PGCE Primary Trainee Teachers' Perceptions and Accounts of Using Manipulatives When Teaching Mathematics on Placement

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Declaration

I, Syreeta Charles-Cole, declare that this thesis was composed by myself and the work contained herein is my own except where explicitly stated otherwise by reference or acknowledgement.

Anonymisation and Transcript Conventions

The transcripts presented in this thesis have been edited to preserve the anonymity and confidentiality of participants.

Transcript notation

…	talking prior to/or following the extract
(…)	material omitted
[*added*]	additional material
[laughter]	indicating non-verbal communication

Word count: 44,929 (excluding abstract, reflective and impact statements, references and appendices)

Abstract

Primary Postgraduate Certificate of Education (PGCE) teacher training courses are intense programmes of study that provide opportunities for trainees to develop and employ the more experiential aspects of classroom teaching such as making use of manipulatives. Manipulatives are tactile objects that can enrich instruction when handled. While there is a large body of complementary mathematical literature endorsing the use