	✓
To find different ways to make numbers up to 20	✓	✓		✓
To find the difference between 2 numbers	✓	✓	✓	✓
To make 2-digit numbers using Numicon shapes		✓	✓	✓
To be able to add 2-digit and 1-digit numbers		✓		
To be able to add 2-digit and 2-digit numbers (<20)		✓		✓
To recognise odd and even numbers			✓	✓
To be able to estimate how many			✓	✓
To count in 2s				✓

Upon completion of the Numicon-based intervention for pupils in the experimental condition, post-test data were collected within two weeks of completion, using the same method as T1 data collection. This was time 2 (T2) data collection. Pupils were administered the alternative form of the SENT-R to that which they had completed at T1.

Once all the T2 data had been collected, statistical analysis was completed of phase 1 data using R-Studio (data disc appendices 1-8).

The design procedure for phase 1 of the study is illustrated in Figure 3.2.

Figure 3.2 An illustration of the design procedure for phase 1 of the current study



3.6 Phase 2: The qualitative aspect of the study

3.6.1 Research question

According to the facilitators of the intervention, what are the outcomes for the children who have participated in the intervention, and what factors impact on these outcomes?

The purpose of this question was to compliment the findings from phase 1 of the study, by identifying any outcomes that facilitators identified for children who had participated in the intervention. It also aimed to further explore any underpinning mechanisms that may impact upon the Numicon-based intervention, and its outcomes.

3.6.2 The Design Procedure

In this section the methodology used and procedures undertaken during phase 2 of the study are discussed. Information is provided about sampling, the semi-structured interview and methods of data analysis

3.6.2.1 *Selection of facilitators*

As already discussed (Section 3.5.7.1), facilitators of the intervention were chosen by the school SENCo or Numeracy Coordinator.

Prior to the implementation of the intervention, all facilitators were invited to take part in a semi-structured interview. These were conducted individually once the experimental condition had received the intervention. Facilitators were provided with additional information via the 'Information Sheet for Facilitators' (Appendix 17) and were given an opportunity to ask any questions. Informed consent was obtained from four of the five facilitators.

3.6.2.2 *Interview with facilitators*

Following the collection of the T2 data, the group facilitators were interviewed individually using a semi-structured interview (Appendix 18)

According to Willig (2009), semi-structured interviews combine,

"features of the formal interview (e.g. fixed time limit; fixed roles of the interviewer and interviewee; existence of an interview agenda) with features of an informal conversation such as the open-endedness of the questions and the emphasis on narrative and experience" (p. 24-5).

Semi-structured interviews were used as they enabled the identification and exploration of underpinning factors that facilitators believed impacted on the intervention. This approach also allowed flexibility, with lines of enquiry and questioning being adapted dependent upon the participants' responses (Robson, 2011). Furthermore, Seale, in personal correspondence to Silverman (2013) argued that interviews are a pragmatic approach to obtaining information about something that the researcher has not experienced. Not only is this viewpoint consistent with the author's paradigm stance, but the author had no personal experience of Numicon.

There are however, some limitations to this method. Firstly, such interviews are *"prone to subjectivity and bias on the part of the interviewer"* (Cohen, Manion & Morrison, 2007, p. 352). Concerns have also been expressed about the reliability of such interviews due to their unstandardised nature (Robson, 2011).

In order to overcome issues of bias and reliability, self-administered questionnaires could have been used. This would have ensured questions were standardised across participants thus enhancing reliability, and have removed any interviewer bias. It was felt however, that such questionnaires may limit the responses the participants provided.

Consideration was also given to using a focus group, which according to Willig (2009) is *"a group interview that uses the interaction among participants as a source of data."* (p. 30). There was an awareness however, that participants may not feel confident at expressing their views in front of others (Willig, 2009), and there may be conflicts and power struggles within the group, as well as issues surrounding confidentiality (Robson, 2011

adapted from Robinson, 1999). It was therefore concluded that this was not an appropriate method of data collection.

3.6.3 Process of data analysis during phase 2

Thematic analysis (TA) was used in order to analyse the interview data. TA is *"a process for encoding qualitative information"* (Boyatzis, 1998, p. 4) that enables the researcher to "*identify, analyse and report patterns (themes) within the data"* (Braun & Clarke, 2006, p. 79). It is a unique form of qualitative research as it does not provide prescriptive methods of data collection, theoretical frameworks, epistemological or ontological frameworks (Braun & Clarke, 2013). Boyatzis (1998) further argues that TA enables researchers to communicate with other researchers who have a different paradigm stance, as well as with a broader audience.

The rationale underpinning the decision to use TA was threefold. Firstly, as TA can be applied across a range of theoretical or epistemological stances it was compatible with the author's personal stance (Braun & Clarke, 2006). Secondly, TA is a primary method of analysis, and is therefore ideal for the first time qualitative researcher (Braun & Clarke, 2006). Finally, as TA is an appropriate form of analysis for exploring individuals' understanding and perceptions (Braun & Clarke, 2013), it was appropriate form of analysis for this study.

It has however been argued that TA is not a valid form of analysis due to a lack of underpinning theory (Braun & Clarke, 2013). Some researchers have also expressed concerns that the voice of the individual can be lost and contradictory information ignored (Braun & Clarke, 2013).

Previously there had been concerns about the lack of clear guidelines on how to conduct TA (Braun & Clarke, 2006). In order to address this, Braun and Clarke (2006) produced a 'Six-Phase Guide' to completing TA which was theoretically and methodologically sound.

The six phases are:

1. Familiarising oneself with data: One immerses oneself in the data. An accurate transcript of the entire data corpus is produced, and the search for patterns and meanings across this data begins.
2. Generating initial codes: Interesting features of the data set are coded and collated.
3. Searching for themes: Codes are collated into potential themes.
4. Reviewing themes: Themes are reviewed to check whether they work in relation to coded extracts and entire data set.
5. Defining and naming themes: Themes are named. These should encapsulate the essence of each theme, providing definitions which summarise what each theme is about.
6. Producing the report

(Braun & Clarke, 2006; Braun & Clarke, 2013)

Throughout the process of TA, the researcher needs to make various decisions. These include whether to use an inductive- a bottom-up method of analysis that is data driven; or theoretical approach- analysis is driven by the researcher's theoretical or analytic interest (Braun & Clarke, 2006). In this study an inductive approach was used in order to explore the facilitators' perceptions of the Numicon-based intervention, and identify any theoretical underpinnings which emerged following data analysis.

Researchers also need to consider whether the themes will be identified at the semantic level- focusing primarily on descriptive nature and surface meaning of the data, which results in interpretation linked to previous literature; or at the latent level- focusing on the assumptions, conceptualisations and underlying ideas of the data (Braun & Clarke, 2006). In this study, themes were identified at the semantic level, focusing on the explicit meaning of the data, and then through interpretation, were linked into theory and previous literature.

Braun & Clarke (2006) identified numerous 'pitfalls' that a researcher needs to be aware of when conducting TA. It is important to actually analyse the

research rather than just paraphrase the data extracts. When generating themes, the researcher needs to ensure they are not a repetition of the questions asked during the data collection phase. Themes also need to capture all the data analysed, and to provide a detailed examination of the data. It is important to ensure that any analytic claims made are consistent with the data, and that the interpretations made are consistent with the theoretical framework in which the researcher is working. In order to reduce the risk of such pitfalls, the author followed the 'six-phase model' (Braun & Clarke, 2006), as well as receiving regular research and peer supervision, which provided an opportunity to share the processes being followed and discuss any limitations or concerns.

3.7 Design Considerations

In order to generate high quality data in mixed methods research, researchers need to ensure that both the quantitative and qualitative data they collect are both valid and credible (Teddlie & Tashakkori, 2009). This can be challenging as mixed methods researchers need to apply two sets of standards to ensure that their data are of high quality. With regards to quantitative data it is important that the data and measurements used are valid and reliable, whilst with qualitative data credibility and dependability are important (Teddlie & Tashakkori, 2009)

According to Teddlie & Tashakkori (2009), regardless of the type of data collected, researchers should ask themselves two key questions. These are:

- *"Am I truly measuring/ recording/ capturing what I intend to rather than something else?*
- *Assuming that I'm measuring/ capturing what I intend to, is my measurement/ recording consistent and accurate?"*

(Teddlie & Tashakkori, 2009, p. 209)

3.7.1 Design considerations for phase 1

As already discussed, quantitative data are concerned with issues of validity, both internal and external, and reliability.

3.7.1.1 *Threats to internal validity*

According to Mertens (2005) internal validity is concerned with controlling any extraneous variables that may impact on the dependent variable. If extraneous variables are truly controlled one can conclude that *"the changes observed in the dependent variable are due to the effect of the independent variable"* (Mertens, 2005, p. 121) and internal validity has been achieved.

The following threats to internal validity were identified in the current study (Table 3.11)

Table 3.11 Threats to internal validity and management of identified threats (Based upon Campbell & Stanley, 1963, from Mertens, 2005, p. 121-124; Cohen, et al., 2007)

Type of Threat	*Definition*	*Management of Threat*
History	External factors may impact on children's attainment and attitude	WLC condition
Maturation	Changes in attainment and attitude may be due to normal child development	
Testing	Children become 'test-wise' as pre- and post-tests are similar	SENT-R contains two parallel tests
Statistical regression	If extreme groups of participants are identified such as those at the lower end of the normal curve, their scores are more likely to improve due to their current position in a normal distribution.	Participants' scores on measures were not extreme and so the risk of statistical regression was removed.
Selection	Individual differences e.g. background and ethnicity may impact on the findings of the study	Each group had similar demographic features e.g. age, gender, SEN, EAL
Mortality	1. Children may be removed from the study 2. Children may miss sessions due to attendance	Information was provided at the start of the study to reduce threat of removal Any child who missed more than 25% of sessions not included in the final data set

Type of Threat	*Definition*	*Management of Threat*
Diffusion of treatments	Members of the experimental condition may share skills learnt during the intervention with those in the control condition	Due to the structure of numeracy lesson, there would be limited opportunities to share skills learnt
Resentful demoralisation of the control group	Those in the control condition become demoralised as they are not receiving any additional support. This impacts on their performance	The WLC condition continued to receive support/ differentiated activities in whole class lessons
Compensatory rivalry by the control group	Those in the control condition may try especially hard to improve their attainment	Due to the age of the children it was unlikely that they understood the wider implications of the study

3.7.1.2 *Threats to external validity*

According to Cohen, et al. (2007), "*External validity refers to the degree to which the results can be generalized to the wider population, cases or situations."* (p. 136). Researchers therefore need to manage threats to external validity, in order to make generalisations from their own research to other populations and settings (Cohen et al., 2007).

In this study, the following threats to external validity were identified (Table 3.12).

Table 3.12 Threats to External Validity and management of identified threats (Based upon Bracht & Glass, 1968, from Mertens, 2005 p.125-126)

Type of Threat	*Definition*	*Management of threat*
Ecological validity	The extent to which findings can be generalised to a wider population	1. Children were representative of the diverse population within the LA
Explicit description of the experimental treatment	A detailed description is provided of the IV (in this case the Numicon-based intervention) so that it can be recreated by others	1. Numicon is a published resource with example lesson plans and ideas provided 2. Session plans, including objectives, were shared with the author 3. Treatment fidelity checks were undertaken
Disruption effects	The introduction of a new treatment may not have any impact as it causes disruption to the norm	Children were used to accessing interventions so it did not cause disruption
Experimenter effect	The effectiveness of the treatment is dependent upon the facilitator, therefore it is not possible to generalise to other situations as the facilitator will not be delivering the treatment	Different members of staff, with experience, facilitated each intervention
Measurement of the dependent variable	Measures need to be effective and valid	1. The SENT-R is a standardised measure 2. The 'Maths and Me Survey' is a psychometrically validated instrument with high internal validity

Type of Threat	*Definition*	*Management of threat*
Interaction of time of measurement and treatment effects	Results of the post-test may be influenced by when it is delivered	Post-tests administered within two weeks of completing the interventions in each school

3.7.1.3 *Additional threats*

Mertens (2005) identifies two additional threats to validity in educational and psychological research, 'treatment fidelity' and the 'strength of the experimental treatment'.

'Treatment fidelity' is when the individual (facilitators) implementing the IV (Numicon-based intervention) do not implement the IV as intended (Gall, Gall & Borg, 2003). As Numicon is not a scripted intervention and can be used in various ways, the author observed one session in schools B and C to identify common features within the interventions. These were used to create a 'treatment fidelity checklist' (Appendix 19). Treatment fidelity checks were then completed in each school (1 to 3 per school) by the author. One check was completed by another TEP.

Table 3.13 collates the information from the treatment fidelity checks. This suggests that each intervention was implemented as intended, with common features present in the majority of sessions.

Table 3.13 Treatment fidelity checks of the Numicon-based interventions

Feature	*No. of sessions present (/8)*	*% of sessions present*
Lesson plan used	7	87.5
Opportunities for group/ paired work	0	0
Numicon specific language[8] used	5	62.5
At least two Numicon-based activities completed	8	100
Session focuses on number	8	100
Mathematical language is used/ discussed	8	100
Misconceptions are addressed	8	100
Children encouraged to contribute	8	100
Numicon used to support understanding of number	8	100

[8] This included terms such as 'Numicon staircase' and 'Numicon plates'

The strength of the experimental treatment considers the fact that an intervention may not be delivered over a long enough period of time for it to be deemed effective (Mertens, 2005). With regards to this study, interventions were delivered for 8 to 10 weeks, with pupils receiving 16 to 25 sessions. Each group received between 300 and 400 minutes of intervention over the autumn term. Decisions about the duration of interventions were made by individual schools based upon previous experiences of successfully implementing the intervention, and the needs of the individual children in each group.

There is little evidence on the ideal duration of group- based numeracy interventions (Dennis, Bryant, & Drogan, 2015), with limited evidence indicating "*a correlation between the length of the intensive support programme children receive and the gains made."* (Dowker, 2009, p. 16). Due to limited evidence, it is therefore difficult to conclude how long a numeracy intervention should be in order for it to be deemed effective.

3.7.2 Design considerations for phase 2

In qualitative research the researcher is the instrument of data collection, and therefore need to have an awareness of the *"values, assumptions, beliefs or biases [that] s/he brings to the study"* (Mertens, 2005, p. 247). It is therefore important that they reflect upon these throughout the study, recognising how they may influence the collection and interpretation of data (Mertens, 2005).

In order to promote credible qualitative research, the following need to be considered (Shenton, 2004; Mertens, 2005):

- Credibility: Does the researcher portray the respondents' viewpoints accurately?
- Transferability: Does the researcher provide enough contextual information, enabling the reader to identify if their situation is similar and whether findings can be transferred to their own context?
- Dependability: Does the researcher provide detailed information about processes involved in the research, enabling replication of the study?

- Confirmability: Does the researcher strive for objectivity by ensuring that data and interpretations can be tracked to their source, rather than being based upon the researcher's characteristics and preferences?
- Authenticity: Does the researcher represent all views fairly?

Table 3.14 identifies the steps taken in order to ensure the current study met the above criteria, thus resulting in credible qualitative research.

Table 3.14 Processes implemented to ensure credible qualitative research in the current study

Criterion	*Processes Implemented*
Credibility	• Transcripts shared with facilitators to ensure accuracy • Regular supervision with research supervisor to discuss and reflect on processes, interpretation of data analysis, and potential bias • Verification by facilitators ensuring their views are represented and interpreted accurately
Transferability	• Detailed information provided about the intervention, participants and context including: o Details about the schools taking part in the study o Pen portrait of facilitators
Dependability	• Detailed description of the research design and data gathering • Reflections on the process of inquiry
Confirmability	• Sources of qualitative data were clear • Author's interpretations were explicit, linked to relevant data • Data and inferences discussed with research supervisor • Inter-rater reliability obtained as part of the TA
Authenticity	• All viewpoints, including contradictions were shared

3.8 Ethical Considerations

According to the British Psychological Society (BPS) the purpose of ethical guidelines are to *"clarify the conditions under which psychological research can take place"* (BPS, 2014, p. 4). Such guidance identifies underlying principles which guide psychological research. It also highlights the importance of conducting research in an ethical manner thus developing *"mutual respect and trust between investigators and participants"* (BPS, 2014, p. 4), and promoting participants' confidence in the investigators (BPS, 2014).

The current author has applied guidance from the following sources, in order to ensure that any actions and decisions undertaken were ethical.

- Code of Ethics and Conduct (BPS, 2009)
- Code of Human Research Ethics (BPS, 2014)
- Code of Research Conduct and Research Ethics (University of Nottingham, 2015)
- Guidance on Conduct and Ethics for Students (HCPC, 2012)

Ethical decisions were also guided by the author's professional and ethical judgement, and ethical approval was obtained from the University of Nottingham's Ethics Committee Review (Appendix 7).

Based upon the above guidance, the following principles were identified as relevant to the current study (Table 3.15).

Table 3.15 Ethical principles and considerations relevant to the current research (Based on BPS, 2009; BPS, 2014; HCPC, 2012; UoN, 2015) For details of references to specific guidance see Appendix 20

Principle	*Specific Considerations (Paraphrased)*	*Actions Taken*
Consent	• Informed consent from all individuals participating in research • Sufficient information provided so all participants especially children understand the nature, purpose, and anticipated consequences of research participation • Informed consent for audio recordings • Adequate records of how consent was obtained	• Informed consent obtained from a senior member of school staff; parents; children and facilitators (Appendix 8, 10, 11 & 18) • Stakeholders Responsibilities sheet provided for schools and meeting with author to discuss the study • Consent obtained from children on one to one basis with author using 'Children's Information Sheet' • Parents invited to meeting to provide additional information about study. Presentation and author's contact details shared with those who could not attend. Information Sheet also shared with parents. • Information Sheet provided for facilitators and the opportunity to meet with author and discuss study prior to completing consent form.
Confidentiality	• Information kept confidential • Keep appropriate records, process, and store confidential information in a fashion designed to avoid inadvertent disclosure. • Removing any details that may lead to identification of participants	• Paper data stored securely at EPS where author was on placement • Electronic data stored on password protected spreadsheet • Consent obtained from children to share assessment data with parents and school staff. Parental consent also obtained to share data with school staff • Children given numerical identifiers • Recorded interviews stored securely on password protected CD

Principle	*Specific Considerations (Paraphrased)*	*Actions Taken*
Respect	• Avoiding unfair, prejudice or discriminatory practice • Participants have right to withdraw and to decline to answer questions	• All children received the intervention as part of the experimental condition or the WLC condition. • Whilst children may have missed other learning opportunities due to participation in the intervention, schools ensured that the intervention was delivered at an appropriate time depending upon the needs of the children • Information sheets for children, parents and facilitators stated that they had the right to withdraw at any time • A script (Appendix 13) was used during T1 and T2 collection, which stated that children did not have to answer all questions and could return to class at any time
Responsibility and Risk	• Avoidance of any actions which may harm the participants or cause additional risk especially if participants are vulnerable • Participants need to be debriefed at the conclusion of their participation in the research	• During T1 and T2 data collection a member of school staff was available in case any of the children experienced anxiety. This however did not occur. • Interviews were completed individually and data were anonymised. Facilitators did not disclose anything personal • Upon completion of T1 and T2 data collection, information was provided regarding what would happen to the data • Debrief statements (Appendix 32 and 33) for parents and facilitators • Summary of findings were shared with schools and parents in writing (Appendix 34 to 35).

3.9 Summary

This chapter began with an introduction to the philosophical assumptions underpinning educational and psychological research, before discussing the paradigm stance of the author and underpinning rationale, and the methodology chosen. It then outlined the procedure followed in the current study, considering both ethical principles and threats to both validity and reliability.

In the next chapter the data collected during this study will be discussed and analysed.

Chapter 4 Data Analyses

4.1 Introduction

This chapter outlines the process of data analyses undertaken during phases 1 and 2 of the study in order to explore the research questions proposed in this study.

4.2 Phase 1: Quantitative data analyses

4.2.1 Types of data analyses

According to Cohen et al. (2007) there are two types of data analyses used in experimental research, exploratory and confirmatory. Exploratory entails discovering the effects of certain variables, whilst confirmatory seeks *"to support or not support a null hypothesis"* (Cohen, et al., p. 272).

In this study both exploratory and confirmatory analyses of the data obtained during phase 1 of the research were conducted, in order to explore the following research questions:

1. Does participation in a Numicon-based intervention have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties?
2. Does participation in a Numicon-based intervention have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?

When completing statistical analyses, two types of statistics are considered, descriptive and inferential. Descriptive statistics describe the data (Howell, 2013), and inferential statistics explore whether an experimental hypothesis is likely to be true or not (Field et al., 2012).

The types of statistics used are dependent upon what type of data has been collected by the researcher. In quantitative data, there are four levels of data which are described in Table 4.1.

Table 4.1 The four levels of data from Robson (2011, p. 420)

Data Type	*Definition*
Nominal	*"Categories used for classification purposes"*
Ordinal	*"A set of categories where they can be ordered in some meaningful way"*
Interval	*"Categories which are not only ordered but also have equal intervals on some measurements scale"*
Ratio	*"The same as interval level, but with a real or true zero"*

With regards to inferential statistics, it is important to identify whether one should use parametric or non-parametric statistical tests. This decision is dependent upon the type of data one has, and certain assumptions which will be discussed next.

4.2.2 Parametric and non-parametric tests

The purpose of both parametric and non-parametric tests is to *"test the plausibility that the null hypothesis is true"* (Robson, 2011, p. 446), where the null hypothesis predicts that the distributions of all samples being investigated will be the same (Hinton, 1995). Such tests provide the probability (p value) that a given effect would occur by chance if there were no difference between the samples (Dancey & Reidy, 2007). If $p < 0.05$ then researchers conclude that the result is statistically significant, as there is only a 5% chance that the result would occur by chance, rejecting the null hypothesis.

4.2.2.1 *Parametric tests*

According to Hinton (1995), parametric tests *"use sample statistics as estimators of population parameters"* (p. 49). Such tests require interval or ratio data, and make certain assumptions about both the characteristics of the underlying populations and the actual sample including:

- Scores are obtained from a random sample in the population
- Observations that make up data are independent of each other, and not influenced by each other
- The population from which the sample is taken is normally distributed unless the sample size is greater than 30
- Homogeneity of variance: Each group has similar variance of scores.

(Pallant, 2013)

4.2.2.2 *Non parametric tests*

If any of the above assumptions are violated then non-parametric tests must be used. Such tests assume that data are made up of independent observations from a random sample (Pallant, 2013). For many parametric tests there is an equivalent non-parametric test.

Some statisticians, such as Pallant (2013), state that non-parametric tests are less powerful than parametric tests and therefore more likely to result in a type-II error. Field et al. (2012) however argue that this isn't true for data that are non-normally distributed.

4.2.2.3 *Limitations of statistical significance testing*

Whilst statistical significance testing is a popular approach used in psychological research it is not without its criticisms (Hubbard & Ryan, 2000). Researchers are therefore encouraged to report the size of an effect, known as the effect size, for statistical significant results (Howell, 2013). The effect size is "*a way of quantifying the size of the difference between two groups"* (Coe, 2002). It is particularly useful when comparing the efficacy of an intervention compared to another group, whether control or comparison (Coe, 2002). According to Howell (2013), Cohen (1988) defined three types of effect sizes (Table 4.2).

Table 4.2 Effect sizes identified by Cohen (1988) taken from Howell (2013)

Effect size	*D*	*Percentage of overlap*
Small	.20	.92
Medium	.50	.80
Large	.80	.69

4.2.3 Meeting parametric assumptions

In order to assess whether data meets the parametric assumptions outlined above, various steps can be taken.

4.2.3.1 *Assessing whether data is normally distributed*

The following methods may be used to identify whether data is normally distributed:

- Using visual representations such as histograms, Q-Q plots or boxplots
- Examining the skewness and kurtosis
- Conducting tests of normality

(Pallant, 2013)

4.2.3.1a *Visual representations*

There are various visual representations that may be used to assess whether data are normally distributed.

Histograms are a good way to spot obvious problems with data, and to examine the shape of a distribution (Field et al., 2012). If the data are normally distributed the following features will be observed on a histogram:

- The distribution will be symmetrical around the mean
- The tails will meet the x-axis at infinity
- The distribution will be bell-shaped

(Dancey & Reidy, 2007)

One can also plot a normal distribution curve over the histogram for comparison purposes (Field et al., 2012), although Howell (2013) argues that this is a *"misleading approach"* (p. 75).

Another way of visually assessing whether data are normally distributed is to use a boxplot, as this provides information about the median, the interquartile range, and whether the data are symmetrical or skewed. It also identifies any outliers (Field et al., 2012). A limitation of the boxplot however, is that it is difficult to distinguish between a normal and bimodal distribution (Dancey & Ready, 2007).

A final visual representation is the Q-Q Plot, which *"plots the quantiles of a variable against the quantiles of a [normal] distribution"* (Field et al., 2012, p. 924). If data are normally distributed then a straight diagonal line will run through the plot at 45° (Howell, 2013).

In the current study both histograms, which enabled any outliers to be identified, and Q-Q plots were used to visually assess whether the data were normally distributed.

4.2.3.1b *Skewness and kurtosis*

In order to identify whether the data have a 'goodness of fit', relative to the normal distribution, researchers can examine the skewness and kurtosis (Foltz, 2013). Skewness refers to *"the symmetry of the distribution"* (Pallant, 2013, p. 59), whilst kurtosis provides *"information about the peakedness of the distribution"* (Pallant, 2013), p.59). The skewness and kurtosis of data were therefore investigated in order to identify whether it were normally distributed.

4.2.3.1c *Tests of normality*

Whilst visual methods can be used to assess if data is normally distributed, such methods do not provide conclusive evidence that this is the case (Razali & Wah, 2011). Tests of normality should therefore be conducted to identify whether data is normally distributed (Razali & Wah, 2011).

The four most common normality tests are the Shapiro-Wilk test, Kolmogorov-Smirnov test, Anderson-Darling test and Lilliefors test (Razali & Wah, 2011). When the power of these test were compared, the Shapiro-Wilk test was found to be *"the most powerful test for all types of distribution and sample sizes*" (Razali & Wah, 2011, p. 32), although for samples less than 30 its power was low. Other researchers however, have claimed that the Shapiro-Wilk provides accuracy for samples as small as 3 (Ahmad & Khan, 2015).

In this study the Shapiro-Wilk test was therefore used to test whether the data were normally distributed. Although the power of the Shapiro-Wilk test maybe low for smaller samples, it was concluded that it was the most appropriate test of normality for the current data.

4.2.3.2 *Testing for homogeneity of variance*

In order to test for homogeneity variance between groups, the Levene's test can be used (Pallant, 2013). This test provides a level of statistical significance, and if the variances are similar then this will not be statistically significant ($p > .05$). In the current study it was important to test whether there was homogeneity of variance between the two groups at T1, as if not any possible differences identified at T2 may be attributed to group differences rather than the intervention. A Levene's test was therefore conducted to explore this.

4.2.4 Data analysed from phase 1

Twenty-six children participated in the current study; sixteen were allocated to the experimental condition and ten to the WLC condition. T1 data (Appendix 21) were collected for all of the children, but one child, from the experimental condition, was absent at T2 data collection (Appendix 22) so their data has been removed from the study.

In order to explore research question 1, the SENT-R was used to assess attainment, which provides interval data. Research question 2 was

concerned with attitudes towards numeracy, which were measured using the 'Maths and Me Survey'. As this uses a Likert scale, the data was classified as ordinal data. Many researchers however, classify data from Likert scales as interval data (Bryman & Cramer, 2005). Robertson, Shema, Mundfrom and Holmes (1995) take an opposing view, explained that data obtained from Likert scales are discrete and non-interval, and therefore should be classified as ordinal. This view is supported by Rainer, McCollin and Ramalhoto (2007) who highlight that if one person rates themselves as a '2' on a Likert measure of life satisfaction, and then on another occasion rate themselves as a '4', this does not mean that they are necessarily twice as happy, but rather that they are feeling more satisfied with their life.

4.2.5 Statistical testing used in phase 1 analyses

As the data obtained from the SENT-R provided interval data, in order to identify the type of inferential statistics to be undertaken, the data was assessed to investigate whether it met parametric assumptions. This is discussed in section 4.2.6.2.

With regards to research question 2, Robertson et al. (1995) argue that even though data from Likert scales are ordinal, if enough individual items are added together to provide an overall score, parametric tests may be used. Cohen et al. (2007) however argue that it is unacceptable to conduct parametric tests on ordinal data. Non-parametric tests were therefore used to analyse the data from the 'Maths and Me Survey'.

4.2.6 Data analyses for research question 1

The DV for research question 1 was attainment as measured by the SENT-R. This data was analysed in order to investigate:

Does a Numicon-based intervention for children in Year 3 experiencing mathematical difficulties, have an impact on their numeracy attainment?

It was hypothesised that participation in the Numicon-based intervention would have a positive impact on the attainment of children allocated to the experimental condition compared to those in the WLC condition.

4.2.6.1 *Descriptive statistics*

Descriptive statistics for research question 1 are outlined in Table 4.3 and include data for children in both conditions at T1 and T2.

Table 4.3 Descriptive statistics of the SENT-R for the experimental and WLC conditions at T1 and T2

	Condition	*N*	*SENT-R Result*		
			Mean	*Range*	*Standard Deviation*
T1	Experimental	15	37.27	38	9.32
	WLC	10	39.6	26	7.93
T2	Experimental	15	40.33	37	12.08
	WLC	10	45.2	39	12.15

Information obtained from the descriptive statistics shows the mean scores for the experimental condition were lower than the mean scores for the WLC condition at both T1 and T2. The difference between scores for the two conditions appears minimal, although a greater difference was observed at T2 between the two conditions.

With regards to the standard deviation scores, the spread of scores for the experimental condition at T1 were greater than the spread for the WLC condition, whereas at T2 the spread between conditions were similar.

The data above suggests that the attainment scores for both conditions increased between T1 and T2. At both times of testing the mean score for the experimental condition was lower.

4.2.6.2 *Does the data meet parametric assumptions?*

This section summarises the steps taken to ensure whether the data were normally distributed, and the conclusions reached.

4.2.6.2a *Visual analyses of data*

In order to explore whether the data were normally distributed for both conditions visual analyses of the data was undertaken. Histograms were produced for each condition to analyse whether T1 scores were normally distributed (Figure 4.1 and Figure 4.2).

Figure 4.1 A histogram to show the distribution of scores for children in the experimental condition at T1

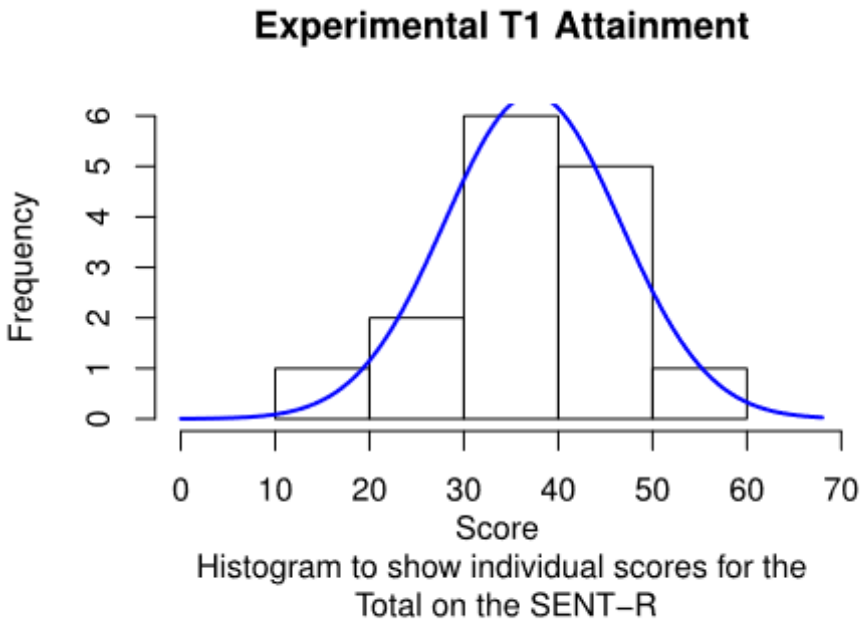
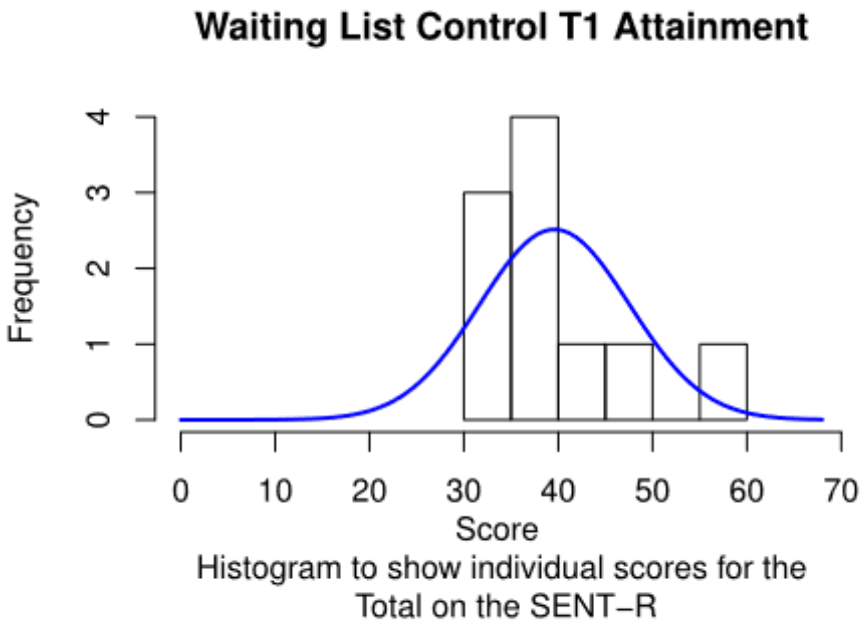


Figure 4.2 A histogram to show the distribution of scores for children in the WLC condition at T1



Following visual analyses of the histograms it was concluded that there were no outliers within each condition. Within both conditions however, the scores appeared negatively skewed with scores clustered towards the higher values. This was especially true for the WLC condition. The distribution for the WLC condition also appeared to show a positive kurtosis with a high peaked distribution.

Q-Q Plots for both conditions were also visually analysed (Figure 4.3 and Figure 4.4).

Figure 4.3 A Q-Q Plot to show the distribution of scores for children in the experimental condition at T1

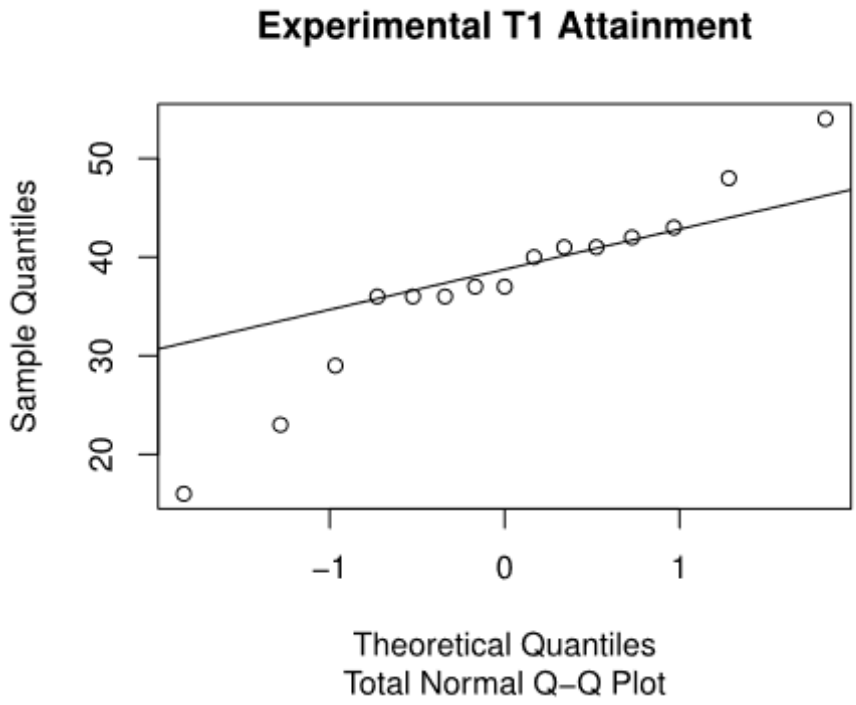
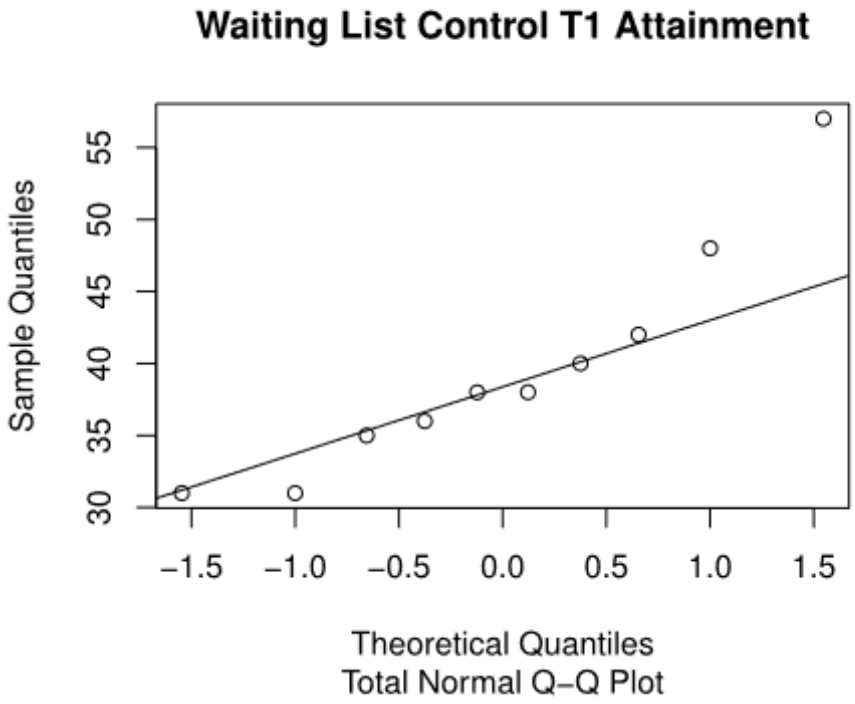


Figure 4.4 A Q-Q Plot to show the distribution of scores for children in the WLC condition at T1



Visual analyses of the Q-Q Plots suggested that the data were normally distributed within both conditions as the majority of scores fell within a line. There were however some scores which fell slightly off the line and so tests of normality were conducted.

4.2.6.2b *Test of normality*

A Shapiro-Wilk test for the T1 data in both the experimental and the WLC condition was conducted (Table 4.4).

Table 4.4 Results for the Shapiro-Wilk test of normality for the T1 scores of the experimental and WLC conditions

Condition	*Statistic (W)*	*Significance (p)*
Experimental	0.935	0.323
WLC	0.894	0.187

As the p value for both conditions was greater than 0.05, it was concluded that neither condition were significantly different from the normal distribution, and therefore met the assumption that data were normally distributed.

4.2.6.2c *Homogeneity of variance*

In order to explore whether there was homogeneity of variance between the T1 scores for the two conditions, a Levene's test for the experimental and WLC conditions, $F(1,28) = 0.143$, $p = .708$, was undertaken.

Based upon the above information, it was concluded that the T1 data for both the experimental and the WLC conditions were normally distributed and that therefore a parametric test could be implemented to investigate research question 1.

4.2.6.3 *Inferential statistics*

An ANCOVA enables exploration of differences between groups, whilst controlling for an additional (continuous) variable known as the covariate, which may be influencing the DV scores (Pallant, 2013).

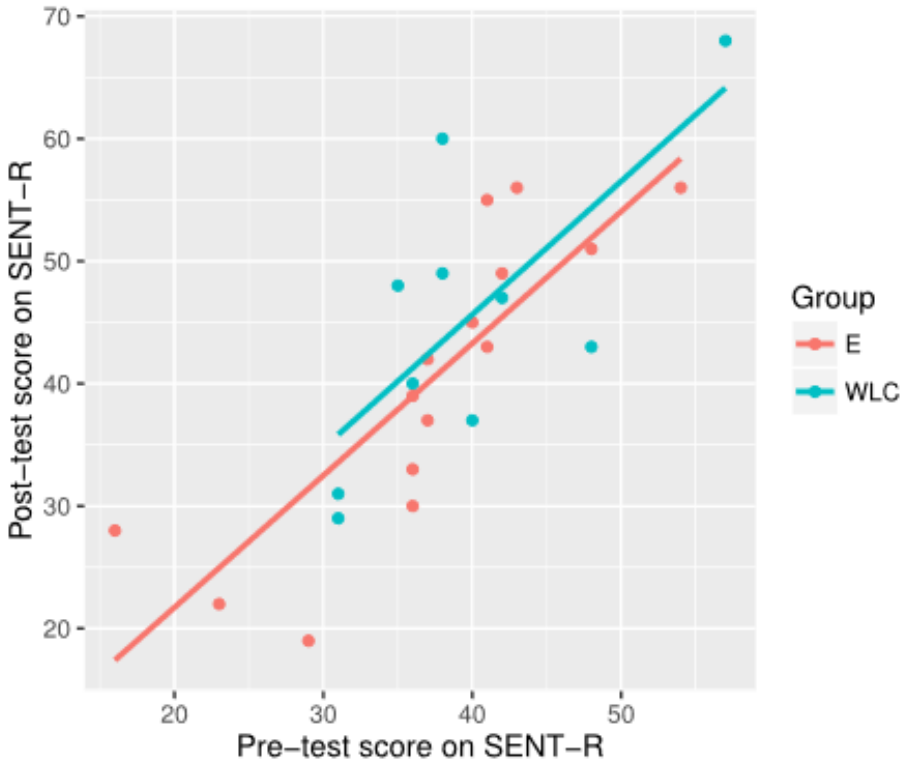
This test was deemed appropriate as it can be used to analyse the data obtained from a two group pre-test/ post-test design, where the pre-test data is the covariant (Pallant, 2013). This enables existing differences between groups to be controlled for and is particularly suitable for small sample sizes, which have not been randomly allocated (Pallant, 2013), both of which were features of this study.

4.2.6.3a *Preliminary analyses for ANCOVA*

When conducting an ANCOVA there are certain assumptions which must be met. Firstly, there must be a linear relationship between the DV and the covariate. The relationship between these variables must be the same for each group. This is known as the 'homogeneity of regression slopes'.

In order to explore whether there was a linear relationship between the DV and the covariate, a scatterplot was plotted showing the individual scores for each condition, with regression lines added (Figure 4.5)

Figure 4.5 A scatterplot to show the relationship between the covariate and the dependent variable with regression lines



The homogeneity of regression slopes was also investigated. The interaction between condition*pre-test scores was found not to be statistically significant ($p = 0.978$), therefore the assumption of homogeneity of regression slopes had not been violated.

4.2.6.3b *ANCOVA*

As the assumptions relevant to ANCOVAs had not been violated, a one-way ANCOVA was conducted to identify whether a Numicon-based intervention had a positive impact on attainment. The IV was the Numicon-based intervention, and the DV was attainment as measured by the T2 scores on the SENT-R. T1 scores on the SENT-R were used as the covariate.

After adjusting for pre-intervention scores, no statistically significant difference was found between the post-test scores for the two conditions (experimental and WLC) on the SENT-R, F (1, 22) = .553, p = .465, partial eta squared = .025. There was a strong relationship between the T1 and T2 scores on the SENT-R, as indicated by a partial eta squared value of .75.

4.2.6.3c *Gains within both conditions*

The ANCOVA compared the difference between the experimental and WLC condition scores at T2, on the SENT-R. Each condition however consisted of children from four different schools, with those in the experimental group receiving interventions from five different facilitators, teaching a range of skills. Raw score gains made by children from each school in both the experimental and WLC conditions were therefore compared. As the number of children from each school was only small, inferential statistics could not be used, instead the mean raw score gains for each school were considered. The findings are presented in Table 4.5.

Table 4.5 The mean raw score gains in attainment made per school for children in both conditions as measured by the SENT-R

School	*Mean raw score gains for children in the experimental condition*	*Mean raw score gains for children in the WLC condition*
A	-4.33	N/A
B	4.4	- 1
C	5.33	15.33
D	5.25	7.5

The above data shows variations between the mean raw score gain on the SENT-R for children in both conditions and from different schools. This suggests that various factors may impact on the attainment of children participating in the intervention including the facilitator, the content of the intervention sessions, and individual characteristics of the children. As there are differences between the mean raw score gains between children in the WLC condition too, this further suggests that individual characteristics of the

children impact on individual attainment, as does the teaching received in whole class learning.

4.2.6.4 *Conclusion*

Descriptive statistics suggested that there had been an increase in the attainment score of children in both conditions at T2, the results of the ANCOVA suggested that the condition in which the children were in (experimental or WLC) did not have a statistically significant impact on their attainment as measured by the SENT-R. Therefore the experimental hypothesis as stated in Chapter 3, Table 3.2, was rejected and the null hypothesis accepted:

Participation in a Numicon-based intervention will not have an impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties.

It is important to note that other factors may have impacted on the scores obtained as T2. These and the findings from the ANCOVA will be considered in Chapter 5.

4.2.7 Data analyses for research question 2

The DV for research question 2 was children's attitudes to numeracy as measured by the two subscales, 'mathematical self-perception' and 'enjoyment of mathematics' on the 'Maths and Me Survey'. This data were analysed in order to investigate:

Does a Numicon-based intervention impacted on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?

It was hypothesised that participation in the Numicon-based intervention would have a positive impact on the children in the experimental condition attitudes towards numeracy compared to those in the WLC condition.

4.2.7.1 *Descriptive statistics*

Descriptive statistics for research question 2 are outlined in Table 4.6 and include data for children in both conditions at both T1 and T2. As the data were ordinal, the medians, ranges and interquartile ranges (IQR) are reported.

Table 4.6 Descriptive statistics of the 'Maths and Me Survey' for the experimental and WLC conditions at T1 and T2

	Condition	*N*	*Maths and Me Survey*					
			Mathematical self-perception			*Enjoyment of mathematics*		
			Median	*Range*	*IQR*	*Median*	*Range*	*IQR*
T1	Experimental	15	32	15	6.5	44	15	8.5
	WLC	10	30	22	10.75	36.5	32	17.75
T2	Experimental	15	33	14	5	44	17	8.5
	WLC	10	31	24	8.5	41	22	5.5

The descriptive statistics show that at T1 children in the experimental condition, on average, had slightly more positive mathematical self-perceptions compared to the WLC condition, and enjoyed mathematics more than those children in WLC condition. The spread of scores on both subscales were greater for the children in the WLC condition at T1.

At T2 there was an average increase of one for the mathematical self-perception of children in both conditions. The spread of scores was greater for children in the WLC condition, with the range of scores increasing by 2. The average score for the enjoyment of mathematics remained constant for children in the experimental group. Although the increase for the children in the WLC condition was 4.5 points from T1 to T2, the average score at T2 was still less than that of the children in the experimental condition, suggesting that those in the WLC control group did not enjoy mathematics as much as those in the experimental group.

The mean Likert rating score for individual statements from each subscale at both T1 and T2 for children in both conditions (Table 4.7) was considered.

Table 4.7 The mean Likert rating score for an individual statement on each subscale at T1 and T2 for the experimental and the WLC condition.

	Condition	*N*	*Maths and Me Survey*	
			Mathematical self-perception	*Enjoyment of mathematics*
T1	Experimental	15	4.02	4.25
	WLC	10	3.43	3.46
T2	Experimental	15	4.08	4.34
	WLC	10	3.75	4.04

Based upon an American sample of 1504 pupils aged 8 to 12 years, the mean Likert rating score for the mathematical self-perception scale is 3.79, and for the enjoyment of mathematics scale is 3.59 (Adelson & McCoach, 2011). At both T1 and T2 the children in the experimental condition had higher mean Likert rating scores on both scales, compared to the standardised average, whilst children in the WLC condition had higher mean Likert scores at T2 on both subscales, but not at T1.

The above suggests that at T1, children in the experimental condition, had higher mathematical self-perceptions (difference = 0.23) and enjoyed mathematics more (difference = 0.66), compared to the average child aged 8 to 12. At T2 there was a slight increase in the average Likert rating score on each subscale (Mathematics self-perception = 0.06; Enjoyment of mathematics = 0.09), with scores remaining above the average score for children aged 8 to 12.

At T1, those in the WLC condition had slightly lower mathematical self-perceptions (difference = -0.36) and enjoyed mathematics slightly less (difference = -0.13) compared to the average child aged 8 to 12. At T2, based on the mean Likert rating score, their mathematical self-perception remained below the average score for children aged 8 to 12 (difference =

-0.04), but their enjoyment of mathematics was greater than the mean Likert rating score (difference = 0.45). When comparing T1 and T2 data, the mean Likert rating score, for children in the WLC condition, increased by 0.32 on the mathematical self-perception subscale, and by 0.58 on the enjoyment of mathematics subscale. These findings will be discussed in more detail in Chapter 5.

4.2.7.2 *Inferential statistics*

As the data obtained from the 'Maths and Me Survey' was ordinal, parametric tests could not be used. Therefore non-parametric tests were used.

In order to investigate whether there was a statistical significant difference between the scores of the two groups on both subscales prior to the intervention; a Wilcoxon rank-sum test, which is a non-parametric equivalent of the independent t-test, and functionally the same as the Mann-Whitney test (Field et al., 2012), was used. The findings were as followed.

Mathematical self-perceptions, as measured by the 'mathematical self-perception' subscale of the 'Maths and Me Survey' for children in the experimental condition (Mdn = 32) were not statistically different from those of children in the WLC condition (Mdn = 30) at T1, W=98.5, p=.201, indicating that the children shared the same distribution.

Enjoyment of mathematics, as measured by the 'enjoyment of mathematics' of the 'Maths and Me Survey' for children in the experimental condition (Mdn = 44) were not statistically different from those of children in the WLC condition (Mdn = 36.5) at T1, W=107, p=.079, indicating that the children shared the same distribution.

In order to test the null hypothesis a Wilcoxon rank-sum test was conducted to compare the T2 scores of children in the experimental and WLC conditions on both subscales of the 'Maths and Me Survey'. The results were as followed:

Mathematical self-perceptions for children in the experimental condition (Mdn = 33) were not statistically different from those of children in the WLC condition (Mdn = 31) at T2, W=91, p=.389, indicating there were no significant differences between the mathematical self-perceptions of children in either condition.

Enjoyment of mathematics, for children in the experimental condition (Mdn = 44) were not statistically different from those of children in the WLC condition (Mdn = 41) at T2, W=89.5, p=.0.435, indicating there were no significant differences between the perceived enjoyment of mathematics for children in either condition.

4.2.7.2a *Gains within both conditions*

The Wilcoxon rank-sum test compared the difference between the experimental and WLC condition scores at T2, on the subscales of the 'Maths and Me Survey'. As previously discussed each condition consisted of children from four different schools, with children experiencing some differences in the experimental condition. It was therefore decided to compare raw score gains made by children from each school in both the experimental and WLC conditions. As the number of children from each school was only small, inferential statistics could not be used, the mean raw score gains between each school were considered. The findings are presented in Table 4.8.

Table 4.8 The mean raw score gains in attitudes towards numeracy made per school for children in both conditions as measured by the subscales of the 'Maths and Me Survey'

School	*Mean raw score gains for children in the experimental condition*		*Mean raw score gains for children in the WLC condition*	
	Mathematical self-perception	*Enjoyment of mathematics*	*Mathematical self-perception*	*Enjoyment of mathematics*
A	- 0.67	0	N/A	
B	1.8	3.8	4	7.6
C	2.67	4	4.67	5
D	- 1.75	- 3.5	- 4	2.5

The above data shows variations between the mean raw score gains on the subscales of the 'Maths and Me Survey' for children in both conditions and from different schools. This suggests that various factors may impact on the attitudes children, in the experimental condition, hold about mathematics including the facilitator, the content of the intervention sessions, and individual characteristics of the children. For example, two of the three children in school A were EAL and so may have had some difficulties in understanding the content of the questions. In school B, many children scored highly on the two subscales at T1 and so a ceiling effect may have occurred, which could explain the small increase in mean gains. In school D, one child's score on both subscales greatly decreased at T2, which will have impacted negatively on the mean gains for the children in this school.

As there are differences between the mean raw score gains for the children in the WLC condition too, this further suggests that individual characteristics of the children impact on individual attitudes, as does the teaching received in whole class learning. At T1, two children in school B had obtained low scores on both subscales. This meant that there was an opportunity for a large increase at T2, which did occur. The same applied to one child in school C. These increases may explain why the mean gains for these two schools appear so great. This will be discussed in chapter 5.

4.2.7.3 *Conclusions*

The results of the Wilcoxon rank-sum test suggested that there was not a statistically significance difference between the attitudes towards numeracy, as measured by the 'Maths and Me Survey', between children in the experimental and WLC condition. The experimental hypothesis as stated in Chapter 3, Table 3.2, was rejected and the null hypothesis accepted:

Participation in a Numicon-based intervention will not impact on the attitudes towards numeracy, of children in Year 3 experiencing mathematical difficulties.

It is important to note that other factors may have impacted on the scores obtained as T2, as discussed previously. The implications of these and findings from the Wilcoxon rank-sum test will be considered in Chapter 5.

4.3 Phase 2: Data analyses

TA was used to address the following research question:

According to the facilitators of the intervention, what are the outcomes for the children who have participated in the intervention, and what factors impact on these outcomes?

A rationale has already been provided as to why TA was chosen, and what type of TA was undertaken (section 3.6.3). The purpose of this section is to discuss the steps actually completed during the analysis using Braun and Clarke (2006) 'Six-Phase Model'.

4.3.1 Familiarising oneself with data

Initially, each recorded interview was listened to. Each interview was then transcribed (data disc appendices 9-12) using a notation system adapted by Braun and Clarke (2013) from Jefferson (2004) for orthographic transcripts (Appendix 23). Transcripts were checked against recordings before being

shared with each facilitator to ensure they were a precise representation of the interviews. In order to become familiar with the data, the transcripts were re-read and notes added about things of interest such as overall impressions; conceptual ideas; and concrete and specific issues (Appendix 24).

4.3.2 Generating initial codes

The purpose of this stage was to identify aspects of the data relevant to the research question. Initially each data extract was summarised or paraphrased (data disc appendix 13). Using 'complete coding', which *"aim[s] to identify anything and everything of interest or relevance to answering [the] research question within [the] entire data set"* (Braun & Clarke, 2013, p. 206), any data that was relevant to the research question was then coded (Appendix 25 & data disc appendix 14). Each code evolved from the initial summarising that had occurred, and provided a brief phase that captured the essence of particular data extracts (Appendix 26). Codes were predominantly data-driven, providing a summary of the data extracts based upon the semantic meaning of the data, and mirrored the language of the facilitators. Some researcher-driven codes were also identified. Such codes identify the *"assumptions and frameworks that underpin what is said in the data."* (Braun & Clarke, 2013, p. 207).

Once the data had been coded, the data extracts were revisited to ensure all data had been coded appropriately. The codes were also revisited to identify whether any overlapped and needed to be developed into broader codes. In total 60 codes were identified at this stage, although some were later disregarded as they were not relevant to the research question or only represented the view of one facilitator.

4.3.3 Searching for themes

During this stage all of the codes were recorded on individual post-it notes. Codes were then grouped into provisional themes known as candidate themes (Appendix 27). Each theme was used to group codes that were related, but contained different ideas and concepts. Codes that were not

necessarily relevant to the research question, or did not appear to fit into any candidate theme were added to the 'miscellaneous' theme (Appendix 28). During this stage, the author met with her research supervisor to discuss her data analyses in more detail.

4.3.4 Reviewing themes

The purpose of this stage was to review and refine the candidate themes ensuring they provided an overall picture of the data.

At this stage all the themes were reviewed, resulting in some themes being disregarded and others reviewed (Appendix 29). For example, the theme 'other' was disregarded as it was felt the codes within this theme such as 'facilitator pleased with outcomes' did not add anything to the findings of the study. In another example, the two themes 'familiarity of Numicon equipment' and 'impact of Numicon equipment' were merged to form a new theme 'the importance of Numicon equipment'. The theme 'children' had been identified, but upon further consideration this theme was disregarded, as it was felt it did not provide any additional information with regards to the research question. The theme 'limitations' was also disregarded, as there was not enough data to support this theme.

4.3.4.1 *Inter-rater reliability checks*

At this stage two other TEPs completed inter-rater reliability checks. According to Boyatzis (1998) inter-rater reliability is a method for attaining reliability, which is critical in TA. In TA, reliability is not concerned with verification, as in the post-positivist paradigm, but with the *"consistency of observation, labelling or interpretation"* (Boyatzis, 1998, p. 144). Boyatzis further explains that reliability enables a researcher to combine qualitative and quantitative approaches to research, allowing, *"the interpretive social scientist's social construction of meaning to be articulated and packaged in such a way that descriptions of social 'facts' or observations seem to emerge*" (p. 145). Such a statement is consistent with the author's epistemological stance and the notion of paradigm pluralism.

In the current study, the purpose of these checks were twofold, firstly to determine the reliability of the codes, and secondly to ensure that the themes and subthemes worked in relation to the coded data.

Consistent with guidance from Joffe (2012), 10% (13 examples) of the data extracts that were relevant to the research question, were shared with the TEPs, who were asked to apply initial codes to the extracts. The concordance between the TEPs and the author's coding was 65 per cent (Appendix 30), with TEP 1 agreeing with 52 per cent of the codes, and TEP 2 78 per cent. Joffe (2012) states that if the concordance is 75 per cent or higher, one can conclude that the coding is relatively reliable and transparent. As the concordance between the author and TEP 1 was less than 75 per cent, the author met with them to discuss the discrepancy between codes. Following this discussion it was apparent that differences in opinion had arisen at TEP 1 was not aware of the context of some of the codes, and had interpreted some of the codes differently to the author. TEP 1 was also conducting TA in her research, using a hybrid approach, and had taken a theoretical approach, rather than inductive approach when interpreting some of the codes in the current study.

The TEPs were then asked to allocate each code that was relevant to the research question to a theme or subtheme to check for inter-rater reliability (Appendix 31). The concordance for matching the codes to the themes and subthemes was 86.5 per cent, with TEP 1 agreeing on 97 per cent of the codes, and TEP 2 with 76 per cent. Consistent with guidance provided by Joffe (2012), these findings suggest that the allocation of codes to themes is relatively reliable and transparent.

4.3.4.2 *Member checks*

To ensure that the results obtained through the TA where credible and represented the views of the facilitators, the author met with three of the four facilitators to discuss her findings and provide them with an opportunity to discuss whether they were representative of their viewpoints and experiences.

All three facilitators felt that the results represented their experiences and viewpoints fairly, and did not feel anything had been misrepresented. Beth commented that “I completely agree with all of it”.

Meeting with the facilitators also provided an opportunity to discuss the findings of the quantitative analyses and to obtain their views on these outcomes. This will be discussed in more detail in Chapter 5.

4.3.5 Defining and naming themes

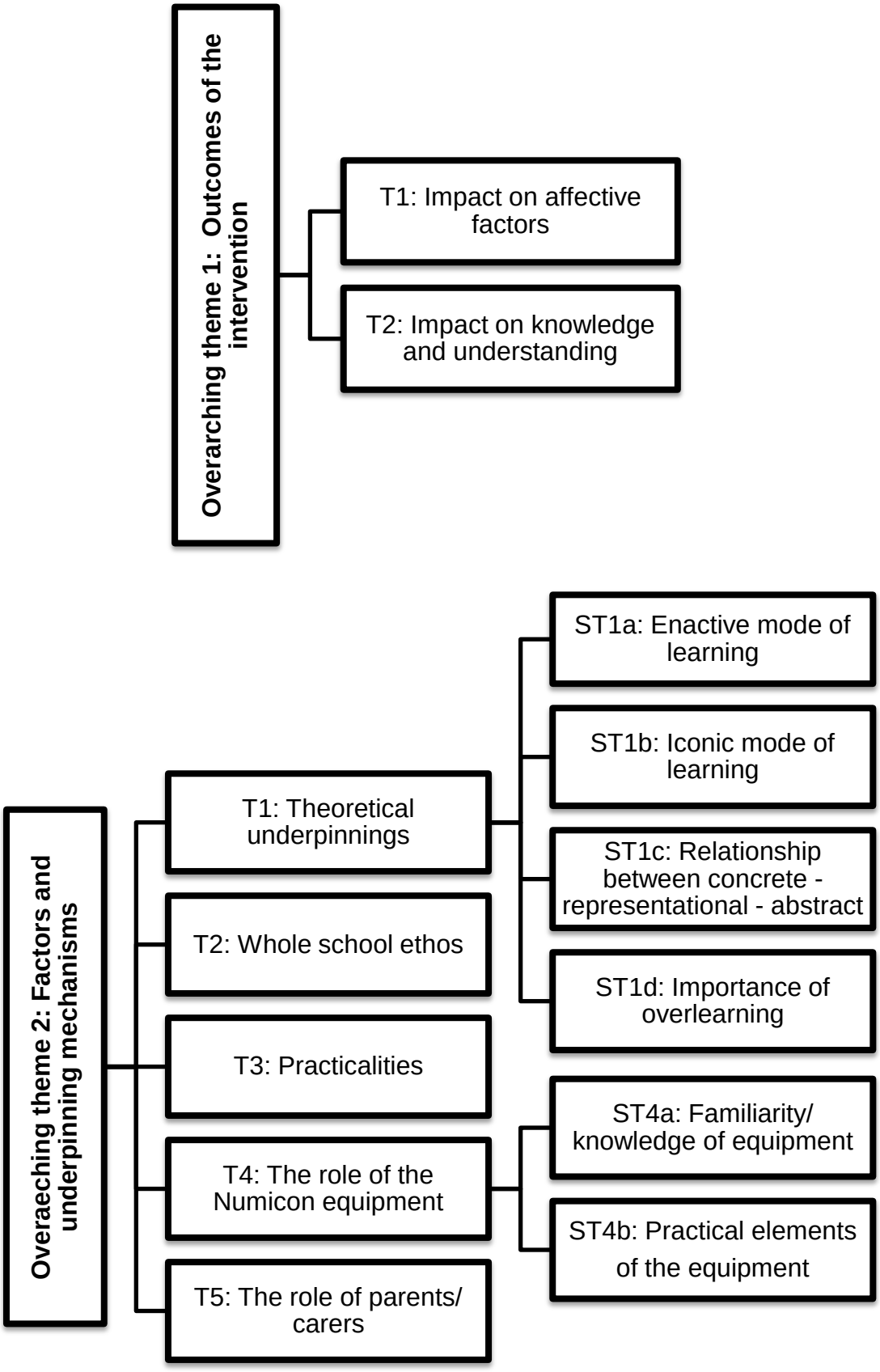
The final stage of the process was to name and define each theme, ensuring that each theme was discrete, and had a *“clear focus, scope and purpose”* (Braun & Clarke, 2013, p. 249). It was important to ensure that each theme told its own story, but also fitted into the overarching story told by the data.

Two overarching themes were identified, which linked to the research question. These were:

- Outcomes of the intervention, which consisted of two themes.
- Factors and underpinning mechanisms, which consisted of five themes, and five subthemes.

A hierarchical overview of the themes is shown in Figure 4.6, and the themes are discussed in more detail below.

Figure 4.6 A hierarchical overview of the overarching themes, themes and subthemes identified through TA



4.3.5.1 *Overarching theme 1*

Overarching theme 1 focused on the outcomes of the intervention, and consisted of two themes, 'impact on affective factors' and 'impact on knowledge and understanding'.

4.3.5.1a *Theme 1: Impact on affective factors*

Facilitators talked about how participation in the intervention had resulted in the children being more confident about mathematics. This was applicable to the children's general approach to mathematics, as well as in their handling of number. Amy for example commented, *"*The children [are] more confident with their maths number skills […] I could see them growing […] overall definitely I could see a confidence in their number skills and handling number". Whilst Debbie commented, "It's definitely helped bring on their confidence".

Facilitators also commented that upon completion of the intervention, the children were more actively involved in numeracy lessons, and more willing to engage in their learning, especially if they were using the Numicon equipment. These ideas are captured in the following comments by Beth and Clare.

> Beth, "It's making them want to learn more."
>
> Clare, "Now, whenever we start doing maths, they all go and grab a box of Numicon"

4.3.5.1b *Theme 2: Impact on knowledge and understanding*

Facilitators also talked about the impact that participation in the intervention had on the children's knowledge and understanding. This included their understanding of both numeracy and the Numicon equipment. With regards to numeracy, participation in the intervention led to a greater understanding and embedding of number sense, with children talking more about mathematics, and using mathematical language. This is captured in the following comments from Amy and Beth.

> Amy: "It's quite good at embedding number skills"

> Beth: “We had parents’ evening last week, and the way the children were able to talk to their parents […]. We’re really pushing the children to deliver the session themselves and talk about what they’ve been doing […]. The kids were actually getting it [the Numicon] out and getting their parents to build the staircase.”

Facilitators also reported that participation in the intervention further developed the children’s understanding during whole class learning. Clare for example said, “It fits into the scheme of things and […] it helps children understand”

A final outcome of the intervention identified during analysis was the impact that participation had on the children’s understanding of and their ability to use the Numicon resources. This is captured in this comment from Clare, “I’ve been pleased with how familiar they’ve become with […]. They’re very familiar with the plates and different techniques. That is usually a really good starting point”

4.3.5.2 *Overarching theme 2*

Overarching theme 2 focused on factors, and underpinning mechanisms, that facilitators perceived impacted on the outcomes of the Numicon-based intervention. It consisted of five themes, including some subthemes, which will now be discussed.

4.3.5.2a *Theme 1: Theoretical underpinnings*

Participants frequently talked about how the concrete and visual nature of the Numicon-based intervention helped children with their understanding of number and abstract mathematical concepts. They also discussed how participation in the intervention provided opportunities for overlearning, focusing on the repetition and consolidation of basic number skills. This theme consisted of four subthemes.

1. *‘Enactive stage of learning’*- This focused upon the fact that Numicon supports and promotes learning at the enactive stage. Debbie for

example talked about how the concrete nature of the resources helped children to remember saying, “Because you can move it physically with your hands it’s easier for them to embed it in their memory”

2. *‘Iconic stage of learning’*- The focus for this was that Numicon supports and promotes learning at the iconic stage. When asked about the positives of Numicon, Beth focused on the visual elements replying:

   “Definitely the visualisation that it gives the children. All of my group are now able to totally visualise all of the pieces. They can explain to you what colour they are what they come before and after. So where we have been trying to push them to maybe move a bit more pictorially they’ve actually been really confident with that”

3. *‘Relationship between concrete - representational and abstract learning’*- This theme highlighted how the visual and concrete nature of Numicon promoted understanding at the abstract level. Clare talked about this relationship, stating, “Doing abstract maths would be very, very difficult for them. This [Numicon] really does enable them to start understanding concepts that would be very difficult.”

4. *‘Impact of overlearning’*- The final subtheme emphasised the opportunities that the Numicon-based intervention provided for consolidation and repetition. Clare highlighted the importance of this saying:

   “I think it gave us an opportunity to recap some of the sort of basic number sense activities that they will have done in previous year groups. That was really useful, to go back over those things and remind ourselves of how numbers fit together”

These comments, and others, highlighted the theoretical underpinnings of Numicon that provide some insight as to why Numicon-based interventions

are perceived as being successful. These will be discussed in more detail in chapter 5.

4.3.5.2b *Theme 2: Whole school ethos*

Facilitators talked about the importance of having Numicon embedded in the whole school ethos, and the need for a consistent approach across the school, if the intervention was to be successful. This included introducing the resources from an early age, ensuring it was used regularly in numeracy lesson, and that children were able to access it whenever they felt it would be beneficial to their learning. It was also important that all staff were 'on board' and saw the benefits of Numicon both at whole class and intervention level. These ideas were captured in the following comments from Clare and Debbie.

> Clare: "As a school there is Numicon in every classroom so it's a very consistent approach. It would be difficult perhaps if one teacher was using it and another wasn't and you were moving from year group to year group and it wasn't always there, but as a school you know it's in every classroom"

> Debbie: "I think because we are using it as a whole school the impact's definitely gone up this year. With the first year I did it the interventions there wasn't a lot of impact, but now cos every class uses it from Reception all the way up to Year 6 I think it's had a big impact on maths."

4.3.5.2c *Theme 3: Practicalities*

When discussing what factors impacted on the outcomes of the intervention, facilitators discussed practicalities within the school setting that were important. All of the facilitators reported that the intervention was easy to implement, with some comments that the equipment needed to implement the intervention was easy to manage and tidy away. Attention was also drawn to the fact that the intervention needs to be consistent with regular sessions, although special events did impact on the delivery of the sessions. Debbie for example commented,

> "It works quite smoothly the only difficulty sometimes is when the class have got something else planned and they forget to tell you […].But we try and have a set time so at least the children and the staff know that's when their session is which helps."

It was also important that those facilitating the intervention had appropriate knowledge about it. Beth, for example, commented,

> "Last year I worked with some of the children in Year five that maybe needed a little bit of extra support and where their basic level wasn't as low as kind of Year two/ Year three. I felt like I wasn't confident enough to know where to go next with it, but I think if you had that knowledge it would be useful cos you would just pitch it differently to the higher KS2 rather than the lowers."

4.3.5.2d *Theme 4: The role of the Numicon equipment*

Facilitators highlighted the role of the Numicon equipment used in the intervention as being an important factor, identifying two subthemes.

1. *Familiarity and knowledge of equipment*- This highlighted the importance of the children being familiar with, having knowledge about, and being shown how to use the Numicon equipment prior to the intervention. Facilitators commented that if the children already had this knowledge they felt less daunted when the intervention began and were able to progress through the intervention at a quicker pace compared to those children who had not previously accessed the intervention. Beth for example commented,

   > "This particular group […]. They'd had it really kind of drummed into them with the Numicon, so by the time they came to us they were so familiar with the Numicon […]. They came with knowledge already so we found we could skip through elements of it quite quickly."

The impact of the intervention however, was less effective for those children who did not know how to use the equipment. This is illustrated by a comment from Debbie,

> "The ones that it hasn't helped for is to having that first understanding of what to do with the Numicon cos when you just look at the box you're just like 'how does that add to that and how do I do it'".

2. *Practical elements*- Facilitators also reported that the appearance of the Numicon equipment impacted on the outcomes of the intervention as they were fun to use and a good resource for teaching number sense. Beth commented, "I think the main thing with the Numicon because just because of the way it looks. It's so different; so for the kids it's fun for them to use." Whilst Amy explained, "I think it's a great resource […].Fab for number bonding, really good for number bonding. Yeah I think it's the best resource"

4.3.5.2e *Theme 5: The role of parents*

A final factor identified by facilitators as impacting on the outcomes of the intervention was the role of parents. Facilitators felt that it was important that parents were aware of Numicon, and understood how it was used to support their children's learning. Clare for example commented:

> "There are a number of evenings that are offered throughout the time that the children are here where the parents can come in and learn to use Numicon […].It's very different to when we were educated […] and so it is important to be able to understand how to use them that helps I think."

4.3.6 The overall story

TA has provided an insight into the four facilitators' views and perceptions of the Numicon-based intervention. Generally they perceived the intervention as positive, identifying positive outcomes for the children who have participated in it with regards to both affective factors and their understanding of

numeracy. A strong emphasis was placed on the role of the intervention in developing ‘number sense’ and confidence.

Facilitators also identified various factors and underpinning mechanisms that impacted on the outcomes of the intervention.

Theme one, ‘theoretical underpinnings’, highlighted the link between the Numicon-based intervention and various theories including Bruner’s ‘Theory of Instruction’ and the notion of ‘overlearning’. The links were consistently identified in various extracts and no contradictions were found within these subthemes.

Within theme two, facilitators stressed the importance of having Numicon embedded in the whole school curriculum at both whole-class learning and intervention level. Although the majority of ideas represented within this theme were consistent, Amy commented that children who were not introduced to Numicon at an early age, such as new arrivals to the school, were still able to access and use it effectively.

Theme three focused on the practicalities that schools should consider when implementing the Numicon-based intervention. There was general consensus within this theme about what practical factors within school impacted on the intervention, some specific to Numicon e.g. the Numicon resources are easy to manage, and others to the implementation of interventions in general such as the need for consistency and knowledgeable facilitators.

The Numicon equipment was also an important factor which impacted positively on the outcomes of the intervention, as it was seen as a good resource for teaching number skills, and children enjoyed using it. Clare did however comment that at times the resources could act as distraction with children focusing on the equipment rather than the actual learning. This view however was not shared by the other facilitators. All of the facilitators however, felt that prior to beginning the intervention, children needed to have used the Numicon equipment, and understand how it worked.

A final factor that impacted on the outcomes was the role of parents. In one school some parents had perceived the intervention as babyish due to the nature and colour of the equipment. This school had therefore worked hard to help parents understand how Numicon worked and why it was beneficial for their children's learning. Whilst other schools did not report that they had received any negative responses towards the intervention, they did highlight the importance of ensuring parents understood and had knowledge about Numicon.

Information gathered from the TA was largely consistent with few contradictions within the data. Generally the intervention was perceived as positive. Some facilitators did however identify some limitations, but these could not be included in the TA as each facilitator identified a different limitation. These however will be discussed in chapter 5.

4.4 Summary

This chapter has focused on the analyses of both the quantitative and qualitative data with reference to the research questions.

Following the statistical analyses of the data obtained in phase 1 of the study, the null hypotheses for research questions 1 and 2 have been accepted. With regards to phase 2, TA has been conducted in order to identify themes that are relevant and answer research question 3.

In the next chapter the implications of all of these findings will be discussed.

Chapter 5 Discussion

5.1 Introduction

The purpose of this chapter is to further explore the findings of the current study and to discuss the implications of these findings, linking them to previous literature.

A critique of the methodology used is undertaken and limitations discussed. This chapter also considers the relevance of the findings for EPs, as applied practitioners, and other professionals working within education; as well as considering further research that could be conducted in order to further explore the effectiveness of the Numicon-based intervention.

5.2 Research findings

The current study used a mixed-method explanatory sequential design. Phase 1, which used a pre-test post-test quasi-experimental design, explored the impact of a Numicon-based intervention on the attainment and attitudes towards numeracy of Year 3 children experiencing mathematical difficulties. Phase 2, using a qualitative approach, explored the factors that impacted on the outcomes of the intervention from the perspective of the intervention facilitators, as well as exploring what they believed were the outcomes for the children who had participated in the intervention.

5.2.1 Research question 1

Does participation in a Numicon-based intervention have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties?

Previous research conducted in England (Bury LST, 2008; Education Leeds, 2005; ECC, 2008; Herbert, 2011; Jones, 2014; OSI 2014a; OSI 2014c; Saunders, 2005), Ireland (Lane, 2009) and the USA (Jenkins, 2013), found that participation in a Numicon-based intervention had a positive impact on

the attainment of children, in primary education, experiencing mathematical difficulties. There were however, various limitations to these studies as highlighted in sections 2.8.4 and 2.9. The purpose of the current study was therefore to explore the efficacy of a Numicon-based intervention on the mathematical attainment of Year 3 children experiencing mathematical difficulties in order to build upon the current evidence base. Year 3 children were chosen as the focus, as the majority of previous studies had focused on KS1 pupils (Bury LST, 2008; ECC, 2008; Jenkins, 2013; Jones, 2014; Lane, 2009).

Consistent with findings from previous research, it was hypothesised that participation in such an intervention would have a positive impact on the attainment of such children. When statistical testing was conducted however, in order to compare the T2 data of children allocated to the experimental condition and the WLC condition, the results were found not to be statistically significant and the null hypothesis was accepted.

Whilst this finding was not consistent with previous research there are various reasons why this outcome may have occurred.

5.2.1.1 *The use of SENT-R*

Firstly there are some limitations with the SENT-R that was used to measure attainment. The SENT-R is based upon the system of National Curriculum levels that were removed in 2014 (DfE, 2014b). Previous research has found that Year 3 children, on average, make 1.2 sublevels progress in numeracy over the academic year; between the autumn and spring term approximately 50% make no progress, 35% make one sublevel progress, and 15% make two sublevels progress (DfE, 2011b). Based upon these statistics, one could argue that the children who participated in this study would be expected to make limited progress over the given time period of the study.

Upon completion of the study, the author analysed the structure of the SENT-R in more detail, identifying that the SENT-R consists of 67 questions, with a maximum score of 76. Each sublevel is assessed by a certain number of

questions, with a different number of marks available at each sublevel (Table 5.1).

Table 5.1 The percentage of questions used to assess each sublevel of the National Curriculum on the SENT-R

Level	*No. of marks*	*% of marks*
P6	6	7.9
P7	7	9.2
P8	6	7.9
1C	8	10.5
1B	5	6.5
1A	4	5.3
2C	5	6.5
2B	18	23.7
2A	17	22.4

Over 50 per cent of the marks available on the SENT-R can only be achieved if a child is working at a Level 2C or above. Therefore, even if a child working at Levels 1C to 1A makes progress over a fixed period of time, the number of marks they are able to gain is less than those a child working at a Level 2C or above would be able to gain. With regards to the current study, this is important as 70 per cent of children in the WLC condition were working at a Level 2C or above, whereas only 36 per cent of the children in the experimental group were working at this level. This suggests that the children in the WLC condition had more opportunity to achieve additional marks at the end of the intervention, as they may have made some progress due to quality first teaching, and therefore would have had a greater number of marks available to them. It is also important to note that at T1, five children in the experimental condition were working at a Level 1C, whilst no children in the WLC condition were working at this level. Even if these children had made a sub-levels progress between T1 and T2, they would only have been able to achieve an additional 5 marks, whilst a child working at a Level 2C who made

a sub-levels progress would have been able to achieve up to an additional 18 marks. This disparity between the number of children working at a Level 1C and Level 2C within the two conditions may explain why there was not a significant difference between the scores of the children in the two conditions.

The SENT-R consists of five strands which measure different components of number. If a child gets two consecutive questions on any strand incorrect then that strand is discontinued. A child however, may be able to answer questions later on within the strand, but would not be given the opportunity to do this. Whilst the author could have chosen to administer the complete measure to each child to address this issue, she did not feel it would be ethical to do this, as it may cause some children anxiety if they were unable to complete questions. The author also felt it was important to administer the measure in the standardised way. One final consideration was that from a pragmatic point of view, it would have been time consuming to administer the complete measure, which would have resulted in the children missing more of their lessons, which the author did not wish to do.

Based upon the above information, one could argue that the SENT-R was not the most appropriate measure. From the measures considered however, it was felt that the SENT-R was the most appropriate (see section 3.5.6.1 for more information on this).

Secondly, as with all assessments, the SENT-R only provides a snapshot of a child's performance and could be influenced by a range of factors. This could include individual characteristics of the child such as their mood or levels of tiredness. In schools A and D the post-test data were collected towards the end of the autumn term (mid-December). As this is seven week term and is also near Christmas, the children may have been especially tired or excited about finishing school and the upcoming festivities. Such factors may have impacted on their performance.

The SENT-R was administered by the author or another TEP, both of whom were unknown adults to the children who participated in the study. This may

have impacted on the children's performance, as they may have felt more at ease if the assessment had been administered by a known adult. It was felt however, that it was more appropriate for the measure to be administered by unknown adults to increase the objectivity of the assessment.

5.2.1.2 *Numicon as a confounding variable*

Although the children in the WLC group did not access the Numicon-based intervention, they were using Numicon equipment during their numeracy lessons, albeit not in a structured or formalised way, and could access additional support from school staff during these lessons. This access to the equipment is a confounding variable, as it may have helped further their knowledge and understanding of mathematical concepts, and hence had a positive impact on their attainment in numeracy. The conclusion that access to Numicon in whole class learning would have a positive impact on attainment is consistent with reports from three primary schools who found an increase in the percentage of pupils achieving Levels 2 and 3 at the end of KS1 (OSI 2014a; OSI, 2014c) and those achieving Levels 4 and 5 at the end of KS2 (OSI 2014c; OSI 2014d). Lane (2009) also reported the positive impact of using Numicon in numeracy lessons to support children of all mathematical abilities, especially those experiencing some difficulties, in the development of basic number concepts.

The children in the WLC condition may also have experienced 'diffusion of treatments', with the children from the experimental condition sharing with them the learning that had occurred in the intervention. Furthermore, in some of the schools, the facilitator of the intervention also worked in the Year 3 classes during numeracy lessons, and therefore in some lessons may have worked with the WLC condition sharing some of the things that they were doing in the intervention, if they thought it would further the learning of the children in the WLC condition too. This hypothesis however, would be contradictory to previous research (Muijs & Reynolds, 2003; Blatchford et al., 2009), which has suggested that children who received additional support during literacy and numeracy lessons from LSAs make less progress than their peers.

Whilst the author acknowledges the limitation of this part of the design, it was not possible to prevent children from the WLC condition from using the Numicon equipment, as not only would it have been unethical to remove a resource that supports children with their learning, but the use of Numicon in numeracy lesson was standard practice in all the schools that had chosen to participate in the research. Furthermore, previous research by Jones (2014) had found that where children were not used to using Numicon equipment, the intervention was less effective. Schools that used Numicon in whole class learning had therefore been specifically recruited in order to address this issue.

5.2.1.3 *The Numicon-based intervention*

It is also important to consider factors relating to the intervention. The Numicon-based interventions that the children participated in were not standardised; each school delivered sessions relevant to the needs of their children. One could therefore argue that the schools were delivering different interventions, which were not comparable. In order to address this, treatment fidelity checks (section 3.7.1.3) were completed, which identified comparable features within the intervention that were present in all sessions observed and could be identified as those elements that make an intervention a Numicon-based intervention. These included:

- At least two Numicon-based activities are completed
- Sessions focused on number
- Numicon is used to support the understanding of number
- Mathematical language is used/ discussed.

Session plans were also examined and common objectives being taught within each school identified (Table 3.10). Overall the interventions focused on 13 objectives with the following being taught in all four intervention groups:

- To know and order Numicon shapes
- To make number pairs to 10
- To find the difference between two numbers.

Whilst there appears to be a lack of consistency between objectives taught within the four intervention groups, the majority of objectives were concerned with identifying 1 and 2-digit numbers, and focused on activities that involved addition or subtraction.

When comparing the current Numicon-based intervention to those delivered in previous studies, only one (Jones, 2014) used the published Numicon intervention. The other studies used plans from the Numicon teaching manuals (Bury LST, 2008; Herbert, 2011) or developed their own plans based upon Numicon (Cambridgeshire, 2007; ECC, 2008; Education Leeds, 2005; Jenkins, 2013; Lane, 2009; Saunders, 2005). The fact that many schools tended not to use the published Numicon intervention makes it difficult for general conclusions to be made about the efficacy of Numicon-based interventions, although all of the studies concluded that participation in the intervention had a positive impact on the attainment of participating children. A possible explanation as to why published interventions tend not to be used is that previous guidance advised that interventions should be personalised to the individual needs of the children (Dowker, 2004, 2009; Williams, 2008). This suggests that published interventions may not be as effective, as they do not address individual needs of the children.

It is important to consider the duration of the interventions. In each school the intervention was delivered for a different period of time, ranging from 300 to 400 minutes of intervention time over the autumn term. The participating schools chose to deliver the interventions for a given period of time based upon previous experience of successfully implementing the intervention and the needs of the individual children in each group. In previous research the duration of the Numicon-based interventions has ranged from 200 minutes (Jenkins, 2013) to 900 minutes (Jones, 2014) yet all have been found to be effective. As there is limited evidence on the ideal duration of group- based numeracy interventions (Dennis et al., 2015), it is difficult to conclude whether the differences in duration impacted on the effectiveness of the interventions and their outcomes.

In the current study the majority of intervention sessions were delivered by support staff. Previous research (Blatchford et al., 2009; Muijs & Reynolds 2003) has found that children who are supported by support staff do not make additional progress compared to those who do not receive support, although this support was based within the classroom.

Research by Sharples et al. (2015) and Blatchford et al. (2012) reported that LSAs who delivered interventions were found to have a positive impact upon the attainment of children if they received appropriate training in how to deliver interventions, as well support and guidance from teachers on how to plan, prepare and implement the interventions. In the current study, although all facilitators had received some training in how Numicon could be used to support the development of number, they had not received specific training on how Numicon could be used in interventions. Furthermore, teaching staff were not always involved in providing guidance on the planning and implementation of the interventions- in school B the class teacher did plan all of the sessions, but in schools A and C, session plans were selected from the Numicon scheme, and in school D the LSA planned the intervention herself. It is not clear what guidance was provided from teaching staff to facilitators in schools A, C and D.

Another important factor identified by Sharples et al. (2015) was that LSAs should be delivering structured interventions. When the author audited the session plans, she felt that the interventions delivered in schools B and C were well structured. In school A however, as all of the session plans were not provided, it was difficult to conclude whether the sessions were well structured, whilst in school D, the author felt that the lesson plans lacked structure.

The points highlighted above suggest that the intervention may not have been as successful as hoped due to a lack of relevant training and in some schools support from teaching staff in the planning and implementation of the intervention. This is supported by the fact that in school B, where the teacher, planned intervention sessions, mean gains (Table 4.5) for children in the

experimental condition were 4.4, whilst for the WLC condition they were -1. Contradictory to this however were the mean gains made by children in school A, who received some sessions from the SENCo. Based upon previous evidence (Williams, 2008) one would expect these children to make the most progress, but this was not the case, with these children making mean gains of -4.33. This may in part be due to the fact that the children in school A were all EAL. The implications of which are discussed later.

Whilst the author acknowledges that the above may provide some rationale as to why the interventions were not as successful as intended, these views are hypothetical and not supported by robust evidence in the current study.

5.2.1.4 *Individual differences*

One factor that is likely to have impacted on the outcomes of the intervention is children's individual differences. During her interview, Beth spoke of the fact that one child had missed some sessions due to absences, which had impacted on her progress within the intervention. Beth also explained that some children were easily distracted, and this impacted on their understanding, whilst other children found it difficult to retain the things that they had been taught. Whilst, according to Amy, 'chaotic home situations' impacted on the children's rate of learning. These examples were consistent with findings from Herbert (2011) who reported, *"The children who made the least progress were often described as inattentive, having poor memories or additional emotional differences."* (p. 3). Herbert also acknowledged the negative impact of poor attendance on the outcomes of the intervention.

Six of the children who participated in the intervention were EAL. Evidence from the SENT-R suggests that some of the children who were EAL may have had some difficulties in understanding the questions asked, which may have influenced their performance, and therefore the outcomes of the study. For example, in school A, where means gains on the SENT-R were negative (Table 4.5) two of the three children were EAL. Beth also reported that children who were EAL had some difficulties in understanding some of the learning that occurred during the intervention. Consistent with guidance from

Dowker (2009) however, who identified that manipulatives play an important role in interventions, especially for children with language difficulties, Amy and Debbie felt that Numicon supported these children in their understanding of mathematical concepts. Whilst children who were EAL may have had some difficulties accessing the intervention, the author wished to include children with EAL in the study as many schools have such pupils, and the author wished for the participants to be representative of the school population within the area where the study was conducted.

The fact that the mean gain scores (Table 4.5) differed for children in the experimental condition from different schools, further highlights the impact of children's individual differences on the outcomes of the intervention. It also suggests that the individual characteristics and the experience of the facilitators may have impacted on the outcomes, although there is not enough evidence to conclude how such factors may have impacted on the outcomes.

When examining the mean gain scores for both conditions, it is apparent that children in the WLC condition made more progress between T1 and T2, with a mean gain of 5.6, compared to those in the experimental condition, who had a mean gain of 3.06. This highlights the importance and role of quality first teaching with regards to children's progress. These findings may also be attributed to other factors such as having access to the Numicon equipment, or the structure of the SENT-R, which have previously been discussed.

To conclude, the findings from this study related to attainment were not consistent with those of previous research and resulted in the acceptance of the null hypothesis. It is important to note however that there is limited research into the effectiveness of Numicon-based interventions, and that previous research is not without its limitations (section 2.9.5). Therefore more research needs to be conducted, to further add to the evidence-base, especially as many schools now use Numicon to support mathematical learning and understanding (Gifford et al., 2015).

5.2.2 Research question 2

Does participation in a Numicon-based intervention have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?

Previous research has suggested that participation in Numicon-based interventions does have a positive impact on children's attitudes towards numeracy. This has included children feeling more confident about numeracy (Bury LST 2008; Doncaster MBC, 2008; Education Leeds, 2005; Lane, 2009; Leicester LA, 2009) and more willing to participate and have a go (Bury LST 2008; Doncaster MBC, 2008; Leicester LA, 2009). Reports from teachers who have used Numicon in both whole class learning and interventions further suggested that Numicon had a positive impact on children's enjoyment of, and attitudes towards numeracy (OSI, 2013a; OSI, 2013b; OSI, 2014a; OSI, 2014b; OUP, 2011).

Consistent with these findings it was hypothesised that participation in the Numicon-based intervention would have a positive impact on the attitudes towards numeracy of children who were experiencing mathematical difficulties. In order to investigate this, the 'Maths and Me Survey' was used at T1 and T2 to measure the attitudes of children in both conditions. Statistical analysis of the data for the two subscales at T2 ('mathematics self-perception' and 'enjoyment of mathematics') revealed that there was not a significant difference between the attitudes of children in the experimental condition and the WLC condition suggesting that participation in the Numicon-based intervention had not had a positive impact on the children's attitudes towards numeracy. The null hypothesis which stated, "Participation in a Numicon-based intervention will not impact on the attitudes towards numeracy, of children in Year 3 experiencing mathematical difficulties" was therefore accepted. Whilst inconsistent with previous findings, there are various factors which need to be considered.

Firstly, many of the children in the experimental condition already had a positive attitude towards numeracy prior to involvement in the Numicon-based intervention. As previously reported, the mean Likert rating score for the mathematical self-perception scale is 3.79, and for the enjoyment of mathematics scale is 3.59 (Adelson & McCoach, 2011), although this is based upon a USA sample. At both T1 and T2 the mean Likert rating score for children in the experimental condition was greater than these. Closer examination of this data revealed that at T1, five children scored below the mean Likert rating score on the mathematical self-perception subscale, and two children scored below the mean Likert rating score on the enjoyment of mathematics subscale. All of these children however had an average mean Likert rating score greater than three on both subscales, which according to Dowker et al. (2012) is a neutral score and therefore suggests that all children in the experimental condition had positive attitudes towards numeracy at T1.

The findings in this study were consistent with previous research that has found children under the age of 9 tend to have a positive attitude towards numeracy (Dowker et al., 2012). There have however been other studies which have found that children experiencing difficulties in mathematics have more negative attitudes towards mathematics compared to their peers (Ashby, 2009; Krinzinger et al., 2009; Mazzocco et al., 2012; Thomas & Dowker, 2000). As the children in this study were identified as experiencing such difficulties, one might expect them to have negative attitudes towards numeracy. It is therefore important to consider why this was not the case.

The ‘Maths and Me Survey’ is a self-report measure, and therefore there is the possibility of response bias, with children answering in a way they believe is socially desirable. It is also important to note that such measures can limit the child’s responses and restrict the expression of their views (Smith et al., 2005), and thus the ‘Maths and Me Survey’ may not truly reflect the attitudes of children towards numeracy. Qualitative methods such as a semi-structured interviews or focus groups may therefore have been more effective in obtaining the children’s views. The purpose of the current study however,

was to compare the attitudes of the children in the two conditions and so a quantifiable measure of attitude was used. There were also concerns that some of the children may find it difficult to engage in an open discussion about numeracy due to their levels of understanding and their confidence.

Another consideration is whether the children understood the content of the 'Maths and Me Survey'. The survey was produced for younger children and the survey's authors have conducted a large scale study with children aged 8 to 12 (Adelson & McCoach, 2011) suggesting that it was suitable for children in Year 3. In the current study however, 35 per cent of the children were EAL and therefore may have had some difficulties in understanding the language used.

Finally, one needs to consider the impact of other factors on children's attitudes towards numeracy. Attard (2011) identified three influences on children's attitudes towards numeracy:

- Outside (family, culture)
- Inside (peers, curriculum)
- Core (pedagogical content; teacher's attitude and relationship with students).

Attard (2011) reported that children describe good mathematics lessons as those that included physical activity or active learning and opportunities to interact with peers and work collaboratively. As Numicon involves physical activity and active learning, it could be argued that it would be perceived positively by children and may therefore have a positive influence on their attitudes towards numeracy. This may further explain why the children in the current study generally perceived numeracy positively as they have been using Numicon for over a year when the study began and therefore it may be a core influence on their attitudes. Their attitudes may also have been influenced by outside and inside factors. It is important to note that these conclusions are purely hypothetical as they have not been explored in the current study.

To conclude, in the current study many children already had positive attitudes towards numeracy, which may explain why the Numicon-based intervention did not impact on their attitudes. Other factors that may have influenced these findings have also been discussed and considered. Based upon the findings from this and previous research however, there appears to be inconsistencies regarding the development of attitudes to numeracy. It is therefore important that additional research is conducted in order to further understand how negative attitudes towards numeracy develop and whether these are linked to mathematical attainment or other factors.

5.2.3 Research question 3

To date the majority of research into the effectiveness of Numicon-based interventions has predominantly focused on the attainment based outcomes of the children who have participated in the intervention. Some studies have also looked at affective factors, but there has been limited, if any research, exploring why Numicon-based interventions are perceived as being effective and what possible factors impact on the effectiveness of such outcomes. For this reason, the following question was investigated:

According to the facilitators of the intervention, what are the outcomes for the children who have participated in the intervention, and what factors impact on these outcomes?

The rationale underpinning this question was twofold. Firstly, the author wanted to further explore what the outcomes were for children who participated in the intervention, as she felt purely using quantitative methods would not be without its limitations, and that the addition of qualitative data would further add to the evidence-base. Secondly, although previous research had shown Numicon-based interventions to be effective, it was not clear why. The author therefore, wanted to explore possible underpinning factors, and felt these could best be explored by talking to those who delivered the intervention and had first-hand experience of it, as well as relevant training, and knowledge and understanding about Numicon.

When analysing the interview data, two overarching themes were identified:

- Outcomes of the intervention
- Factors and underpinning mechanisms

With regards to the outcomes of the intervention, the facilitators placed a strong emphasis on the impact it had on affective factors. Facilitators reported that children were more confident about numeracy, especially with regards to handling and using number. The children were also engaging more actively in their numeracy lessons, seeking out Numicon equipment independently in order to support their learning. When the author met with Debbie to discuss the findings of the study, Debbie further commented that the children who had participated in the intervention were accessing lessons more, and that parents had commented how their children appeared more confident about maths. This was consistent with previous information provided by education practitioners who had used Numicon to support children's learning, and further supported the opinion that Numicon-based interventions have a positive impact upon affective factors. For example, both Bury LST (2008) and Education Leeds (2005) reported that participation in Numicon-based interventions resulted in high levels of engagement and enjoyment. Whilst Leicester LA (2009) reported that children appeared more confident, re-engaging and participating in whole class learning following participation in the intervention. These views were supported by Lane (2009) who reported that children developed confidence of themselves as learners. Wilson (2014) also reported that manipulatives in general had been found to impact positively on children's confidence in numeracy.

Facilitators also felt that participation in the intervention had positively impacted on the children's knowledge and understanding of both numeracy concepts such as number sense, and the Numicon equipment. Children were more confident at using mathematical language and sharing their mathematical thinking with others. Beth, when the author met with her to discuss the findings, explained how at a recent parents' evening, the children had been able to explain how they had used Numicon to start to understand concepts such as addition and subtraction. Again, the views represented by

the intervention facilitators were consistent with those of other education professionals who had participated in previous research. For example in one study, teachers reported that Numicon supported children in their understanding of mathematical language and enabled them to recognise the numerosity of number (Devon Primary Mathematics Team, 2006). In another, Numicon was reported to support children in learning concepts such as rapid recall of number bonds to 10, which they had previously struggled to understand (Leicester LA, 2009). According to Jenkins (2013), teachers felt that participation in a Numicon-based intervention had resulted in improvements in various number skills including rote counting and the relationship between numerals and quantities.

When considering possible factors and underpinning mechanisms that may impact upon the outcomes of the intervention, the facilitators identified five key areas.

The facilitators frequently talked about the visual and concrete nature of the resources. Such features have been identified by the NCETM (2014) as playing an important role in the development of procedural and conceptual knowledge, which are key concepts of the mastery approach to mathematics. The emphasis on visual and kinaesthetic learning has its theoretical underpinnings in Bruner's theory of "enactive-iconic-symbolic" modes of representation (Hoong et al., 2015), which enables children to learn through manipulation and action; organisation and imagery; and language (Bruner, 1966). It also highlighted the role that manipulatives play in developing mathematical understanding, which was consistent with the beliefs of Toptas et al. (2012) and Uttal et al. (2009).

Another concept discussed by the facilitators was how the use of concrete and visual materials helped children to develop an understanding of abstract concepts. These ideas were consistent with the CPA approach to learning mathematics, which previous studies have found to be effective when teaching mathematical concepts (Flores, 2010; Flores et al., 2014; Fyfe et al.,

2015; Hughes, 2011), and which OUP (2016) state as being *"at the heart of Numicon"* (p. 4).

Finally, facilitators highlighted the importance of providing children with opportunities to consolidate their learning through overlearning, thus further developing their understanding of basic number skills. This again is consistent with the views of OUP (2016) that highlight that the use of Numicon enables fluent recall of mathematical facts. The NCETM (2014) also highlight the central role that practice and consolidation play in the mastery approach to mathematics. Furthermore, previous research and guidance has concluded that a key feature of effective interventions is providing children with regular opportunities to practise and consolidate basic number concepts, upon which other skills can be built (Fuchs et al., 2008; Haseler, 2008). Research has also highlighted how consolidation of basic concepts during intervention sessions positively impacts on children's engagement of activities which involve the 'using and applying of mathematics' (Doncaster MBC, 2008). This emphasis on repetition and consolidation is a vital part of mastery, enabling children to become more fluent and develop a deeper understanding of mathematical concepts (NCETM, 2014).

Another important factor was the importance of having Numicon embedded in the whole school ethos. Facilitators commented that if Numicon was used in whole class learning across the school, this had a positive impact on the outcomes of the intervention. This was consistent with findings from previous research which had found that the effectiveness of Wave 3 intervention sessions was enhanced by the use of Numicon in whole class teaching (Doncaster MBC, 2008). Leicester LA (2009) had also identified that schools where pupils made significant progress in numeracy were those that had made Numicon a whole school priority. These findings further support the facilitators' views that if it is important for Numicon to be part of the whole school ethos and embedded into the numeracy curriculum.

Facilitators identified practical factors which impacted on the outcomes of the intervention. Many of these, such as having regular sessions and the impact

of special occasions, were relevant to the implementation of any intervention within schools. One important point that was raised was the importance of facilitators having appropriate knowledge. This, consistent with other research (Doncaster MBC, 2008; ECC, 2008; Education Leeds, 2005; Herbert, 2011; Jones, 2014) highlights the importance of ensuring facilitators are appropriately trained.

The Numicon equipment was also identified as impacting on the outcomes of the intervention. Facilitators highlighted the importance of children understanding and knowing how to use the actual equipment, as well as the practical elements of the equipment which made it successful. With regards to children understanding and knowing how to use the equipment, Jones (2014) found that children who participated in the Numicon-based intervention needed time to learn how to use the equipment, which may have impacted on the effectiveness of the intervention. Brown et al. (2009) and Kaminski et al. (2009) also drew attention to the fact that children need to be taught how to use manipulatives in numeracy.

When thinking about the practical elements of the equipment, the facilitators drew attention to the fact that, due to its appearance, the Numicon equipment enabled children to develop an understanding of number sense. This was consistent with Tacon (2005) who had also proposed that the Numicon plates developed children's understanding of arithmetic and place value, as well as the use of mathematical language. This view was supported by Doncaster MBC (2008) who commented that *"Numicon equipment provides a unique and important structured imagery of the size of numbers and arithmetic processes"* (p. 5). Facilitators also commented that the plates were fun to use, which was consistent with findings by Leicester LA (2009) who reported that children had found the equipment *"attractive, enjoyable and accessible"* (p. 2).

A final factor which facilitators identified as impacting on the outcomes of the intervention was the role of parents. Facilitators discussed the importance of parents knowing about Numicon and how it was used in schools in order to

support their children's learning. Whilst the majority of facilitators commented that parents viewed Numicon positively, Debbie spoke of one parent who viewed it as babyish. She discussed that the school had addressed this opinion by inviting parents to 'Maths Evenings' where staff shared how Numicon was used across the whole school regardless of age or ability, and what the benefits of this were. Previous research (Education Leeds, 2005; Leicester LA, 2009) has also acknowledged the role of parents although it had not been examined in great detail.

The above information suggests that facilitators generally perceived the intervention as effective and were pleased with the outcomes. They were able to identify a range of factors which impacted on these outcomes and appeared to have some understanding of underpinning mechanisms linked to psychological theory.

Although facilitators generally spoke positively about Numicon, some limitations were identified. These however were not included in the TA as they were only identified by individual facilitators. Limitations included:

- Difficulties in using Numicon to teach subtraction and to support children when working with larger or more complex numbers.
- Some children were easily distracted by the equipment, finding it difficult to concentrate during intervention sessions.

To conclude, by completing the second phase of the study, a greater insight into Numicon-based interventions has been obtained, which has added to the findings of this study. This will be discussed in more detail in section 5.6.

5.3 Methodological limitations of the current study

As with all research, it is important to discuss the limitations of the current study for both phases 1 and 2.

5.3.1 Limitations of phase 1

With regards to phase 1, one needs to consider the reliability and validity of the study. In section 3.7.1 any possible threats to phase 1 of the study were considered. Although various steps were taken to address these, there were still some limitations during this phase.

5.3.1.1 *Internal validity*

Various factors impacted on the internal validity of the current study.

Firstly, the current sample was smaller than originally intended. The author had intended to recruit 60 participants, but due to a range of factors, the final sample size was 25. This may explain why no statistical significance was found between the experimental and waiting-list control group for both research questions one and two, as according to Pallant (2013) non-significant results in small samples (n < 20) may be due to insufficient power. In order to achieve a power level of 0.8, which is generally seen as acceptable (Robson, 2011) a sample size of 42, with 21 participants in each condition, would have been required, assuming an effect size of 0.80 and a significance level of .05[9].

The lack of a comparison group is also a limitation. Although the null hypotheses were accepted for both research questions 1 and 2, the facilitators did report that participation in the intervention had a positive impact on the children's mathematical knowledge and understanding. It would have been interesting to have explored whether participation in a different intervention had a similar impact, or if the impact was due to the actual specifics of the Numicon-based intervention, as suggested by the facilitators. In the current study, the intention had been to compare the Numicon-based intervention to another numeracy intervention, but this was not possible as 83 per cent of schools who expressed an initial interest in participating in the study used Numicon-based interventions.

[9] Yager, N. (2016) Sample size calculator https://www.ai-therapy.com/psychology-statistics/sample-size-calculator (accessed: 02/04/2016)

Whilst participation in the intervention did not appear to have an immediate impact on the attainment and attitudes of the children in the experimental condition, it may have impacted in the long term, with the children making greater progress later on in the academic year. It would therefore have been beneficial to collect data when the WLC condition had completed the intervention and at the end of the academic year. Due to the time constraints of the Doctorate programme however, this was not possible.

As previously discussed (section 5.2.1) individual differences, such as children being EAL, environmental factors or levels of attention, may have affected the outcomes of the study. Whilst this could be viewed as a limitation, the sample was representative of the local area and therefore enables some generalisations about findings to be made, albeit with caution.

According to Frederickson (2002), RCTs are the gold standard in research and are the best way of exploring the effectiveness of an intervention (Robson, 2011). One of the benefits of a RCT is that participants are randomly allocated to either condition which reduces the risk of the threats of individual differences; although it has been acknowledged that such methods are not always appropriate in real world research and so many researchers use quasi-experimental designs (Mertens, 2005). In the current study not all of the children were randomly allocated to each condition, and whilst individual differences were controlled for during statistical testing as the pre-test score was used as the covariate, later analysis of the data found that a higher percentage of children in the experimental condition were working at Level 1. The implications of this have previously been discussed (section 5.2.1), and are another possible limitation in the current study.

A final limitation which has already been discussed in section 5.2.1 is the diffusion of treatments.

5.3.1.2 *External validity*

Numerous factors also impacted on the external validity of the current study.

The first limitation is concerned with ecological validity, which is the extent to which findings can be generalised to a wider population. As already stated, whilst the participants were representative of the wider population within the LA where the study was conducted, the sample size was only small, and so any generalisations need to be made with a caveat acknowledging this limiting factor.

All four schools who participated in the study delivered interventions that were slightly different. It is therefore difficult to provide an explicit description of the experimental treatment. In order to address this limitation, treatment fidelity checks (section 3.7.1.3) were completed, and session plans examined to identify what objectives had been taught across the intervention (Table 3.10).

As previously discussed in sections 5.2.1 and 5.2.2, the measures used for research questions one and two were not without their limitations. A rationale as to why it was felt these measures were appropriate (section 3.5.6) has previously been provided. The implications of this for future research will be discussed in section 5.5.3.

The impact of the experimenter effect has previously been highlighted. This is the belief that findings cannot be generalised as the effectiveness of the treatment, in this case the intervention, is dependent upon the facilitator. In order to address this, the current study employed five facilitators, although one could still be argued that the individual differences of the facilitators did impact on the outcomes, as previously discussed (section 5.2.1). Generalisations therefore have to be made with caution.

5.3.2 Limitations of Phase 2

As qualitative data was collected during phase 2 one has to consider threats to the following:

- Credibility
- Transferability

- Dependability
- Confirmability
- Authenticity

To reduce the threats to credibility, transcripts were shared with the facilitators via email, asking them if they felt they were a true representation of their views. Although all facilitators felt that the transcripts were accurate one cannot be sure that they actually read the transcripts in detail. The author also completed 'member checks' with three of the facilitators to ensure that her interpretation of the data collected represented the facilitators' views and that she interpreted them accurately. All three facilitators reported that the findings were representative of their views, although they may have felt obliged to agree. In order to address this, when meeting them, the author did ask explicitly if there was anything they disagreed with, weren't happy with or wished to add.

In order to address threats to transferability, contextual information including pen portraits about the facilitators and information about the schools and interventions was provided.

The purpose of dependability is to ensure that the study can be replicated. Detailed information about the steps taken when completing TA was provided (section 4.3) so that the study could be replicated. This however is not without its limitations. For example, although a semi-structured questionnaire was used when interviewing the facilitators, some of the questions differed within each interview as they were in response to information provided by the facilitator.

Throughout the study, the author has strived for objectivity, thus reducing any threats to confirmability. She does however acknowledge that her own views and biases have influenced the research. For example, during the semi-structured interviews, the author was aware that some schools had strong home-school links and so asked specific questions about the role of parents. Furthermore, although the author sought inter-rater reliability, there was not

100 per cent agreement between her and the two TEPs suggesting that personal characteristics and preferences of the author may have influenced the identification of themes. A concordance of 86.5 per cent with regards to the identification of themes was however achieved, suggesting that the themes were relatively reliable and transparent (Joffe, 2012). When considering the codes, the concordance between the author and the TEPs was 65 per cent. Following a discussion with TEP 1 however, additional agreement was obtained.

It is also important to acknowledge the potential bias of the facilitators. The facilitators explained positive outcomes in terms of specific features of Numicon, but do other factors such as small groups and adult support impact on the outcomes of interventions? Furthermore, the facilitators were all experienced and confident at delivering Numicon-based interventions, which may explain why they attributed positive outcomes to Numicon. If they were experienced in delivering other interventions, would they attribute positive outcomes to the specifics of these interventions?

The final limitation of phase 2 was the sample size. According to Braun and Clarke (2013), when completing TA, researchers should have a sample of at least six individuals. The author had intended to recruit more schools to participate in the study and hence have more facilitators that she could interview, but this was not possible. Due to the small sample, caution needs to be taken when generalising these findings.

5.4 Ethical considerations

Throughout the study, various ethical guidelines were followed to ensure that it was conducted ethically. Whilst various steps had been taken, some points were raised that warrant further discussion.

Although parents were invited to the research meeting, many could not attend. Written details were therefore shared with parents, including the author's contact details, should they have any queries. Whilst the majority of

parents who received this written information provided consent, some commented that they had not had an opportunity to ask questions about the research. Where this response was given, the author asked school staff to speak to the parents and provide them with the author's details again. Staff did this and one parent did contact the author via email. This does however raise questions about whether some of the parents fully understood what they were consenting to. As some parents were EAL, consent letters were translated into various languages, it was difficult however, for some of these parents to ask additional questions about the research. This again raises questions about what the research community can do to ensure parents fully understand what they are consenting to.

Another concern was whether the children actually understood the information sheet and consent form. When obtaining consent, the author met with each child independently, discussing the information sheet and consent form with them. She was careful to use child friendly language and if the children appeared unsure further explore what they were having difficulties understanding. Some children however, may have had some difficulties in understanding every component of the forms, which raises questions again about what can be done within the research community to ensure children are providing informed consent.

When completing data collection at T1 and T2, the children were reminded that they could withdraw at any time and did not have to participate in the study. Whilst all children seemed happy to participate, one cannot be sure if parents or school staff had told children that they had to participate. Furthermore, the children may have felt they could not say no as the author was a visiting adult in the school.

Another consideration is whether the facilitators felt obliged to participate in the interviews as a member of the school's SLT had agreed for the school to take part in the study and this included allowing time for facilitators to be interviewed. One facilitator did however, chose not to be interviewed and the

author did ensure that the others were happy to participate before conducting the interviews.

One also needs to acknowledge potential power imbalances in the current study. The majority of facilitators were teaching assistants, therefore did they feel obliged to talk positively about Numicon as schools have invested a lot of money into the resources, and they are being told to deliver it by SENCos and Numeracy Coordinators.

In conclusion, although guidance from the BPS (2009; 2014), HPCP (2012) and University of Nottingham (2015) was followed, the current study still raises some ethical considerations. The author believes however, that she did all that she could to ensure that this study was conducted ethically, and in line with the guidance she consulted.

5.5 Implications of the current study

5.5.1 Professional implications for EPs

As discussed in the literature review (section 2.9) there is currently limited research into the effectiveness of Numicon-based interventions, the majority of which is not without its methodological limitations. In addition quantitative findings in the current study have resulted in the acceptance of the null hypothesis for research question 1, which states that participation in the intervention did not have a positive impact on attainment. Despite limited research, in a survey of 457 teachers, 50 per cent reported that they used Numicon in numeracy (Gifford et al., 2015). EPs therefore could have a role in conducting more research into the effectiveness of Numicon in order to add to the evidence-base. This will be discussed in section 5.5.3.

EPs could also be in a position to potentially advise teachers on how Numicon and other interventions can be used effectively to support children experiencing mathematical difficulties. This is consistent with recommendations from the Scottish Executive (2002) who drew attention to

the fact that EPs should be providing more support to schools in the areas of managing and delivering interventions. EPs also could potentially have a role in emphasising the importance of early intervention and personalising interventions to the needs of the child (Dowker 2004, 2009; Williams, 2008). Through such practices, EPs potentially play a vital role in improving mathematical outcomes for children experiencing mathematical difficulties.

As has previously been discussed (section 5.2.1), there were some limitations with the SENT-R used to measure attainment. Whilst other measures were available, these too were not without limitations (section 3.5.6.1). As EPs play an important role in the assessment of mathematics (Gillam, 2014) they need to consider the appropriateness of measures used, and in turn may need to consider the development of more appropriate measures, which provide an accurate assessment of a child's numeracy skills.

With regards to children's attitudes towards numeracy, contradictory research exists as to whether younger children experience negative attitudes to the subject. In the current study, the majority of children appeared to have positive attitudes. Previous studies however, (Ashby, 2009; Krinzinger et al., 2009; Mazzocco et al., 2012; Thomas & Dowker, 2000) have found that young children experiencing mathematical difficulties are more likely to have negative attitudes towards numeracy compared to their peers. This again is an area which warrants more research, and as evidence-based practitioners, is something EPs could potentially undertake.

There are also potential implications regarding how EPs obtain the child's voice. Whilst it is common practice for self-report measures including Likert scales to be used, it has been argued that these can restrict the expression of children's views (Smith et al., 2005). EPs therefore need to consider alternative and innovative ways in which they can obtain the child's voice including observations, audio recordings and photos to facilitate discussions with the child (Smith et al., 2005).

Although findings from the current study suggest that Numicon may not have a positive impact on attainment, information obtained in phase 2 suggests that participation in the Numicon-based intervention has impacted positively on affective factors, which play an important role in children's learning. EPs need to continue to promote this, highlighting that education is not only about attainment, but also promoting positive attitudes towards learning.

A further professional implication is how informed consent is obtained from both parents, especially those who are EAL, and the children themselves. Whilst EPs always obtain such consent, there are some concerns regarding whether this is really informed, and as a profession this is something that needs to be explored further.

In phase 2 of this study, the facilitators were able to articulate why they felt the Numicon-based interventions had been successful. This included some reference to theoretical underpinnings, although it was not clear what training the facilitators had had in this area. EPs are ideally placed to provide training to school staff regarding the learning and theoretical frameworks that underpin the teaching and learning of mathematics, as well as information on the types of difficulties children experience. They can support schools in developing evidence-based practice.

A final implication is the role of EPs in raising awareness of the long term impacts of mathematical difficulties (Gross, 2009; Parson & Bynner, 2005) to other professionals and parents.

5.5.2 Implications for other professionals

As has already been stated, professionals working within school need to have appropriate knowledge about the learning and theoretical frameworks that underpin the teaching and learning of mathematics. Whilst such information can be provided by EPs, school professionals also have a responsibility to seek continuing professional development opportunities, which enable them to further their knowledge and understanding.

School professionals also have a responsibility to ensure that the interventions and support that they are providing children with mathematical difficulties are effective and appropriate. They therefore need to monitor the outcomes of such interventions both in the short and long term, something which this study was unable to do.

Another implication is the importance of ensuring school staff are appropriately trained to deliver interventions. Whilst all of the facilitators in the current study had received some training, Beth did comment that there were some areas where she lacked confidence and did not feel she had the necessary knowledge to use Numicon to support the children higher up the school who were experiencing mathematical difficulties.

This study has also highlighted the importance of the role of parents in supporting children with mathematical difficulties. Schools therefore need to provide opportunities for parents to learn more about the learning that currently occurs in schools, and to ensure parents have information on how they can support their child in their learning, resulting in a consistent approach between home and school.

5.5.3 Implications for future research

As already discussed due to limited research into the effectiveness of Numicon-based interventions, and the limitations in previous research and the current study, there is a need for additional research to explore the efficacy of such interventions on the attainment of primary school children experiencing mathematical difficulties. Ideas for future research are discussed in Table 5.2 including research questions, rationale underpinning the research and possible designs.

Table 5.2 Ideas for future research

Research question	*Rationale underpinning research*	*Design*
Does a Numicon-based intervention have a positive impact on the numeracy attainment of KS1 or KS2 children experiencing mathematical difficulties?	Limited research into the efficacy of Numicon-based interventions for primary-aged children, especially in KS2. Therefore research could focus upon children in either KS1 or KS2.	Single-case experimental design: • Participants act as own controls (Smith, 2012) • Monitors individual variability (Barlow & Hersen, 1984) • Extraneous factors which may result in unusual data points can be identified (McCormick, 1995)
Does a Numicon-based intervention have a positive impact on basic number skills such as number bonds, place value and number sense?	In the current study, facilitators of the intervention commented that participation in the intervention had positively impacted on children's understanding of basic number skills and number sense.	Pre- Post-test quasi experimental design with WLC and comparison condition: • WLC condition reduces threat of maturation • Comparison condition addresses issue of whether any differences are due to specifics of Numicon or having adult support in a small group. • Measure focuses on basic number skills/ number sense OR: SCED with weekly data collected using Precision Teaching based assessment probe that assesses number skills/ number sense

Research question	*Rationale underpinning research*	*Design*
Is there a relationship between the duration of Numicon-based interventions and numeracy attainment?	In the current study, the duration of each of the interventions was different, which may have influenced the outcome of the intervention. There is also limited research on the ideal duration of group-based numeracy interventions (Dennis et al., 2015)	Pre- Post-test quasi experimental design with WLC and comparison condition: • Children allocated to intervention groups lasting for different durations. • Pre- and post-test data collected • Mean gains for each group calculated • Statistical analyses to identify correlation coefficient • WLC and comparison conditions control for additional threats
Does the frequency that children use Numicon in numeracy lessons impact on the outcomes of a Numicon-based intervention?	In the current study facilitators talked about the importance of children using Numicon in numeracy, and understanding how to use it. It is not clear however, how frequently children actually used Numicon in numeracy lessons. Furthermore, there was a difference between the mean gains of children in different schools, which may be related to their experience of Numicon in numeracy lessons.	Pre- Post-test quasi experimental design with WLC and comparison conditions: • Pre- and post-test data collected • Records kept of frequency in which children use Numicon in numeracy lessons • Mean gains for each child calculated • Statistical analyses to identify correlation coefficient between individual mean gains and number of times the child uses Numicon in numeracy lessons • WLC and comparison conditions control for additional threats

Research question	*Rationale underpinning research*	*Design*
According to school staff, who are experienced in delivering Numicon-based interventions, what are the outcomes for children who participate in the interventions, and what factors impact on these outcomes?	The current study explored a similar question. Due to the small sample size however, caution has to be applied when making generalisations. It would therefore be beneficial to obtain the views of a range of school staff who deliver interventions.	The use of semi-structured interviews or focus groups to obtain information from the staff. Data analysed using TA or another form of qualitative data analysis.
According to children who participated in the Numicon-based intervention what impact did participation have on their numeracy skills and the way that they think about numeracy?	In the current study, the facilitators reported that participation in the Numicon-based intervention had had a positive impact on the children's learning and attitudes towards learning. These views however were not supported by data collected from the children using quantitative methods of data collection. It would therefore be beneficial to obtain the children's views about the intervention.	The use of semi-structured interviews or focus groups to obtain information from the children. These could be supported by visual images etc. Data analysed using TA or another form of qualitative data analysis.
According to parents, what are the benefits of the Numicon-based intervention, and are there any limitations?	In the current study, the facilitators discussed the importance parental involvement and of them having appropriate knowledge and understanding about the intervention. It would therefore be beneficial to obtain their views about the intervention.	The use of semi-structured interviews or focus groups to obtain information from the parents. Data analysed using TA or another form of qualitative data analysis.

5.6 Author's reflections

In the current study a mixed methods approach was used to investigate the effectiveness of a Numicon-based intervention. Findings from phase 1 were statistically non-significant, resulting in the acceptance of the null hypothesis, and were inconsistent with previous findings. I hope that these findings will open up a discussion about the use of Numicon as an intervention, and will promote other professionals working in education to further explore the efficacy of such interventions. I feel it is important for such research to be completed, as many schools currently use Numicon to support children with mathematical difficulties, despite limited research into the efficacy of it.

Not only has this study raised questions about the efficacy of Numicon-based interventions, but it has also raised questions about the role of LSAs in delivering interventions. Whilst I did not initially intend to investigate this area, I feel that findings from this study suggest that the training that LSAs receive and the level of support that they receive in planning and implementing interventions may impact on the attainment of children accessing the interventions, and therefore warrants further research. I strongly believe that SLTs within schools have a duty to ensure that LSAs are appropriately trained and supported when delivering interventions.

Completing this study has highlighted some of the many challenges that researchers face when undertaking real world research. In particular I found it particularly challenging to identify what a 'Numicon-based intervention' looked like due to differences within schools. I did however conclude that there is an 'essence' of Numicon was involves teaching children number sense through the use of concrete resources (the Numicon plates) which support them in understanding the more abstract concepts of number. There were also some difficulties in recruiting schools, which I had not expected. Another challenge was obtaining informed consent from parents. Whilst the majority of parents consented to their children participating in the research, some were unable to attend the 'Research Meetings', and so I was unable to discuss my research with them in person, addressing any concerns that they

may have had. This has highlighted the importance of parental engagement and has also made me consider whether parents are always providing informed consent.

I thought that this would be a relatively straightforward project to implement, but it became apparent that it wasn't. I realised that whilst schools wished to take part in the research, for them it was not a high priority. This helped me to be more pragmatic and to accept that there are limitations to real world research and some factors are beyond the researcher's control.

Currently there are many changes in the teaching of numeracy, with an emphasis on the mastery approach to mathematics. It will be interesting to see how this is implemented in schools, and whether schools still continue to use manipulatives and other approaches to support children in their learning. There seems to be some inconsistencies within the guidance regarding manipulatives and their role in the mastery approach.

I hope that my study will encourage others to complete research into the efficacy of different numeracy interventions and to further explore the attitudes that children and young people hold towards numeracy. In my opinion numeracy is just as important as literacy and we need to ensure that there is appropriate support in place for children experiencing difficulties in numeracy. We also need to ensure that everyone who works with children and young people do all they can to promote positive attitudes towards numeracy, as the research suggests that in older children, negative attitudes can impact upon engagement and performance in numeracy.

Chapter 6 Conclusion

The current study investigated the efficacy of the Numicon-based intervention for children in Year 3 experiencing mathematical difficulties.

Based upon findings from phase 1 of the study, it was concluded that participation in the Numicon-based intervention did not have a positive impact on attainment or the attitudes towards numeracy of Year 3 children experiencing mathematical difficulties.

In phase 2 participation in the intervention was identified as having a positive impact on the children's understanding of basic number skills and number sense, as well as affective factors such as confidence and engagement. Factors that impacted on the outcomes of the intervention were the importance of a whole school ethos with Numicon embedded into the numeracy curriculum; the practicalities involved in implementing an intervention; elements of the Numicon equipment; and the role of parents. Facilitators also identified theoretical underpinnings that they felt explained why Numicon-based interventions were effective including Bruner's iconic and enactive modes of learning; the relationship between concrete, representational and abstract learning; and the importance of overlearning through repetition and consolidation.

The author concluded that whilst there were limitations in the current study, it was of value as it had identified professional implications for EPs and other educational professionals, as well as possible areas for future research.

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Appendices

Appendix 1 Summary of articles excluded following title scan

Exclusion criteria	*No. of papers rejected*
2: Not accessible in English	33
3: Provides information about a range of interventions/ strategies for teaching numeracy	54
4: Does not report the efficacy of Numicon	11
5: Sample are from a special population e.g. Down Syndrome	49
Other reasons rejected:	
School policies	3
Article not about mathematics/ education	15
Training	6
Impact of numeracy difficulties	1
	172

Appendix 2 Records from systematic search rejected based upon inclusion and exclusion criteria following article screening

Authors	*Title*	*Database*	*Exclusion Criteria*
Arnarsdóttir, A.B. (2010)	Professional training and attitude of primary school teachers towards mathematics	GS	3
Bateman, T. (2003)	`Numicon'... `not-at-all-a-con'	Z; GS	4
Cordingley, P., & Mitchell, R. (2013)	AERA 2013.	GS	3
Cordingley, P., Bell, M., Rundell, B., & Evans, D. (2003)	Research for Teachers.	GS	3
Dabell, J. (2008)	Sum, Sea and Sand	EH	3
Devon Primary Maths Team (2006)	An Image of Number: The Use of Numicon in Mainstream Classroom	GS	6
DfE (2014)	Closing the gap with the new primary national curriculum	EEP; GS	4
Doncaster MBC (2008)	Multi-sensory Mathematics for Wave 3 Intervention-Doncaster L.A.	OUP	6
Dowker, A. (2009)	What Works for Children with Mathematical Difficulties	OUP	3
Dowker, A. & Sigley, G. (2010)	Targeted interventions for children with arithmetical difficulties	RG; GS	3
Garrote, A., Opitz, E.M. & Ratz, C. (2015)	The mathematical competences of students with mild to moderate intellectual disabilites: A cross-sectional study	GS	3
Gifford, S., & Rockliffe, F. (2012)	Mathematics difficulties: does one approach fit all?	GS	3
Gold, K. (2002)	A move into the mainstream.	EH	5
Gunnarsdóttir, S. Þ. (2013)	Outdoor teaching in Gefnarborg Garði	GS	3

Authors	*Title*	*Database*	*Exclusion Criteria*
Henriques, L.S. (2013)	Development of calculation skills in children with Down syndrome	GS	5
Horner, V. (2002)	Numicon, Numeracy and a Special Need	EH; Z; GS	5
Horner, V. (2007)	Teaching number skills and concepts with Stern Structural Arithmetic materials.	RG	5
Johnson, J.	Sabbatical Report	GS	3
Johnson, S. (2014)	Teacher Research into STEM Interventions	GS	3
Kent County Council	A multi-sensory approach to Arithmetic: Primary Excellence Project.	Hand search	6
Leicester LA (2009)	Numicon Project Report: 2008-2009 (Leicester LA)	OUP	6
Murphy, C. (2015)	Changing Teachers' Practices Through Exploratory Talk in Mathematics: A Discursive Pedagogical Perspective	GS	3
Neumark, V. (1999)	Many hands make light work.	EH	6
Not known (TES, 2014)	WHAT'S HOT?	EH	4
Oxford School Improvement (2013)	Case Study from Canon Evans C of E Primary School	OUP	6
Oxford School Improvement (2013)	Case Study from Goodyers End Primary School	OUP	6
Oxford School Improvement (2014)	Pupil Premium and Numicon at Queen's Park Academy	OUP	6
Oxford School Improvement (2014)	Case Study from St Joseph's RC Primary School	OUP	6
Oxford School Improvement (2014)	Case Study from SS Aiden & Oswald RC Primary School	OUP	6

Authors	*Title*	*Database*	*Exclusion Criteria*
Oxford School Improvement (2014)	Case Study from Glycollen Primary School	OUP	6
Oxford School Improvement (2014)	Case Study from Francis Askew Primary School	OUP	6
Oxford School Improvement (ND)	Practical Experiences, Visual Imagery and Problem Solving at the Heart of Good Practice in Mathematics	OUP	4
Oxford University Press (ND)	The impact of Numicon	OUP	6
Oxford University Press (2011)	The Numicon Approach Impact Report (2008- 2011)	OUP	6
Saunders, E. (2004)	Number fun? You can count on it!	GS	5
Sigurðardóttir, D. (2011)	“That is four and then he got three and that makes it seven” What strategies do children use when solving mathematical problems?	GS	3
Spencer, S.	Getting started with early algebra	GS	3
Tacon, R., Atkinson, R. & Wing, T. (2004)	Learning about numbers with patterns using structured visual imagery (Numicon) to teach arithmetic	GS; OUP	6
TES (2008)	Four catch-up schemes and how they help pupils struggling with maths.	EH	3
Torkildsen, G. (2011)	What information could Regneprøven provide on students' numeracy and arithmetic skills after 2nd grade?	GS	3
Travers, J. (2011)	Teachers’ organisational practices and their perceptions of the benefits of support by withdrawal for mathematics in Irish primary schools	GS	3

Authors	*Title*	*Database*	*Exclusion Criteria*
Watson, A. (2013)	Reflecting on calculation: when drilling becomes fulfilling	GS	3
Webster, R. (2013)	The Making a Statement project	GS	3
Williams, H.J. (2014)	The relevance of role play to the learning of mathematics in the primary classroom	GS	3
Williams, P. (2008)	Intervention in mathematics in primary schools	GS	3
Wing, T. (2007)	Gathering Evidence for Numicon (1997-2007)	OUP	6
Wing, T. (2009)	The Post-Piagetian Child: Early Mathematical Developments and a Role for Structured Materials.	GS	3
Wing, T. & Tacon, R. (2007)	Teaching Numeracy Skills and Concepts with Numicon Materials	EH; PI; S; WoS; E; Z; RG; GS	5
	Intensive instruction - a multisensory approach: A case study of SEN-students in the subject of mathematics basic number sense during intensive, multisensory instruction.	GS	3

Key for databases: E= Embase; EEP= Educational Evidence Portal; EH= EBSCO Host; GS= Google Scholar; PI= PsycInfo; OUP= Oxford University Press; RG= Research Gate; S= Scopus; Z= Zetoc

Appendix 3 Articles identified for systematic literature review

Author	*Date*	*Title*	*Database*
Bury Learning Support Team	2008	"We Think Numicon Rocks!" Response to Bury Learning Support Team Pilot Project.	Hand search (Dowker, 2009)
Cambridgeshire LA	2007	Numicon Research Summary.	OUP
Churches	2016	Closing the Gap: Test and Learn-Research report	GS
Education Leeds	2005	Multisensory Approach to the Teaching and Learning of Mathematics: Pilot project.	OUP
Every Child Counts	2008	Report on Research Phase of Every Child Counts – Summer term 2008.	OUP
Herbert, S.	2011	Numicon Pilot Report.	Hand Search (Jones, 2014)
Jenkins, M.C.	2013	Numicon Instruction as a Supplemental Mathematics Intervention for Kindergarten Students.	PI; GS
Jones, C.	2014	A Randomised Control Trial Evaluating the Impact of Numicon on Key-Stage 1 Pupils' Numeracy Attainment, Metacognitive Awareness and Mathematics Affect.	
Lane, M.	2009	Exploring the use of Numicon in a Mainstream Primary Classroom in the Republic of Ireland.	GS
Saunders, S.	2005	Joining Luke's Wires	EH

Appendix 4 Criteria for each of the Weight of Evidence strands

	High	Medium	Low
A: Quality of the design: • Clear purpose • Sample clearly defined (no, gender, age, other characteristics) • Method is clearly explained • Ethical considerations are highlighted • Intervention explained including duration, facilitator, description of sessions • Treatment fidelity of sessions • Control group • Comparison group • Standardised measures are used • Data analysed using significance testing and details provided • Limitations are discussed	Meets 9 to 11 of the criteria	Meets 5 to 8 of the criteria	Meets 4 or less criteria
B: Is the design appropriate for answering the research question? • Design is a RCT or quasi experiment design • Measures used assess attainment in numeracy • Pre and post-test data is collected • Sample are appropriate e.g. age/ setting • Data analysis is appropriate inc. significance	Meets all 5 of the criteria	Meets 3 or 4 of the criteria	Meets 2 or less of the criteria
C: How relevant is the topic and the context of the paper to your own research question? • Numicon is used as an intervention and in whole class • Study was conducted in UK • Sample are in KS2 • Sample are identified as having difficulties in numeracy • Study evaluates impact of Numicon on attainment • Study evaluates impact of Numicon on attitudes • Study explores factors that may impact on Numicon • There is a control group	Meets 7 or 8 of the criteria	Meets 4 to 6 of the criteria	Meets 3 or less of the criteria

Appendix 5 Weight of Evidence analyses of the key studies identified for the systematic literature review

Strand		Bury	Cambridge-Shire	Churches	ECC	Herbert	Jenkins	Jones	Lane	Leeds	Saunders
A	Purpose	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Sample	N	N	N	N	N	Y	N	N	N	N
	Method	Y	N	N	Y	Y	Y	Y	N	N	N
	Ethics	N	N	Y	N	N	N	Y	N	N	N
	Intervention	N (description of sessions)	N	N (no information given)	N (length of session)	N	Y	Y	N	N	N
	T/ment Fidelity	Y	N	N	N	N	Y	Y	N	N	N
	Control	N	N	Y	N	N	Y	Y	N	N	N
	Comparison Group	N	N	Y	Y	N	N	Y	N	N	N
	Standardised Measures	N (No details → inconclusive)	N (No details → inconclusive)	Y	Y	Y	Y	Y	Y	Y	Y
	Significance testing	N	N	Y	N (no details provided)	N	Y	Y	N (no details about method)	Y	N (no details about method)
	Limitations	N	N	Y	N	N	Y	Y	N	N	N
	Rating for A	**low**	**low**	**med**	**low**	**low**	**high**	**high**	**low**	**low**	**low**

		Bury	Cambridge-Shire	Churches	ECC	Herbert	Jenkins	Jones	Lane	Leeds	Saunders
B	RCT/ Quasi exp.	N	N	Y	N	N	N	Y	Y	N	N
	Assesses attainment in numeracy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Pre- and Post-test data/ standardised measure	N (No details)	N	Y	Y	Y	Y	Y	Y	Y	Y
	Appropriate sample	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Appropriate statistical analysis	N	N	Y	N	Y	Y	Y	N	Y	N
	Rating for B	**low**	**low**	**high**	**med**	**med**	**med**	**high**	**med**	**med**	**med**

		Bury	Cambridge-shire	Churches	ECC	Herbert	Jenkins	Jones	Lane	Leeds	Saunders
C	Whole class and intervention	N	N	N	N	N	N	N	N	N	Y
	UK study	Y	Y	Y	Y	Y	N	Y	N	Y	Y
	Sample from KS2	N	N	N	N	N	N	N	N	Y	Y
	Sample experiencing numeracy difficulties	Y	Y	Y	Y	Y	Y	Y	Y (Maj)	Y	Y
	Impact on attainment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Impact on attitude	Y (qualitative)	Y (qualitative)	N	N	Y	N	Y (anxiety)	Y (qualitative)	Y	Y
	Underpinning factors	N	N	N	N	N	N	N	N	N	N
	Control group	N	N	Y	N	N	Y	Y	N	N	N
	Rating for C	**med**	**med**	**med**	**low**	**med**	**low**	**med**	**low**	**med**	**med**
D	**Overall rating**	**low**	**low**	**med**	**low**	**med**	**med**	**high**	**low**	**med**	**med**

Appendix 6 Expression of interest letter

«SENCo_Name»
«School»
«Address_1»
«Address_2»

Please ask for: Kate Forder
Tel: 01604 364770
Our ref: LSE/ «School»
Your ref:
Date: 26th January 2015

Dear «SENCo_first_name»,

I am a Trainee Educational Psychologist currently studying at Nottingham University and on placement in Northamptonshire County Council Educational Psychology Service. As part of my training I am interested in completing a research thesis investigating the impact of Numicon on the attainment and attitude towards numeracy of children who are experiencing difficulties in this area.

I am therefore contacting primary schools within the local area, in order to obtain the following information:

- Which numeracy interventions are delivered within schools and in which year groups?
- If schools use Numicon, is it:
    - Used for both whole class teaching and as an intervention?
    - In which year groups is it used?

I am also looking for schools who would be interested in participating in my proposed research study. If schools are not delivering Numicon there may still be an opportunity to participate in the study as a comparison group in which Numicon is compared to a different numeracy intervention.

The benefits of participating in the study would be as followed:

- An independent evaluation of a numeracy intervention being delivered within school
- Standardised assessment data provided about numeracy attainment for identified pupils, which can inform planning and teaching
- Data provided regarding children's attitudes towards numeracy as measured by a psychometrically validated instrument
- Support from a Trainee Educational Psychologist with seven years teaching experience in the development of session plans for Numicon or a comparison intervention
- Opportunity to share with parents/ carers the work school is completing to support children experiencing difficulties in numeracy
- Opportunity to reflect upon the outcomes of a particular numeracy

intervention in order to further develop the support provided for children experiencing difficulties in numeracy
- Evidence to support targeted spending of the Pupil Premium and for applications of High Needs Funding if required
- Evidence to Ofsted that schools are taking a reflective approach and are engaging in wider educational research

I would be grateful if you could complete the attached form and return it to the Educational Psychology Service by the 13th February 2015.

If you have any queries please do not hesitate to contact me, Helen Watson (Placement Supervisor) or Dr. Sarah Atkinson (Research Supervisor) at the details below:

Kate Forder
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

Helen Watson (Placement Supervisor)
Email:
Tel: 01604 364770

Dr Sarah Atkinson (Research Supervisor)
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

Kind regards

K. Forder
(Trainee Educational Psychologist)

Please complete the information below and return it by the 13th February 2015 to:

Kate Forder
Educational Psychology Service
Springfield,
Cliftonville,
Northampton
NN1 5BE

Name of school:

_____

Name of contact:

_____

Contact Phone No:

_____

Email address:

_____

Is Numicon used in your school for whole class teaching? YES / NO
If so, in which year groups?

_____

Is Numicon used in your school with intervention groups? YES / NO
If so, in which year groups?

_____

Details of any other numeracy interventions used in school including year groups in which used:

_____

_____

Would you be interested in finding out more about the proposed research study?
YES / NO

Thank you for taking the time to complete this form.

Appendix 7 Confirmation of ethical approval received from the University of Nottingham Ethics Committee Review

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA
School of Psychology
The University of Nottingham
University Park
Nottingham
NG7 2RD
tel: +44 (0)115 846 7403 or (0)115 951 4344

SJ/wb
Ref: 628
Monday, 16 March 2015

Dear Kate Forder & Sarah Atkinson,

Ethics Committee Review

Thank you for submitting an account of your proposed research.
That proposal has now been reviewed and we are pleased to tell you it has met with the Committee's approval.

However: Please note the following comments from our reviewers;
The information and pre-meeting sheets are quite lengthy and contain some quite technical terms e.g. "randomly allocated". The applicants should review this material, bearing in mind that some parents/carers and children may have limited vocabulary and reading ability.

Final responsibility for ethical conduct of your research rests with you or your supervisor. The Codes of Practice setting out these responsibilities have been published by the British Psychological Society and the University Research Ethics Committee. If you have any concerns whatever during the conduct of your research then you should consult those Codes of Practice. The Committee should be informed immediately should any participant complaints or adverse events arise during the study.

Independently of the Ethics Committee procedures, supervisors also have responsibilities for the risk assessment of projects as detailed in the safety pages of the University web site. Ethics Committee approval does not alter, replace, or remove those responsibilities, nor does it certify that they have been met.

Yours sincerely



Professor Stephen Jackson,

Chair, Ethics Committee

Appendix 8 Stakeholders' responsibilities sheet



The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Stakeholders' Responsibilities

The following document provides background information about the study, as well as outlining benefits and responsibilities:

Summary of study:

The purpose of the study is to evaluate the impact of Numicon on the attainment and attitudes towards numeracy of children experiencing difficulties in numeracy.

In order to investigate this, there will be two conditions:

- Intervention Group: Children who will receive the Numicon Intervention in the autumn term
- Waiting-list Control Group: Children who will receive the Numicon Intervention in the spring term

Children who would benefit from participation in a numeracy intervention will be selected by school staff. Selected children will be randomly allocated to either the intervention or the waiting-list control group.

The Numicon interventions will be delivered during the autumn term 2015 in accordance with normal practice within the school. The interventions will be delivered/ facilitated by an experienced member of staff who works within the school. Those children allocated to the waiting-list control group will receive the same Numicon intervention in the spring term commencing in January 2016.

The children will be assessed individually both before and upon completion of the interventions by the researcher and a colleague from the Educational Psychology Service. The assessments will consist of a numeracy assessment and a questionnaire about their attitudes towards numeracy. Assessments will take place throughout the school day, with each assessment lasting for 30-45 minutes. If a child does not wish to complete the assessments they can withdraw at any time. They will also be a member of school staff present should any child wish to access such support.

Completed assessment sheets will be stored securely. The researcher will have access to these and schools will also be able to access copies of the numeracy assessment sheets for their pupils. Children will be given a numerical identifier which will be used to record and report data scores anonymously in the research. A password protected document, only accessible by the researcher, will record which child has which numerical identifier. Schools will be provided with the data for their pupils and parents will receive information about their child's data if you wish.

As part of the research the researcher will be meeting with the facilitators of the intervention to discuss what factors they identify as impacting upon the outcome of the Numicon intervention. These findings will be shared with schools in order to help them develop the support they provide for pupils experiencing difficulties in numeracy. Parents/ carers will also receive a summary of the key findings of the research.

Benefits to the school:

- An independent evaluation of a numeracy intervention being delivered within school.
- Assessment data provided about numeracy attainment for identified pupils which can inform planning and teaching.
- Data provided regarding children's attitudes towards numeracy as measured by a psychometrically validated instrument.
- Support from a Trainee Educational Psychologists with seven years teaching experience in the development of session plans for Numicon upon completion of the research.
- Opportunity to share with parents/ carers the work school is completing to support children experiencing difficulties in numeracy.
- Opportunity to reflect upon the outcomes of a particular numeracy intervention in order to further develop the support provided for children experiencing difficulties in numeracy.
- Evidence to support targeted spending of the Pupil Premium and for applications of High Needs Funding if required.
- Evidence to Ofsted that schools are taking a reflective approach and are engaging in wider educational research.

Roles and responsibilities:

The Researcher:

- To provide consent forms for parents/ carers, children and facilitators.
- To act as point of contact for the nominated member of school staff and the Local Authority.

- To deliver an open meeting for parents/ carers about the programme and provide letters for schools to send out to inform parents/ carers about this meeting.
- Working collaboratively with school staff, to help develop session plans that could be used as part of the Numicon intervention upon completion of the research.
- To generate numerical identifiers for all pupils and use these to allocate them to experimental and waiting control groups.
- To provide measures of attainment and attitudes towards numeracy for all pupils.
- To administer measures of attainment and attitude on an individual basis with the support of a teaching assistant both pre- and post- the interventions.
- To observe two to three sessions of the intervention programme during the autumn term.
- To contact the nominated member of staff weekly to monitor interventions and discuss any concerns.
- To ensure the waiting-list control group receive the Numicon intervention.
- To feedback all findings of the research project to the school, parents/ carers and the Local Authority and provide a full debrief to all participants and stakeholders.

The School

- To nominate a member of staff to act as an initial point of contact for the researcher, and parents/ carers.
- To select up to 6 children per group (a total of 12 pupils), from Y3 to participate in the research project.
- To provide a venue for the parents/ carers meeting on ..... and send out information about the meeting to relevant parents/ carers.
- To distribute and collect consent forms and return to the researcher by the given date.
- To provide a member of staff to work collaboratively with the researcher to develop intervention session plans if wish to do so upon completion of the research.
- To provide an experienced member of staff to deliver/ facilitate the intervention.
- To provide a member of staff to support in the administration of the measures of attainment and attitude.
- To release the facilitator of the intervention for 2 hours upon completion of the intervention so that a semi-structured interview can occur.

- The key contact or facilitator should contact the researcher if they have any concerns or are experiencing any difficulties in the delivery of the intervention.

If you have any queries at any time or would like to discuss the study in more details, please contact:
Kate Forder (Trainee Educational Psychologist and Researcher) at
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

OR: Dr. Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy
Ethics No: 628

"*The study has been explained to me to my satisfaction and I am happy for .....Primary School to take part in it. I understand that the school's involvement is dependent upon consent from parents/ carers and children"*

Signed..... (School contact)

Date:.....

"*I have discussed the study with the above contact and outlined the purpose and benefits to the school, as well as the roles and responsibilities of both myself and the school"*

Signed: .....(Researcher)

Date:.....

Appendix 9 Presentation shown at parents/ carers research meeting

Numicon Research Meeting

Kate Forder (Trainee Educational Psychologist)

Outcomes

- To provide background information regarding the research.
- To share the research method.
- To obtain consent.
- To share next steps.
- To answer any questions.

The Researcher

- Trainee Educational Psychologist (TEP)
- Studying for Doctorate in Applied Educational Psychologist at University of Nottingham
- Placement: Northamptonshire County Council Educational Psychology Service
- Completing thesis on impact of Numicon intervention

Research Questions

1. *What impact does Numicon have on the attainment/ results of children experiencing difficulties in numeracy (maths)?*
2. *Does participation in Numicon impact on how children feel about numeracy?*
3. *What do school staff who deliver Numicon think about it?*



What is Numicon?



- Multisensory mathematics programme
- Originally developed in 1996
- Can be used in whole class or with a small group (intervention)
- Use of imagery and apparatus --> making numbers 'real'

Numicon in this school

- Used in whole class and as intervention
- Intervention:
  - For children experiencing difficulties in numeracy
  - Delivered by member of school staff
  - 12 weeks- 3 x a week for 15 mins



The Research

- Children currently in Y2 selected by school to take part in Numicon intervention in Y3
- Also opportunity to take part in research
- Will still receive intervention

Method

- Children allocated to Group A or Group B
- Group A receive intervention in Autumn term
- Group B receive intervention in Spring term
- All children will receive the intervention



Method cont.

- Data collected for all children in Group A and Group B in September and December
- Purpose: To monitor children's progress.
- Measures
  - Attainment: Sandwell Early Numeracy Test
  - Attitudes: 'Maths and Me' Survey
- Time: 30 mins approx.

Data Protection

- Children and schools will not be named
- Data:
  - Will be used in thesis which may be published
  - Saved on password protected spreadsheet
  - Children given number identifier (only known by researcher)
  - Child's results shared with school and parents/ carers (attainment)

Consent

- Parental written consent for child to take part in research- can be given today
- Consent obtained from child
- Participation voluntary
- Can withdraw at any time
- Child will still receive intervention



Consent Form: Parents/ Carers

- Have you read and understood the Information Sheet?
- Have you had the opportunity to ask questions about the study?
- Have all your questions been answered satisfactorily?
- Do you understand that you are free to withdraw your child from the study? (at any time and without giving a reason)
- I give permission for my child's data from this study to be shared with other researchers provided that my anonymity is completely protected
- I give permission for my child's data/ numeracy assessment forms to be shared with their school
- Do you agree for your child to take part in the study?

Consent form: Children

- Has an adult read the information sheet with you?
- Do you understood the Information Sheet?
- Have you had a chance to ask any questions about the project?
- Were you happy with the answers you were given?
- Do you understand you can stop taking part in the project at any time without saying why?
- I am happy for my scores to be shared with others as long as they are not told my name
- I am happy for my numeracy assessment to be shared with my teachers and my parents/ carers
- I am happy to take part in the project

Completed with researcher (member of staff available)

Next Steps



- **July 2015:**
  - Parent consent forms signed
  - Child's consent obtained
- **Sept. 2015:**
  - Data collection (Group A and B)
  - Group A receive intervention (12 weeks)
- **Dec. 2015:**
  - Data collection (Group A and B) --> Research complete
- **Jan. 2016:**
  - Group B receive intervention

Any Questions



Contact Details

- *Researcher:* Kate Forder (Trainee Educational Psychologist)
  Email: lpxkf1@nottingham.ac.uk
  Tel: 01604 364770

- *Researcher Supervisor:* Dr. Sarah Atkinson
  Email: s.atkinson@nottingham.ac.uk
  Tel: 0115 8467238

Appendix 10 Information sheet for parents/ carers



The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

NUMERACY RESEARCH STUDY AT
[ADD NAME OF SCHOOL AND LOGO]
Information Sheet for Parents/ Carers

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researchers: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
Kate Forder (Trainee Educational Psychologist and Researcher) at
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

This is an invitation for your child to take part in a research study to investigate if Numicon, a numeracy intervention, helps children, who are finding numeracy hard, improve in their maths skills and feel happier about numeracy.

Before you decide if you wish for your child to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

Your child's school currently use Numicon to support children who find numeracy hard, and have therefore chosen to be part of this research study. Children in year 3, who teachers feel find numeracy hard, including your child, are therefore being invited to take part in this study.

If you agree for your child to take part in the study, they will be placed in one of two groups:

- Group A: Children who will receive the Numicon Intervention in the autumn term
- Group B: Children who will receive the Numicon Intervention after Group A have received the intervention.

Children will work individually with me or a colleague from the Educational Psychology Service, at the start of the autumn term and upon completion of the autumn term intervention. They will complete some questions to assess their numeracy skills and a questionnaire about what they think of about numeracy.

Assessments will take place throughout the school day, with each assessment lasting for 30-45 minutes. If a child does not wish to complete the assessments they can withdraw at any time. They will also be a member of school staff present should any child wish to access such support.

Participation in this study is totally voluntary and you are under no obligation to allow your child to take part. You are free to withdraw your child at any point before or during the study. All data collected will be kept confidential and used for research purposes only. It will be stored in compliance with the Data Protection Act.

If you have any questions or concerns please don't hesitate to ask now. We can also be contacted after your participation at the above address.

We can also be contacted after your participation at the above address.

If you have any complaints about the study, please contact:
Stephen Jackson (Chair of Ethics Committee)
stephen.jackson@nottingham.ac.uk

SCHOOL OF PSYCHOLOGY
PARENT/ CARER CONSENT FORM

A research study to evaluate the impact of Numicon on the attainment and attitudes towards numeracy of children experiencing difficulties in numeracy
Ethics Approval Number: 628
Researcher: Kate Forder, *e-mail: lpxkf1@nottingham.ac.uk*
Supervisor: Dr. Sarah Atkinson, email: s.atkinson@nottingham.ac.uk
Please answer the following questions:

- Have you read and understood the Information Sheet? YES/NO
- Have you had the opportunity to ask questions about the study? YES/NO
- Have all your questions been answered satisfactorily? YES/NO
- Do you understand that you are free to withdraw your child from the study? (at any time and without giving a reason) YES/NO
- I give permission for my child's data from this study to be shared with other researchers provided that my anonymity is completely protected YES/NO
- I give permission for my child's data/ numeracy assessment forms to be shared with their school YES/NO
- Do you agree for your child to take part in the study? YES/NO

"This study has been explained to me to my satisfaction, and I agree for my child to take part. I understand that I am free to withdraw my child at any time."

Signature of the parent/ carer: Date:
Name (in block capitals):

I have explained the study to the above parent/carer and they have agreed for their child to take part

Signature of researcher: Date:

Appendix 11 Information sheet for children

Information Sheet for Children

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy



Ethics Approval Number: 628

Researchers: Kate Forder (Email- lpxkf1@nottingham.ac.uk)

Supervisors: Dr. Sarah Atkinson (Email- s.atkinson@nottingham.ac.uk)

Hi my name is Kate and I am working with your teachers and teaching assistants to look at how we can help children in numeracy. Your teacher has told me that this year you will be working in a special numeracy group called Numicon. I want to know if Numicon helps children to become better at numeracy and changes how they think about numeracy. I would therefore like to invite you to take part in a project that I am doing. Before you decide if you would like to take part, it is important for you to understand why the project is being done and what it will involve. Please take time to read the following information carefully.

You will be taking part in the Numicon group in during Year 3, in the autumn or spring term.

If you decide to take part in this project you will also be asked to complete the following tasks:



- Before the Numicon group begins in September, I or a person I work with will come and ask you some questions. These will include some numeracy questions and some questions about what you think about numeracy. This will take about 30 - 45 minutes
- Once the Numicon group has finished in November, we will come back and ask you the questions again

If at any time you do not want to answer any questions or wish to stop taking part in the project you can do this.

Both sets of questions will provide a score which I will report in my write-up about the project. You will not be named in this project and neither will your school. If you are happy for me to do so, I will also share your scores with your teacher and your parents/ carers. Your teacher will also be able to see your answers to the numeracy questions, but not to the questions about what you think about numeracy.

If you have any questions about the project please ask me, your parents/ carers or your teacher.

With an adult please complete the attached form.

SCHOOL OF PSYCHOLOGY

CHILDREN'S CONSENT FORM

A research study to evaluate the impact of Numicon on the attainment and attitudes towards numeracy of children experiencing difficulties in numeracy

Ethics Approval Number: 628

Researcher: Kate Forder, *e-mail:* lpxkf1@nottingham.ac.uk

Supervisor: Dr. Sarah Atkinson, email: s.atkinson@nottingham.ac.uk

Please answer the following questions by colouring the correct face:

Has an adult read the information sheet with you?	
Do you understand the Information Sheet?	
Have you had a chance to ask any questions about the project?	
Were you happy with the answers you were given?	
Do you understand you can stop taking part in the project at any time without saying why?	
I am happy for my scores to be shared with others as long as they are not told my name	
I am happy for my numeracy assessment to be shared with my teachers and my parents/ carers	
I am happy to take part in the project	

A research study to evaluate the impact of Numicon on the attainment and attitudes towards numeracy of children experiencing difficulties in numeracy

Ethics Approval Number: 628

"I have been told about this project and know what it is about. I am happy to take part and understand I can stop taking part at any time"

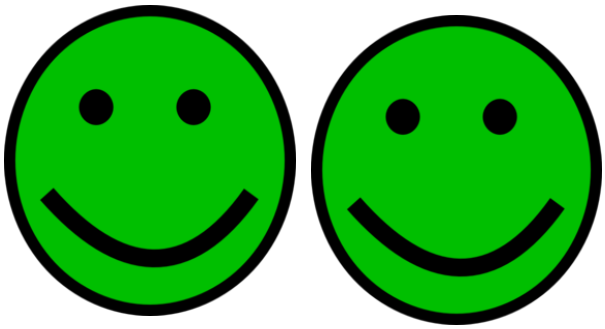
Signature of the child: Date:

Name (in block capitals)

I have explained the study to the above child and they have agreed to take part

Signature of researcher: Date:

Appendix 12 Prompt cards to support completion of the 'Maths and Me Survey'



Strongly agree



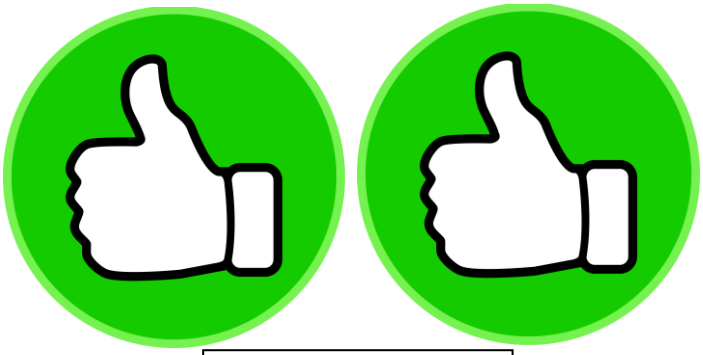
Agree

Neither agree nor disagree

Disagree



Strongly disagree



Strongly agree



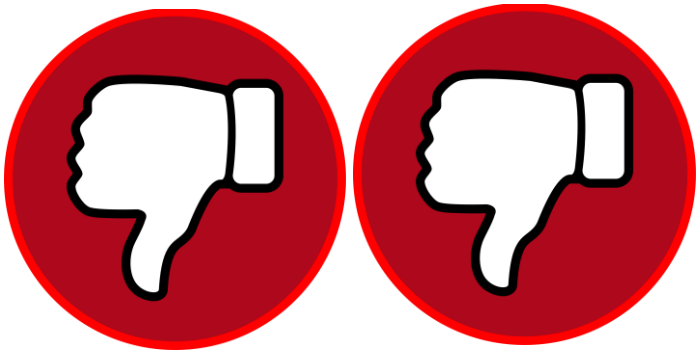
Agree



Neither agree nor disagree



Disagree



Strongly disagree

Appendix 13 Script for administration of SENT-R and the 'Maths and Me Survey'

Hi my name is XXXX and I'm looking at how special numeracy groups can help children with their numeracy schools.

As you're going to be taking part in a numeracy group, I would like to ask you some questions about what you think about numeracy, and also complete a booklet of numeracy activities.

Administering the 'Maths and Me Survey'
Ask child to choose whether they would like to use thumbs or faces

I'm going to read 18 statements about numeracy. For each one I'd like you to choose the picture which best describes how you feel about the statement, so if you strongly agree you'll point to the card with two thumbs up/ smiley faces. If you agree, it's the card with 1 thumb up/ smiley face. If you neither agree nor disagree it's the card with the thumb pointing sideways/ straight face. If you disagree it's the card with one thumb down/ sad face and if you strongly disagree it's the card with two thumbs down/ sad face. Remember it's what you think so there is no right or wrong answer.

If you don't understand a question I can repeat it and explain what it means. If there are any questions you don't want to answer, you can leave them out. Do you have any questions? Here's the first statement.

Once the questionnaire has been completed

Thank you for completing that activity, now we're going to complete some numeracy activities. Remember if you want to stop or have a break at any time you can. If you're not sure about an answer, don't worry, you can leave it out. The important thing is to try your best.

Administer the SENT-R
Thank you for answering the questions. You worked really hard, as I know some of them weren't easy.
I'm going to take these back to my office and mark them. I'll share your scores with your teacher and parents/ carers, but not your actual answers about your feelings towards numeracy. I'm also going to report your scores in my project but I will not mention your name anywhere so no one will know that they are your scores.

Is there anything you would like to ask or tell me before you return to class.

Appendix 14 Questions asked to provide a pen portrait of facilitators

1. What is your job title?
2. How long have you held this position?
3. How long have you worked in primary education?
4. Have you had any other positions, other than working in schools, which have involved working with children? If so what and for how long?
5. Do you have any qualifications that are relevant to your current position?
6. How long have you been delivering Numicon interventions in school?
7. Have you delivered other maths interventions? If so which?
8. Have you received any training in supporting children with maths difficulties including on specific interventions? If so what and by whom?

Appendix 15 Example session plan from school B

Numicon Intervention Plan w/b 2.11.15		
Objective	Activities	Next steps
To learn number pairs to 20. To be able to make 20 in different ways.	Recap the learning that the children have made so far with their Numicon intervention. Ask the children to make the number 12. Which number goes with it to make 20? Use two 10 shapes and lay the 12 on top. What shape is left? Repeat with some more 'teen' numbers. What do we notice? (There is always a ten shape with teen numbers and the other numbers are number pairs to 10). Provide the children with a number between 0 and 20. Ask the children to visualise the number in Numicon in their head. Can they visualise the number that goes with it to make 20? If not, ask them to draw the shapes to work out the answer. Repeat with a few more examples. Challenge the children to make 20 in as many ways as they can. Share ideas and ask the children what they notice e.g. when a child has used 2 /3 /4 numbers to make 20.	

Appendix 16 Example session plan from school D

Week 3 11/11/15

Can you show a number bond to 20?

See sheet

Can you count to 30?

Using objects to show arrays- adult demonstration

Appendix 17 Information sheet for facilitators



The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Information Sheet for Facilitators

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researchers: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
Kate Forder (Trainee Educational Psychologist and Researcher) at
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

This is an invitation for you to take part in a research study to investigate the impact of Numicon, a numeracy intervention, on the attainment and attitude towards numeracy of children who are experiencing difficulties in numeracy in Key Stage 2.

Before you decide if you wish to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

The purpose of the study is to investigate the impact that Numicon has on children's attainment and attitudes towards numeracy. I am also interested in exploring what factors facilitators of the Numicon intervention think impact on whether or not it is a successful intervention. As you will be facilitating a Numicon intervention for children in Year 3, I would like to invite you to be part of this research study.

If you agree to participate in the study I would like to interview you at the end of the autumn term intervention to discuss factors which you think impact upon the success of Numicon within your school. I will be interviewing

facilitators from different schools within the area, and will provide all schools with a summary of factors based on the information provided. Therefore your data will be anonymous. If however you have particular concerns about the delivery of

Numicon within your school we will discuss this and whether you would like this to be shared directly with senior members of staff. We will also look at possible ways to address these concerns.

Participation in this study is totally voluntary and you are under no obligation to take part. You are free to withdraw at any point before or during the study. All data collected will be kept confidential and used for research purposes only. It will be stored in compliance with the Data Protection Act.

If you have any questions or concerns please don't hesitate to ask now. We can also be contacted after your participation at the above address.

If you have any complaints about the study, please contact:
Stephen Jackson (Chair of Ethics Committee)
stephen.jackson@nottingham.ac.uk

SCHOOL OF PSYCHOLOGY
FACLITATOR'S CONSENT FORM

A research study to evaluate the impact of Numicon on the attainment and attitudes towards numeracy of children experiencing difficulties in numeracy
Ethics Approval Number: 628
Researcher: Kate Forder, *e-mail:* *lpxkf1@nottingham.ac.uk*
Supervisor: Dr. Sarah Atkinson, email: s.atkinson@nottingham.ac.uk

Please answer the following questions:

- Have you read and understood the Information Sheet? YES/NO
- Have you had the opportunity to ask questions about the study? YES/NO
- Have all your questions been answered satisfactorily? YES/NO
- Do you understand that you are free to withdraw from the study? (at any time and without giving a reason) YES/NO
- I give permission for my data from this study to be shared With other researchers provided that my anonymity is completely protected YES/NO
- I am happy for the interview to be recorded YES/NO
- Do you agree to take part in the study? YES/NO

“This study has been explained to me to my satisfaction, and I agree to take part. I understand that I am free to withdraw at any time.”

Signature of facilitator: Date:

Name (in block capitals)

I have explained the study to the above facilitator and they have agreed for to take part

Signature of researcher: Date:

Appendix 18 Semi-structured interview for facilitators

The following questions will be used to guide an interview with facilitators of the Numicon intervention.

- What do you think were the outcomes of the Numicon intervention that you recently delivered? Were you pleased with these outcomes? Why/ why not?
- What aspects of Numicon do you feel are positive and negative? Why?
- Are there other factors within school that impact upon the outcomes of Numicon?
- Are there personal characteristics of the children that impact upon the outcomes of Numicon?
- What other factors impact on the outcomes of Numicon?
- Practically how easy in Numicon to implement?
- Do you think Numicon is a successful intervention for all children experiencing difficulties in numeracy? Why/ why not?
- What, if any, are the benefits of using the Numicon equipment?
- Did you identify any barriers/ difficulties when implementing and delivering Numicon?
- Any other comments?

Appendix 19 Treatment fidelity checklist

Date of observation:
Observer:
Session number:

Feature	*Observed YES/ NO*	*Comments/ Evidence*
Facilitator uses lesson plan		
Opportunities for group/ paired work		
Numicon specific language is used e.g. 'Numicon staircase'		
At least two different activities are completed which include using the Numicon pieces		
Session focuses on number and no other strands of numeracy e.g. shape, space, or measure		
Mathematical language is used and discussed		
Children's misconceptions are addressed		
All children are encouraged to contribute and share ideas		
Numicon pieces are used to support children's understanding of number e.g. How do we know 3 is 1 more than 2? How do we know these numbers are odd?		

Appendix 20 Ethical guidance from the British Psychological Society, the Health and Care Professions Council and the University of Nottingham

Ethical Consideration	*Guidance*			
	BPS (2009)	*BPS (2014)*	*HCPC (2012)*	*UoN (2015)*
Obtaining informed consent of all clients participating in research	1.3(ii)	4/ 10.1.1	*9*	1.1.2
Providing sufficient information so all participants especially children understand the nature, purpose, and anticipated consequences of research participation	1.3(i)	4/ 10.1		
Obtaining informed consent for audio recordings	1.2(x)	4		
Adequate records of how consent was obtained	1.3(iii)	4		
Information kept confidential		5	*2*	3.8/ 4.1.1
Keep appropriate records, process, and store confidential information in a fashion designed to avoid inadvertent disclosure.	1.2(i/ iii)			4.1.4
Removing any details that may lead to identification of participants		2.1/ 5	*2*	*4.4*
Avoiding unfair, prejudice or discriminatory practice	1.1(iii)	2.1	*1*	
Participants have right to withdraw and to decline to answer questions	1.4(ii/ iii) 3.3(vi/ viii)	2.1/ 4		

Ethical Consideration	*Guidance*			
	BPS (2009)	*BPS (2014)*	*HCPC (2012)*	*UoN (2015)*
Avoidance of any actions which may harm the participants or cause additional risk especially if participants are vulnerable	3.1(i)	2.4/ 3		3.11
Risk of ‘labelling’		3		
Participants may request advice regarding a particular need	3.3(ix)	6		
Participants need to be debriefed at the conclusion of their participation in the research	3.4(i)	8		

Appendix 21 Raw data collected at T1

Participant	*Experimental Group: SENT-R Data Pre- Test (T1)*						
	Form	*Identification of number*	*Oral counting*	*Value/ computation*	*Object counting*	*Language*	*Total*
Child 1	A	7	7	9	4	9	36
Child 2	B	6	9	8	4	10	37
Child 3	A	6	4	8	4	7	29
Child 4	B	6	7	10	4	9	36
Child 5	A	7	10	11	4	10	42
Child 6	B	6	10	13	4	7	40
Child 7	A	6	7	13	4	13	43
Child 8	B	6	7	9	4	10	36
Child 9	A	7	10	7	4	9	37
Child 10	B	5	5	2	3	1	16
Child 11	B	6	7	2	4	4	23
Child 12	A	10	9	14	4	11	48
Child 13	B	8	9	8	4	12	41
Child 14	A	10	10	18	4	12	54
Child 15	B	6	8	11	4	12	41

Participant	*Waiting List Control Group: SENT-R Data Pre-test (T1)*						
	Form	*Identification of number*	*Oral counting*	*Value/ computation*	*Object counting*	*Language*	*Total*
Child 1	A	6	4	8	4	9	31
Child 2	A	6	8	15	4	9	42
Child 3	B	6	8	10	4	12	40
Child 4	A	7	4	9	4	7	31
Child 5	B	7	9	18	4	10	48
Child 6	A	5	7	13	4	9	38
Child 7	B	6	7	12	4	9	38
Child 8	A	8	9	2	4	12	35
Child 9	A	10	10	20	4	13	57
Child 10	B	6	8	9	4	9	36

	Experimental Group: Maths and Me Survey Pre-test data (T1)																			
Participant	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q 10*	*Q 11*	*Q 12*	*Q 13*	*Q 14*	*Q 15*	*Q 16*	*Q 17*	*Q 18*	*Self-Perception*	*Enjoyment of Maths*
Child 1	5	5	3	5	3	5	5	5	5	5	5	5	5	5	1	5	5	5	36	46
Child 2	2	5	3	4	4	5	3	4	3	4	4	3	3	5	3	4	3	3	30	35
Child 3	5	5	2	4	5	4	4	4	5	5	4	1	5	2	4	4	2	5	33	37
Child 4	1	5	5	3	5	4	3	5	3	5	5	3	4	4	5	4	2	5	31	40
Child 5	5	5	4	3	5	4	1	5	4	5	5	4	4	4	5	5	5	4	32	45
Child 6	5	5	4	4	5	3	1	4	4	5	4	5	5	5	4	5	4	5	31	46
Child 7	5	5	5	3	5	5	5	5	1	5	5	5	3	5	5	5	5	5	38	44
Child 8	5	5	5	3	5	5	3	5	3	5	5	5	5	5	5	5	5	5	36	48
Child 9	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	40	49
Child 10	5	4	5	2	5	3	1	3	4	1	5	4	4	5	5	4	3	5	28	40
Child 11	5	4	4	5	4	1	2	2	4	4	4	4	1	4	4	4	4	4	27	37
Child 12	5	5	4	4	3	4	5	2	5	5	5	5	5	5	5	5	3	5	32	48
Child 13	4	4	4	4	4	3	3	2	4	4	4	4	3	4	4	4	5	4	28	40
Child 14	2	3	4	5	3	3	3	2	1	4	5	2	5	4	3	5	1	4	25	34
Child 15	3	5	4	5	3	5	5	5	5	5	5	3	5	5	5	5	5	5	35	48

	Waiting List Control Group: Maths and Me Survey Pre-test data (T1)																		
Participant	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q 10*	*Q 11*	*Q 12*	*Q 13*	*Q 14*	*Q 15*	*Q 16*	*Q 17*	*Q 18*	*Self-Perception*	*Enjoyment of Maths*
Child 1	5	5	5	3	5	5	1	4	1	5	5	5	4	5	1	5	5	5	33	41
Child 2	4	3	5	1	3	3	1	1	2	2	1	5	1	3	2	2	2	5	21	25
Child 3	1	2	1	1	2	2	2	5	1	2	3	1	1	2	1	2	1	2	16	16
Child 4	4	3	4	5	2	4	2	5	2	2	5	5	3	5	4	5	2	4	29	37
Child 5	4	5	5	4	4	4	2	4	2	5	4	5	5	5	5	4	5	4	32	44
Child 6	4	5	5	5	3	5	3	5	5	5	5	4	5	5	5	5	3	5	35	47
Child 7	2	1	2	3	1	4	1	1	1	1	4	2	2	5	2	4	2	2	15	25
Child 8	5	5	4	5	3	5	5	5	5	5	5	5	5	5	3	5	5	5	37	48
Child 9	4	5	3	5	3	4	3	4	3	4	4	3	4	4	3	4	3	4	31	36
Child 10	3	3	5	4	2	5	2	1	1	3	1	5	2	5	3	3	2	2	25	27

Appendix 22 Raw data collected at T2

Participant	*Experimental Group: SENT-R Data Post-test (T2)*						
	Form	*Identification of number*	*Oral counting*	*Value/ computation*	*Object counting*	*Language*	*Total*
Child 1	B	8	7	5	4	9	33
Child 2	A	5	9	8	3	12	37
Child 3	B	6	8	2	3	0	19
Child 4	A	7	8	3	4	8	30
Child 5	B	8	10	15	4	12	49
Child 6	A	6	9	15	4	11	45
Child 7	B	6	9	25	4	12	56
Child 8	A	7	8	10	4	10	39
Child 9	B	8	9	10	4	11	42
Child 10	A	6	7	6	4	5	28
Child 11	A	6	7	4	4	1	22
Child 12	B	8	10	18	4	11	51
Child 13	A	9	8	13	4	9	43
Child 14	B	9	10	20	4	13	56
Child 15	A	11	10	20	4	10	55

	Waiting List Control Group: SENT-R Data Post-test (T2)						
Participant	*Form*	*Identification of number*	*Oral counting*	*Value/ computation*	*Object counting*	*Language*	*Total*
Child 1	B	6	5	7	4	7	29
Child 2	B	6	8	16	4	13	47
Child 3	A	6	9	11	4	7	37
Child 4	B	7	9	2	4	9	31
Child 5	A	6	8	13	4	12	43
Child 6	B	8	8	15	4	14	49
Child 7	A	11	8	23	4	14	60
Child 8	B	10	9	13	4	12	48
Child 9	B	11	10	29	4	14	68
Child 10	A	6	9	12	4	9	40

	Experimental Group: Maths and Me Survey Post-test data (T2)																			
Participant	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q 10*	*Q 11*	*Q 12*	*Q 13*	*Q 14*	*Q 15*	*Q 16*	*Q 17*	*Q 18*	*Self-Perception*	*Enjoyment of Maths*
Child 1	1	5	3	5	5	5	5	5	5	5	5	5	5	5	1	5	3	5	34	44
Child 2	4	5	4	5	3	5	3	5	3	5	5	3	5	5	1	5	3	5	34	40
Child 3	5	4	3	4	1	5	2	5	2	5	2	5	2	3	5	1	5	4	29	34
Child 4	5	4	2	5	5	5	1	5	5	5	5	5	5	5	5	4	5	5	32	49
Child 5	5	5	4	4	2	5	4	5	5	5	5	5	5	5	5	4	5	5	34	49
Child 6	5	5	5	5	5	5	4	4	3	5	5	4	5	5	4	5	5	5	38	46
Child 7	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	38	50
Child 8	5	5	5	4	5	5	1	5	2	4	5	5	4	5	5	5	5	5	35	45
Child 9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	40	50
Child 10	4	4	4	4	4	4	4	5	5	5	5	4	5	5	5	4	5	5	33	48
Child 11	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	30	40
Child 12	5	4	5	5	3	5	3	3	5	5	5	3	5	5	3	4	5	4	33	44
Child 13	3	5	4	3	1	5	3	2	3	5	5	4	5	4	2	4	3	5	26	40
Child 14	3	4	5	4	3	4	1	4	3	4	5	3	5	5	4	3	2	5	28	39
Child 15	3	5	3	5	2	5	1	2	2	5	5	1	5	4	1	4	1	5	26	33

	Waiting List Control Group: Maths and Me Survey Post-test Data (T2)																			
Participant	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q 10*	*Q 11*	*Q 12*	*Q 13*	*Q 14*	*Q 15*	*Q 16*	*Q 17*	*Q 18*	*Self-Perception*	*Enjoyment of Maths*
Child 1	5	4	4	4	3	5	2	4	5	4	5	4	3	4	5	4	2	5	31	41
Child 2	3	4	4	5	3	4	5	3	3	4	5	3	5	5	5	3	3	5	31	41
Child 3	3	1	2	5	2	1	5	3	5	3	2	3	1	5	1	2	3	4	22	29
Child 4	5	4	3	4	4	5	3	3	2	4	5	4	4	4	4	4	5	5	31	41
Child 5	5	5	4	5	3	5	5	4	5	5	5	5	5	5	4	5	5	5	36	49
Child 6	1	5	5	5	5	5	5	5	3	5	5	3	5	5	5	5	5	5	36	46
Child 7	3	3	5	4	2	3	2	3	4	5	3	2	5	5	4	4	2	5	25	39
Child 8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	40	50
Child 9	4	5	3	5	3	5	3	4	3	5	4	3	5	5	3	4	3	5	32	40
Child 10	3	2	3	2	1	3	1	1	1	3	3	4	3	5	1	2	3	3	16	28

Appendix 23 Notation system used for orthographic transcripts

From: Braun, V. & Clarke, V. (2013) *Successful Qualitative Research: A practical guide for beginners.* London: SAGE Publications (p. 165-166)

Feature	Notion and explanation
Identity of speaker; Turn-taking in talk	Identity of speaker signal by speaker's name followed by colon e.g. Anna: Start new line when new speaker enters conversation, and start first word of each turn with a capital letter
Laughing, coughing, etc.	((laughs)) and ((coughs)) signals a speaker laughing/ coughing during a turn of talk. ((General laughter)) signals multiple speakers laughing at once and should be on a separate line.
Pausing	((pauses)) signals a significant pause i.e. a few seconds or more. Can also use (.) to signal a short pause and ((long pause)) to signal a much longer pause.
Overlapping speech	Type ((in overlap)) before the start of the overlapping speech.
Inaudible speech	Use ((inaudible)) for speech and sounds that are completely inaudible. If you think you heard what the speaker said, but you are not sure if it's correct, use single parentheses to signal your best guess as to what is said.
Non-verbal utterances	Render phonetically and consistently common non-verbal sounds uttered by participants. These include 'erm', 'er', 'mm' and 'mm-hh'
Use of punctuation	It is common to use punctutation to signal some feature of spoken language, such as using a question mark to signal the raising intonation of a question. However, adding punctuation can change the meaning of an extract of data.
Reported speech	Reported speech is when a person provides an apparent verbatim account of the speech/ thoughts of another person, or reports their own speech in the past. Signal this with the use of inverted commas around the reported speech.
Identifying information	You can change identifying information such as people's names and occupations, place, events etc. by • By changing details and providing unmarked appropriate alternatives e.g. 'Bristol' to 'Manchester'. • By replacing specific information with marked generic descriptions indicated by square brackets e.g. 'London' might be replaced with [large city]

Appendix 24 Author's summary of initial impressions of interviews with the facilitators

Initial impressions of Amy's interview:

- Numicon impacts on confidence especially with regards to basic number skills and using actual equipment, which impacts on children's understanding of number. This is due to the visual element of Numicon which links into the idea that concrete learning can lead to abstract learning. Also highlights importance of repetition and overlearning.
- Gender differences? Practical aspects particularly beneficial for boys.
- Could not identify any limitations
- Perceives Numicon as a great resource.
- Important used within whole class learning as well as intervention
- Important that children are introduced to the equipment early on in their school careers.
- Appropriate for EAL/ children with SCLN, and is accessible to all. Does however acknowledge that may not be suitable for all children.
- Individual differences impact on how a child responds to Numicon e.g. a child with SEN takes longer to learn and progresses at a slower pace. Also suggests that home life impacts on outcomes of intervention.

Initial impressions of Beth's interview

- Views Numicon as a positive intervention, which impacts on children's number sense and basic number skills e.g. place value, addition.
- Equipment is seen positively: Linked to concrete nature of resource which enable children to visualise abstract concepts, as well as practical elements e.g. colour and shape. Seen as fun resource.
- Personal characteristics of children can impact on outcomes e.g. ability to retain info; concentration.
- Not as successful for EAL- language barrier?
- Role of parents- important understand what Numicon is and how beneficial. Helps children to develop thinking and ability to share understanding as they can discuss Numicon with parents
- Builds confidence, enjoyment.
- Sessions need to be regular and frequent -> importance of repetition/ consolidation
- Children need to know how to use Numicon and be familiar with equipment
- Limitations:
    - Can it teach all skills e.g. subtraction?
    - Impact if child misses some sessions? Breaks between sessions impacts on recall

    - Is it appropriate for all ages in primary school, or only for developing early number skills
    - Knowledge of facilitator to teach wider range of skills using Numicon

Initial impressions of Clare's interview

- Purpose of intervention: Recap previous learning (repetition and consolidation of basic number skills/ number sense.
- Supports mathematical language and enables children to understand the relationship between different numbers.
- Very good for teaching number sense, basic skills and introducing four operations
- Opportunities to link into whole class learning
- Used as a 'step up' resource. Aim is to move children away from using Numicon.
- Supports the use of other resources and equipment
- Embedded into school curriculum and used throughout school. Introduced when children are young.
- Important that children are familiar with, and know how to use, equipment
- Children feel comfortable with Numicon --> good starting point for consolidation and new learning
- Provides practical and visual learning opportunities which support learning opportunities for children who struggle to understand abstract concepts.
- Children remember things, as Numicon enables them to make connections between their learning.
- Equipment is engaging, bright and colourful. Fun element.
- Personal characteristics do not impact on outcomes, but not sure if suitable for children with dyscalculia. Also could not comment on EAL as they have not used it with such children
- Importance of sharing with parents and helping them to understand how Numicon is used.
- Practical benefits include easy to manage and doesn't take up a lot of space
- Limitations- Equipment can be distracting, as children tend to play with it.

Initial impressions of Debbie's interview

- Numicon has positive impact on attitudes and approaches to numeracy in class room
- Parents can see it as babyish. Children share how Numicon is used in order to remove some of negative perceptions. Other parents view it positively.

- Important used across whole school by all ages and abilities as challenges parental perceptions, as well as removing stigma of using apparatus to support learning. Changes attitudes towards the resource.
- Being used across the school has led to impact on maths
- Children need to know how to use resource
- Concrete nature of resource --> positive experience for EAL/ SCLN as removes barrier of language difficulties.
- Visual nature of resource and fact that children can manipulate it --> positive impact on learning and easier for children to retain. Children make connections between different plates and numbers, and between the concrete and abstract.
- Can be difficult to fit sessions in due to special events in school
- Intervention can be adapted to meet needs of child
- Feels confident at using Numicon
- Practically it is easy to use
- Removes distractions that can be associated with other resources such as multilink cubes
- Children excited about Numicon --> becoming involved in their maths and learning.

General themes/ ideas that have emerged:

- Numicon has positive impact especially with regards to basic number skills/ number sense
- Enables children to visualise abstract concepts and to use concrete resources to understand such concepts.
- Equipment is viewed positively from both a practical and learning perspective.
- Numicon impacts on confidence and enables children to perceive maths as fun. Promotes enjoyment.
- In order for Numicon to be successful, children need to be familiar with, and able to use, the equipment.
- Numicon is more successful if embedded within whole school ethos and used to support all children with mathematics. It should be introduced as early as possible.
- Majority of interviewees believe Numicon is beneficial for EAL/ children with SCLN, but one believes language difficulties may act as a barrier.
- Whilst Numicon is perceived to be effective for a lot of children, interviewees do not all agree that it would be suitable for a child with specific mathematical difficulty.
- Strong emphasis on repetition and consolidation
- Importance of parents being aware of and understanding how Numicon is used

Appendix 25 Example of codes identified for data extracts

No.	Extract	Codes
A1	*Facilitator:* The children more confident *Researcher:* ((in overlay)) Ahem *Facilitator:* With them with their maths number skills I thought they were aware I could see them growing *Facilitator:* Cos I did about eight children and overall definitely I could see a confidence in their *Researcher:* ((in overlay)) Yeah *Facilitator:* ((pause)) Number (.) skills and handling number	Intervention --> confidence in number sense and maths Visible and/ or quicker progress
A5	*Facilitator:* Very hands on ((pause)) great for boys	Intervention is +ve due to 'hands on'/ tactile element Gender differences
A9	*Facilitator:* And to support them cos they're they're introduced to it (.) from quite early on *Researcher:* Yea so do they start are they introduced to it in like Foundation Stage *Facilitator:* ((in overlay)) Nursery	Numicon should be introduced at an early age
B4	*Researcher: ...*what are the positives of using Numicon *Facilitator:* Erm definitely the visualisation that it gives the children all of my group now are able to totally visualise all of the pieces they can explain to you what colour they are what they come before and after (.) so where we have been trying to push them to maybe move a bit more pictorially *Facilitator:* Erm they've actually been really confident with that	Visual element develops understanding of basic skills/ concepts Intervention is +ve due to visual element Visualisation enables children to move to pictorial stage Intervention --> familiarity/ confidence with Numicon resources

No.	Extract	Codes
B5	*Facilitator:* ...and the positives just in general erm we had erm parents' evening last week *Facilitator:* And the way the children were able to talk to their parents we've changed the set up slightly *Researcher:* ((in overlap)) yes *Facilitator:* And we're really pushing the children to deliver the session themselves and talk about what they've been doing so we had the Numicon out and for the parents to actually understand (.) so many of them said "I've heard about Numicon, but we don't know what it is" so the kids were actually getting it out and getting their parents to build the staircase and (.) the kids just seemed to really enjoy using it	Numicon enables children to talk about maths/ use mathematical language Important that parents understand/ know about Numicon Children enjoy using Numicon/ sessions Opportunities for children to share their learning with parents
B23	*Facilitator:* Last year I worked with some of the children in year five that maybe needed a little bit of extra support (.) and where their basic level wasn't as low as (.) kind of year two year three (.) it I felt like I wasn't confident enough to know where to go next with it ((pause)) but I think if you had that knowledge it would be useful cos you would just pitch it differently to the higher key stage two rather than the lowers	Facilitator needs to be confident at using Numicon Facilitator needs appropriate knowledge
C3	*Facilitator:* And it's also as erm the ten sessions we're on erm it complimented what we were doing in class lessons so we have done a few weeks of addition (.) and we've now moved onto subtraction	Synergy between intervention and whole class/ previous learning
C9	*Facilitator:* But as a starting point (.) they feel really comfortable with it so it doesn't feel as daunting as it would introducing something new	Familiarity is important for knowledge/ not feeling overwhelmed

No.	Extract	Codes
C13	*Facilitator:* Erm (.) as a school there is Numicon in every classroom so it's a very consistent approach it would be difficult perhaps if one teacher was using it and another wasn't and you were moving from year group to year group and it wasn't always there but as a school you know it's in every classroom and we use it regularly and it's on wall displays and (.) so (.) *Facilitator:* I guess it would be more difficult if that wasn't *Researcher:* ((in overlay)) Yeah *Facilitator:* If it wasn't a whole school approach	School staff need to be 'on board' if going to be successful Intervention more successful if Numicon is used in whole class learning Consistent and whole school
C17	*Facilitator:* So ((pause)) doing abstract maths (.) would be very very difficult for them this ((pause)) it really does enable them *Researcher:* ((in overlay)) Mm *Facilitator:* To start understanding concepts that would be very difficult	Visual and concrete nature of resources supports understanding of abstract concepts
D7	*Facilitator:* And it's concrete ((long pause)) the ones that it hasn't helped for is to having that first understanding of what to do with the Numicon cos when you just look at the box you're just like 'how does that add to that and how do I do it'	Intervention is +ve due to 'hands on'/ tactile element Children need to be shown/ know how to use Numicon Progress dependent on understanding/ being familiar with Numicon plates
D10	*Facilitator:* (.) So it's it's a great tool for them (.) visually to have and then just because you can ((pause)) move it physically with your hands it's easier for them to embed it in their memory ((laughter))	Intervention is +ve due to visual element Physical action/ manipulation of resources supports children in remembering learning

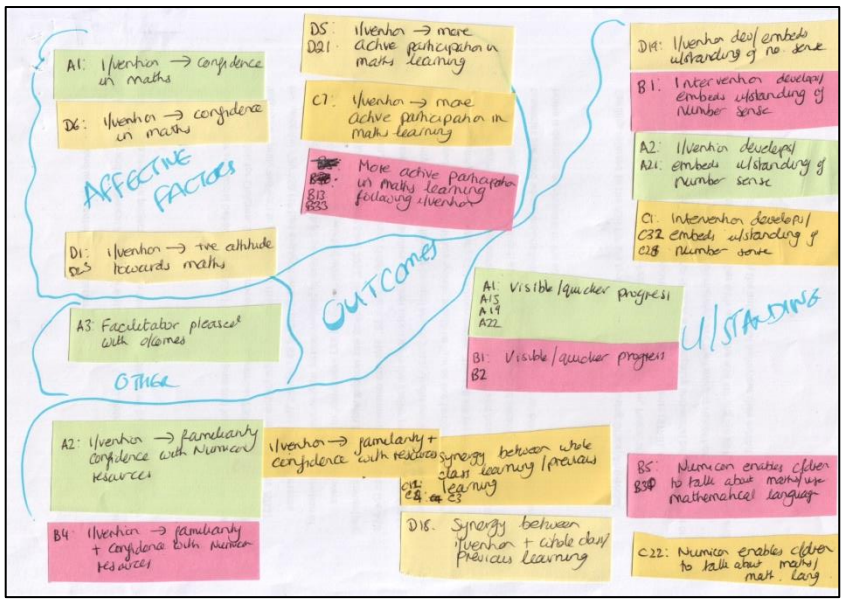
No.	**Extract**	**Codes**
D11	*Researcher:* Erm do you find things like actually (.) erm putting the ((pause)) intervention within school so things like getting the sessions in and all those kind of things are there any difficulties around that or does it work quite smoothly *Facilitator:* It works quite smoothly the only difficulty sometimes is when the class have got something else planned and they forget to tell you	-ve impact of special occasions/ events on delivering intervention

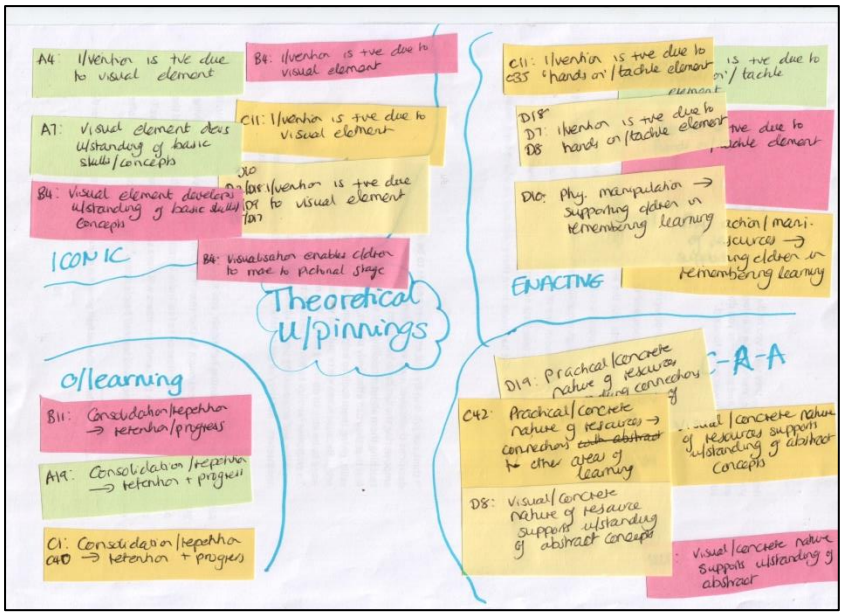
Appendix 26 Codes identified at stage 1 of TA

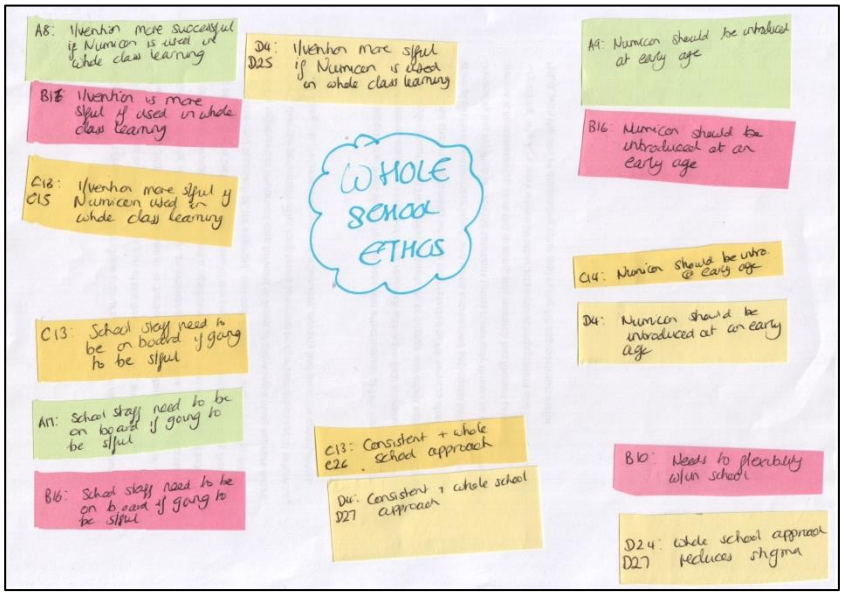
1. [Participation in the] intervention --> [results in] confidence in number sense and maths
2. [Participation in the] Intervention --> [results in] familiarity/ confidence with Numicon resources
3. [Participation in the] Intervention develops/ embeds understanding of number sense
4. Visible and/ or quicker progress
5. [Participation in the] intervention --> [results in] positive attitude towards maths
6. [Participation in the] intervention --> [results in] More active participation in mathematical learning
7. Children enjoy using Numicon /sessions
8. Numicon enables children to talk about maths/ use mathematical language
9. Good resource for EAL/ new arrivals
10. EAL children experience difficulties due to language barrier [contradiction]
11. Gender differences
12. SEN children take longer to learn how to use Numicon
13. Suitable resource for SEN/ children with numeracy/ learning difficulties
14. Children's home situations/ backgrounds impact on outcomes of intervention
15. Suitable for lower KS2/ age appropriate resource
16. Facilitator pleased with outcomes
17. Perceived as great resource
18. Intervention is +ve due to visual element
19. Visual element develops understanding of basic skills/ concepts
20. Visualisation enables children to move to pictorial stage
21. Intervention is +ve due to 'hands on'/ tactile element
22. Physical action/ manipulation of resources supports children in remembering learning
23. Practical/ concrete nature of resource --> making connections to other areas of learning
24. Limitation: Using Numicon for larger numbers/ more complex maths
25. Limitation: Using Numicon to teach subtraction
26. Can be distracted by equipment --> not engaging
27. Intervention more successful if Numicon is used in whole class learning
28. Numicon should be introduced at an early age
29. School staff need to be 'on board' if going to be successful
30. Consistent and whole school approach
31. Whole school approach reduces stigma

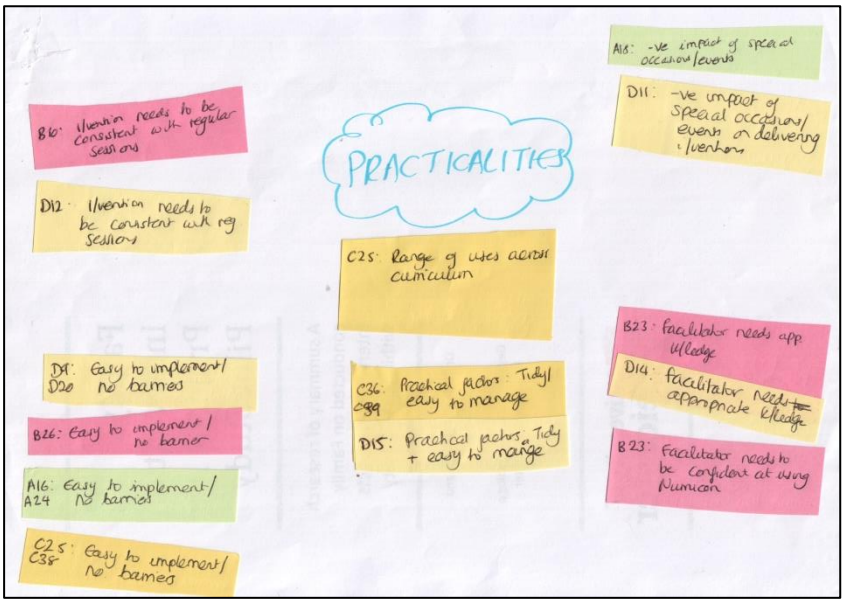
32. Children need to be shown/ know how to use Numicon
33. Progress dependent on understanding/ being familiar with Numicon
34. Familiarity is important for knowledge/ not feeling overwhelmed
35. Easy to implement/ No barriers
36. Consolidation --> retention and progress
37. Repetition --> retention and progress
38. -ve impact of special occasions/ events on delivering intervention
39. Differences between those who have and those who haven't received intervention
40. Individual differences impact on outcomes
41. Important that parents understand/ know about Numicon
42. Opportunities for children to share their learning with parents
43. Viewed positively by parents
44. Consistency between home and school
45. Parents perceive as babyish [contradiction]
46. Absences impact on outcomes of intervention
47. Intervention needs to be consistent with regular sessions
48. Needs to be flexibility within school
49. Facilitator needs to be confident at using Numicon
50. Facilitator needs appropriate knowledge
51. Appearance of actual equipment is big benefit for Numicon
52. Looks fun to use due to appearance
53. Good resource for teaching/ embedding number sense
54. Visual and concrete nature of resources supports understanding of abstract concepts
55. Synergy between intervention and whole class/ previous learning
56. Numicon = starting point/ step-up resource
57. Changes in the education system
58. Compliments other resources
59. Practical factors: Tidy and easy to manage
60. Less distracting than other resources

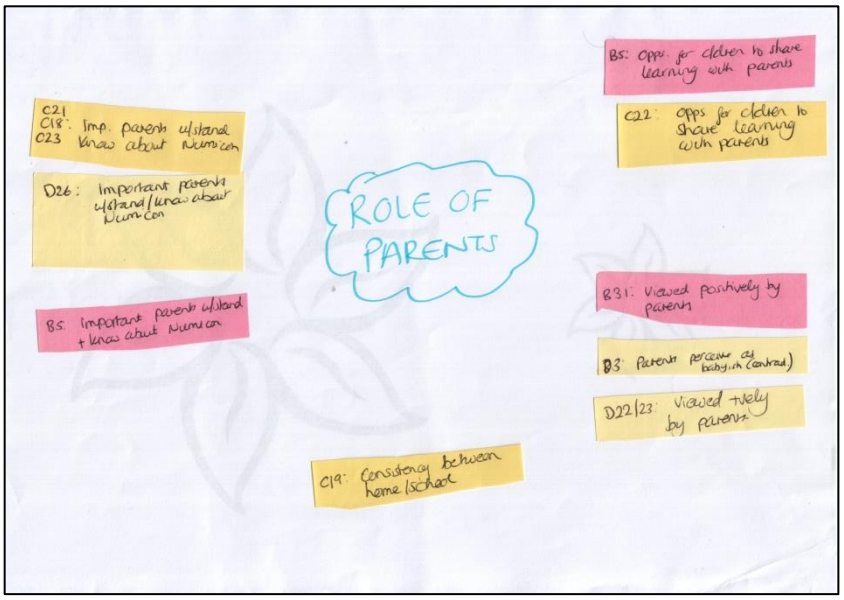
Appendix 27 The initial sorting of codes into candidate themes

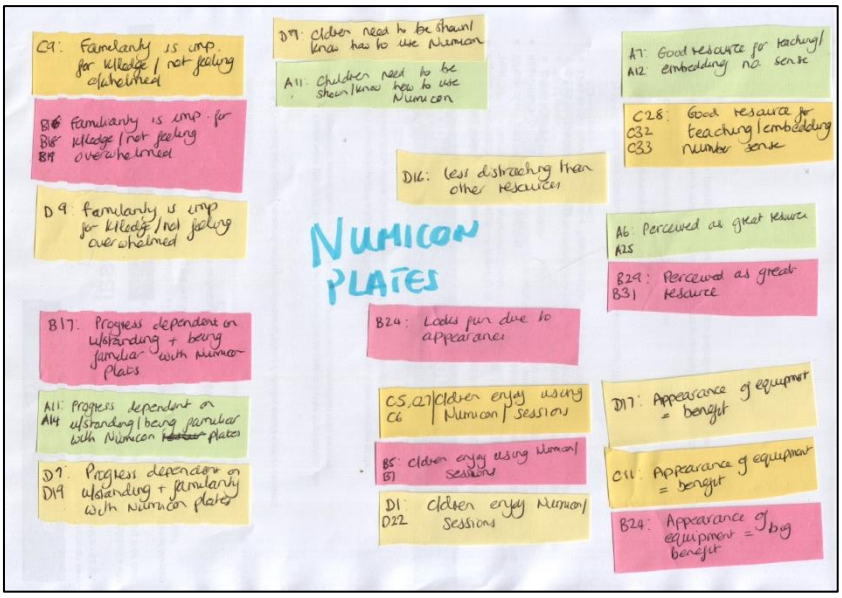


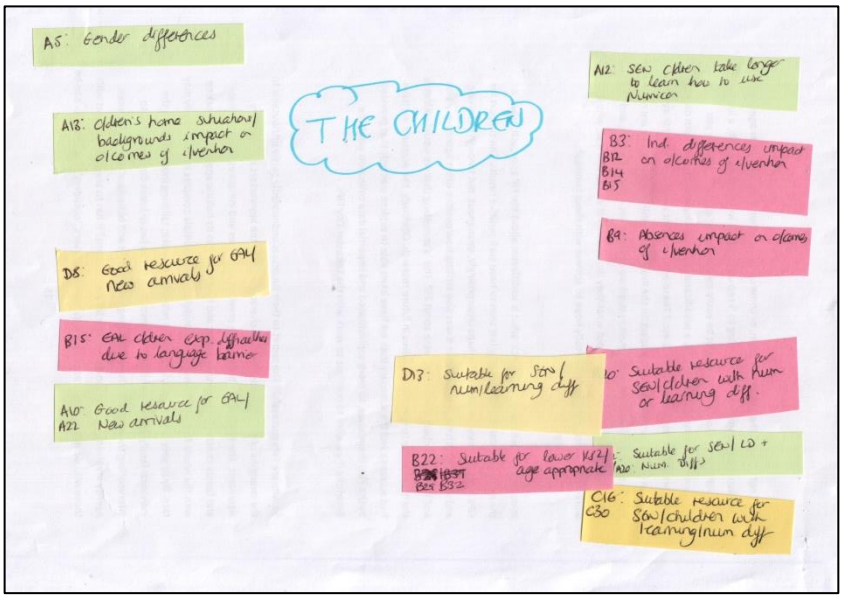


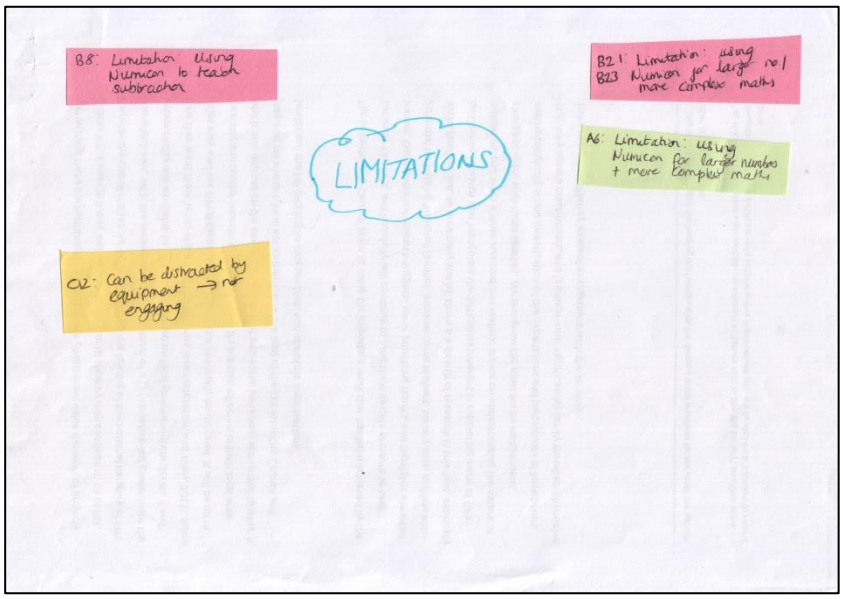


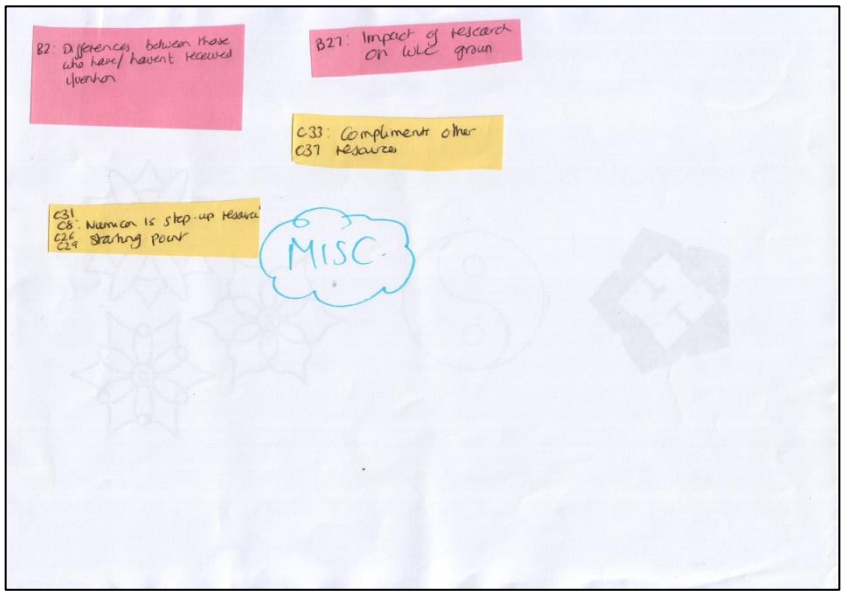

PRACTICALITIES
B6: Intervention needs to be consistent with regular sessions
D12: Intervention needs to be consistent with reg sessions
A18: -ve impact of special occasions/events
D11: -ve impact of special occasions/ events on delivering intervention
C25: Range of uses across curriculum
B23: Facilitator needs app knowledge
D14: Facilitator needs appropriate knowledge
B23: Facilitator needs to be confident at using Numicon
D1: Easy to implement/ D20 no barriers
B26: Easy to implement / no barrier
A16: Easy to implement/ A24 No barriers
C25: Easy to implement/ C38 no barriers
C36: Practical factors: Tidy/ easy to manage
C39
D15: Practical factors: Tidy + easy to manage


ROLE OF PARENTS
B5: Opps for children to share learning with parents
C22: Opps for children to share learning with parents
C21 C18: Imp. parents understand know about Numicon C23
D26: Important parents understand/know about Numicon
B5: Important parents understand + know about Numicon
B31: Viewed positively by parents
B3: Parents perceive as boring (contrast)
D22/23: Viewed truely by parents
C19: Consistency between home/school


NUMICON PLATES
C9: Familiarity is imp. for knowledge / not feeling overwhelmed
B6 B18 B19: Familiarity is imp for knowledge / not feeling overwhelmed
D9: Familiarity is imp for knowledge / not feeling overwhelmed
D9: Children need to be shown/know how to use Numicon
A11: Children need to be shown/know how to use Numicon
A7: Good resource for teaching/ A12 embedding no sense
C28: Good resource for C32 teaching/embedding C33 number sense
D16: less distracting than other resources
A6: Perceived as great resource A25
B29: Perceived as great resource B31
B24: Looks fun due to appearance
B17: Progress dependent on understanding + being familiar with Numicon plates
A11: Progress dependent on A14 understanding/being familiar with Numicon plates
D7: Progress dependent on D19 understanding + familiarity with Numicon plates
C5, C7 C6 Children enjoy using Numicon/ sessions
B5: Children enjoy using Numicon/ sessions B7
D1: Children enjoy Numicon/ D22 sessions
D17: Appearance of equipment = benefit
C11: Appearance of equipment = benefit
B24: Appearance of equipment = big benefit


A5: Gender differences
A18: Children's home situations/ backgrounds impact on outcomes of intervention
THE CHILDREN
A12: SEN children take longer to learn how to use Numicon
B3: Ind. differences impact B12 B14 B15 on outcomes of intervention
B9: Absences impact on outcomes of intervention
D8: Good resource for EAL/ new arrivals
B15: EAL children exp. difficulties due to language barrier
A10: Good resource for EAL/ A22 New arrivals
D13: Suitable for SEN/ num/learning diff
D10: Suitable resource for SEN/children with num or learning diff.
B22: Suitable for lower KS2/ age appropriate
B24 B27 B32
Suitable for SEN/ LD + Num. Diffs
C16: Suitable resource for C30 SEN/children with learning/num diff


B8: Limitation: Using Numicon to teach subtraction
LIMITATIONS
B21: Limitation: using B23 Numicon for large no/ more complex maths
A6: Limitation: using Numicon for larger numbers + more complex maths
C12: Can be distracted by equipment → not engaging


B2: Differences between those who have/ haven't received intervention
B27: Impact of research on WLC group
C33: Complement other C37 resources
C31 C8: Numicon is step-up resource C26 C29 Starting point
MISC.

Appendix 28 Grouping of codes into candidate themes

Theme	*Codes*
Affective factors	1. Intervention --> confidence in maths 2. Intervention --> positive attitude towards maths 3. More active participation
Understanding	1. Intervention develops/ embeds understanding of number sense 2. Enables children to talk about maths/ use mathematical language 3. Synergy between intervention and whole class/ previous learning 4. Visible/ quicker progress in numeracy 5. Familiarity/ confidence with Numicon equipment
Other	1. Facilitator pleased with outcomes
Whole school ethos	1. Intervention more successful if Numicon is used in whole class learning 2. School staff need to be 'on board' 3. Consistent and whole school approach 4. Whole school approach removes stigma 5. Numicon should be introduced at early age 6. Range of uses across curriculum
Practicalities	1. Easy to implement/ no barriers 2. Needs to be flexibility within school 3. Intervention needs to consistent with regular sessions 4. Facilitator needs appropriate knowledge 5. Facilitator needs to be confident 6. Resource is tidy and easy to manage 7. Negative impact of special occasions/ events on delivering intervention

Theme	*Codes*
Familiarity of Numicon equipment	1. Children need to be shown/ know how to use equipment 2. Familiarity is important for knowledge/ not feeling overwhelmed 3. Progress dependent on understanding/ being familiar with equipment
Impact of Numicon equipment	1. Appearance of equipment is benefit 2. Equipment looks fun 3. Less distracting than other resources 4. Good resource for teaching/ embedding number sense 5. Children enjoy using Numicon/ Sessions
The children	1. Gender differences 2. Good resource for EAL/ new arrivals 3. EAL children experience difficulties due to language barrier 4. Suitable resource for SEN and children with learning/ numeracy difficulties 5. SEN children take longer to learn how to use equipment 6. Absences impact on outcomes 7. Individual differences impact on outcomes 8. Home backgrounds impact on outcomes
Theoretical underpinnings	1. Enactive stage of learning a. Intervention is positive due to tactile/ 'hands on' element b. Physical manipulation of resources --> supporting children in remembering learning 2. Iconic stage of learning a. Intervention is positive due to visual element b. Visual element develops understanding of basic skills/ concepts

Theme	*Codes*
Theoretical underpinnings	3. Concrete - Representational - Abstract a. Practical/ concrete nature of resources --> making connections to other areas of learning b. Visual/ concrete nature of resources supports understanding of abstract concepts c. Visualisation enables children to move to pictorial stage of learning 4. Impact of overlearning a. Consolidation --> retention and progress b. Repetition --> retention and progress
Limitation	1. Using Numicon to teach subtraction 2. Using Numicon to teach larger numbers/ complex maths 3. Equipment can distract children --> not engaging
Role of parents	1. Important parents understand and know about Numicon 2. Opportunities for children to share learning with parents 3. Viewed positively by parents 4. Parents perceive Numicon as babyish 5. Consistency between home and school
Miscellaneous	1. Differences between those who have and have not received intervention 2. Numicon is step-up resource/ starting point 3. Compliments other resources 4. Impact of research on WLC group 5. Suitable for lower KS2/ age appropriate resource

Appendix 29 Codes and themes that were disregarded at stage 4 of TA

The following codes were disregarded as they only represented the views of one facilitator:

- Intervention --> positive attitude towards maths
- Consistency between home and school
- Whole school approach reduces stigma
- Facilitator needs to be confident at using Numicon
- Needs to be flexibility within school
- Less distracting than other resources
- Looks fun due to the appearance
- Visualisation enables children to move to pictorial stage

The following codes were disregarded as it was felt they were not relevant to the research questions:

- Facilitator pleased with outcomes
- Differences between those who have and have not participated in intervention
- Impact on WLC group of intervention
- Compliments other resources
- Numicon is step-up resource/ starting point
- Range of uses across the curriculum
- Perceived as great resource
- Suitable for lower KS2/ age appropriate resource

The ‘limitations’ theme was disregarded as two of these codes only represented the views of one facilitator and it was felt there was not enough codes remaining to generate a theme.

The ‘children’ theme, and all associated codes, were disregarded as it was felt it was not relevant to the research questions.

A new theme was identified: “Numicon Equipment”, with two subthemes:

1. Familiarity/ knowledge of equipment
2. Practical elements

Appendix 30 Inter-rater reliability for coding of data extracts

No.	Extract	Actual codes	TEP 1	TEP 2
1	*Facilitator:* The children more confident *Researcher:* ((in overlay)) Ahem *Facilitator:* With them with their maths number skills I thought they were aware I could see them growing *Facilitator:* Cos I did about eight children and overall definitely I could see a confidence in their *Researcher:* ((in overlay)) Yeah *Facilitator:* ((pause)) Number (.) skills and handling number	1 4	1	1 4 41? 3
2	*Facilitator:* Very hands on ((pause)) great for boys	12	12	12? 9 10
3	*Facilitator:* And to support them cos they're they're introduced to it (.) from quite early on *Researcher:* Yea so do they start are they introduced to it in like Foundation Stage *Facilitator:* ((in overlay)) Nursery	19	2 21	19 2?
4	*Researcher:* ...what are the positives of using Numicon *Facilitator:* Erm definitely the visualisation that it gives the children all of my group now are able to totally visualise all of the pieces they can explain to you what colour they are what they come before and after (.) so where we have been trying to push them to maybe move a bit more pictorially *Facilitator:* Erm they've actually been really confident with that	2 9 10 11	9 10 11	2 9 11

No.	Extract	Actual codes	TEP 1	TEP 2
5	*Facilitator:* ...and the positives just in general erm we had erm parents' evening last week *Facilitator:* And the way the children were able to talk to their parents we've changed the set up slightly *Researcher:* ((in overlap)) yes *Facilitator:* And we're really pushing the children to deliver the session themselves and talk about what they've been doing so we had the Numicon out and for the parents to actually understand (.) so many of them said "I've heard about Numicon, but we don't know what it is" so the kids were actually getting it out and getting their parents to build the staircase and (.) the kids just seemed to really enjoy using it	7 8 30 31	30 31	7 8? 30? 31
6	*Facilitator:* And it's concrete ((long pause)) the ones that it hasn't helped for is to having that first understanding of what to do with the Numicon cos when you just look at the box you're just like 'how does that add to that and how do I do it'	12 23 24	23	23 24? 25?
7	*Facilitator:* And it's also as erm the ten sessions we're on erm it complimented what we were doing in class lessons so we have done a few weeks of addition (.) and we've now moved onto subtraction	43	43	43
8	*Facilitator:* Last year I worked with some of the children in year five that maybe needed a little bit of extra support (.) and where their basic level wasn't as low as (.) kind of year two year three (.) it I felt like I wasn't confident enough to know where to go next with it ((pause)) but I think if you had that knowledge it would be useful cos you would just pitch it differently to the higher key stage two rather than the lowers	37 38	37 38	37 38

No.	Extract	Actual codes	TEP 1	TEP 2
9	*Facilitator:* But as a starting point (.) they feel really comfortable with it so it doesn't feel as daunting as it would introducing something new	25	7	25? 2?
10	*Facilitator:* Erm (.) as a school there is Numicon in every classroom so it's a very consistent approach it would be difficult perhaps if one teacher was using it and another wasn't and you were moving from year group to year group and it wasn't always there but as a school you know it's in every classroom and we use it regularly and it's on wall displays and (.) so (.) *Facilitator:* I guess it would be more difficult if that wasn't *Facilitator:* If it wasn't a whole school approach	18 20 21	21	21 22?
11	*Facilitator:* (.) So it's it's a great tool for them (.) visually to have and then just because you can ((pause)) move it physically with your hands it's easier for them to embed it in their memory ((laughter))	9 13	13 10 41 42	13 27? 28?
12	*Researcher:* Erm do you find things like actually (.) erm putting the ((pause)) intervention within school so things like getting the sessions in and all those kind of things are there any difficulties around that or does it work quite smoothly *Facilitator:* It works quite smoothly the only difficulty sometimes is when the class have got something else planned and they forget to tell you	29	35 36	29
13	*Facilitator:* So ((pause)) doing abstract maths (.) would be very very difficult for them this ((pause)) it really does enable them *Researcher:* ((in overlay)) Mm *Facilitator:* To start understanding concepts that would be very difficult	42	42 10 41	42 6?

Appendix 31 Inter-rater reliability for themes

Theme/ Subtheme	Actual Codes	TEP 1	TEP 2
Impact on affective factors: Participation in intervention has an impact on affective factors which influence approaches to learning numeracy	1 2	1 2	1 22
Impact on knowledge/ understanding: Participation in intervention improves children's knowledge and understanding of numeracy	3 4 5 6 7	3 4 5 6	3 4 6 2 21
Whole school ethos: A whole school approach, with Numicon embedded into the school curriculum, is a factor that impacts on the outcome of the intervention	8 9 10 11	8 9 10 11	8 9 10 11 5 13 14
Practicalities: Practical factors that are important elements of intervention	12 13 14 15 16	12 13 14 15 16	12 15 16
Familiarity/ knowledge of equipment: C/dren's familiarity/ knowledge of equipment impacts on outcomes	17 18 19	17 18 19 7 14	17 18 19 7
Practical elements: Features of Numicon equipment impact on outcomes	20 21 22	20 21 22	20
Enactive stage of learning: Numicon supports/ promotes learning at enactive stage	23 24	23 24	23 24 27
Iconic stage of learning: Numicon supports/ promotes learning at iconic stage	25 26	25 26	25 26
Relationship between concrete - representational and abstract learning: Visual/ concrete nature of Numicon promotes understanding at abstract level	27 28	27 28	28
Impact of overlearning: Numicon provides opportunities for consolidation and repetition which benefit learning	29 30	29 30	29 30
Role of parents: Important that parents are aware of Numicon and play a role in learning	31 32 33	31 32 33	31 32 33

Appendix 32 Debrief statements for parents/ carers





Debrief Statement for Parents/ Carers

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researcher: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
Kate Forder (Trainee Educational Psychologist and Researcher) at
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

The purpose of this debrief statement is to provide you with information regarding the next steps in the above research study. I would also like to take this opportunity to thank you for agreeing to let your child participate in the study.

As you'll probably be aware, children in group A have now completed the Numicon intervention. I hypothesised that participation in the Numicon intervention, would result in a positive impact in numeracy attainment and attitude towards numeracy for children in group A. In order to investigate this, children from both group A and B have completed assessments in numeracy and have also been asked about their attitudes towards numeracy. At the time they were advised what would happen to their data and verbally confirmed whether they were happy for their data to be shared with others. The next step is for these results to be analysed.

Once the analysis has been completed, the findings will be shared anonymously with other researchers, the Educational Psychology Service,

parents/ carers of children who participated in the study, the children themselves and schools within the local area. Your child's data, if you have previously agreed, will also be shared with the relevant staff at their school, enabling them to further support your child.

If you would like to withdraw your child from the study please contact me at the details above.

Children in group B began the Numicon intervention in January 2016. Although this does not form part of the research study, I will be contacting your child's school to ensure the intervention is being delivered. Your child's school will complete their own assessment to measure the impact of the Numicon intervention on your child's attainment and attitude towards numeracy, using similar measures to those used as part of the study.

If you have any further queries regarding the research, please don't hesitate to contact me, or my supervisor, at the details above.

Many thanks

Kate Forder (Trainee Educational Psychologist)

Appendix 33 Debrief statement for facilitators



The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Debrief Statement for Facilitators

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researchers: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
Kate Forder (Trainee Educational Psychologist and Researcher) at
Email: lpxkf1@nottingham.ac.uk
Tel: 01604 364770

Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

The purpose of this debrief statement is to provide you with information regarding the next steps in the above research study. I would also like to take this opportunity to thank you for agreeing to participate in the study.

I have spoken to you and other facilitators of the Numicon intervention in order to explore what factors impact upon the success of the Numicon intervention. The next step is now to analyse this information, in order to identify common factors and themes.

Once the analysis has been completed, the findings will be shared anonymously with other researchers, the Educational Psychology Service, parents/ carers of children who participated in the study, and schools within the local area. If you have raised any specific concerns, and have agreed to it, these will be discussed with the senior leadership team in your school.

If you would like to withdraw from the study please contact me at the details above.

If you have any further queries regarding the research, please don't hesitate to contact me, or my supervisor, at the details above.

Many thanks

Kate Forder (Trainee Educational Psychologist)

Appendix 34 Summary of research for schools



The University of Nottingham
UNITED KINGDOM • CHINA • MALAYSIA

NUMERACY RESEARCH STUDY

Summary of Research for schools

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researchers: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
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Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

I would like to take this opportunity again to thank you for participating in the above research. The research is now complete and so the purpose of this letter is to share with you the key findings from the study.

As you'll be aware, the purpose of the study was to investigate the following questions:

1. *Does participation in a Numicon-based intervention have a positive impact on the numeracy attainment of children in Year 3 experiencing mathematical difficulties?*
2. *Does participation in a Numicon-based intervention have a positive impact on the attitudes towards numeracy of children in Year 3 experiencing mathematical difficulties?*
3. *According to the facilitators of the Numicon-based intervention, what are the outcomes for the children who have participated in the intervention, and what factors impact on these outcomes?*

In order to assess the impact on numeracy attainment, the 'Sandwell Early Numeracy Test- Revised' was used. Based upon this measure, some children who participated in the Numicon-based intervention during the autumn term (experimental group) and some who did not (waiting-list control group), showed some improvements between September 2015 and December 2015 in their numeracy attainment. This suggests that the Numicon-based intervention did not have an impact on the children's numeracy attainment. It is important to note however that this only provides a snapshot of the children's performance and may have been influenced by other factors such as levels of tiredness or the child's mood on the day of assessment. Furthermore, there are some limitations with the measure:

- The measure is based upon the National Curriculum levels which were removed in September 2014. Over 50 per cent of the questions target level 2; therefore if a child is working at a level 1, the opportunities for them to progress are reduced. Interestingly only 36 per cent of the experimental group were working at a Level 2, whereas 70 per cent of the waiting-list control group were working at a Level 2.
- Previous research has found that Year 3 children, on average, make 1.2 sublevels progress in numeracy over the academic year, with approximately 50% making no progress, 35% making one sublevel progress, and 15% making two sublevels progress between the autumn and spring term (DfE, 2011[10]). Based upon this, one could argue that the children who participated in this study would be expected to make limited progress over the given time period of the study.

Children's attitudes towards numeracy were measured using the 'Maths and Me Survey'. Prior to the implementation of the Numicon-based intervention, many children already had positive attitudes towards numeracy in both groups. Therefore, the Numicon-intervention did not impact on the children's feelings towards numeracy.

Upon completion of the intervention, I interviewed the members of staff who had delivered it, in order to explore their views regarding what factors impacted on the outcomes of the intervention. The following points were raised:

- Participation in the intervention had a positive impact on the children's confidence, their willingness to join in during numeracy lessons, their use of language linked to numeracy, and their

[10] Department for Education: Education Standards Analysis and Research Division (2011b) *How do Pupils Progress Between Key Stages 2 and 3?* (DFE-RR096). London: Department for Education. Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/182413/DFE-RR096.pdf

understanding of basic number skills.

- Numicon needs to be embedded in the whole school curriculum. It needs to be used across the school, and introduced from an early age if the intervention is to be successful.
- It is important that a specific time is set aside for the intervention, and that staff who deliver the intervention are appropriately trained.
- If the intervention is to be successful, it is important that the children are taught how to use the Numicon equipment and are familiar with the resources.
- The intervention is successful because it is visual and tactile. By using the equipment, children begin to learn and remember basic number skills and develop an understanding of number sense. It also helps children to understand abstract number concepts.
- Taking part in the Numicon-based intervention enables the children to practise basic number skills, reinforcing and consolidation their understanding of basic number skills and number sense.
- Children enjoy using Numicon and think the Numicon-based intervention is fun.
- It is important that parents/ carers know about Numicon and understand why it is used in school to support their children's learning.
- The Numicon-based intervention was generally viewed as positive, some limitations that were identified however included using Numicon with older children (upper KS2) who are working below expectations, and using Numicon to teach more complex concepts such as working with larger numbers and subtraction.

I hope you are pleased with the outcomes of the study, and would once again like to thank you for your support. If you have any questions or would like to discuss the findings in more detail, please don't hesitate to contact me at the details above. Please also feel free to share these findings with school staff and Governors.

Kind regards

K. Forder
(Researcher and Trainee Educational Psychologist)

Appendix 35 Summary of research for parents/ carers

NUMERACY RESEARCH STUDY AT
«School»
Summary of Research for Parents/ Carers

A study to evaluate the impact of Numicon on the numeracy attainment and attitude towards numeracy of children in lower Key Stage 2 identified as experiencing difficulties in numeracy

Ethics Approval Number: 628
Researchers: Kate Forder
Supervisors: Dr. Sarah Atkinson

Contact Details:
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Dr Sarah Atkinson (Research Supervisor) at:
Email: s.atkinson@nottingham.ac.uk
Tel: 0115 8467238

I would like to take this opportunity again to thank you for agreeing to let your child take part in the above study. The research is now complete and so the purpose of this letter is to share with you the key findings from the study.

As you'll be aware children in the study were placed in either group A or group B. Group A received the Numicon-based intervention during the autumn term, and group B during the spring term.

At the start of the autumn term (September 2015) I met with all of the children who were taking part in the study to complete a numeracy assessment and a questionnaire about their views towards numeracy. I then completed the same assessment and questionnaire in December 2015.

The overall findings from the study were as followed:

- Some children in both groups A and B improved on the numeracy assessment between September 2015 and December 2015. This

suggests that the Numicon-based intervention did not have an impact on the numeracy assessment. Discussions with the members of staff who delivered the intervention however, suggest that the intervention did have an impact on the children's confidence, their willingness to join in during numeracy lessons, their use of language linked to numeracy, and their understanding of basic number skills.

- Many of the children already had positive attitudes towards numeracy before the study began. Therefore, the Numicon-intervention did not impact on the children's feelings towards numeracy.
- The members of staff who delivered the interventions identified the following things as being important:
    - Numicon needs to be used across the school, and introduced from an early age if the intervention is to be successful.
    - The Numicon-based intervention is successful because it is visual and tactile. By using the equipment, children begin to learn and remember basic number skills. It also helps children to understand difficult concepts about number.
    - Taking part in the Numicon-based intervention enables the children to practise basic number skills, and to reinforce their understanding of such skills.
    - Children enjoy using Numicon and think the Numicon-based intervention is fun.
    - It is important that parents/ carers know about Numicon and understand why it is used in school to support their children's learning.

Thank you once again for your support during this study. If you have any questions or would like to discuss the findings in more detail, please don't hesitate to contact me at the details above.

Kind regards

K. Forder
(Researcher and Trainee Educational Psychologist)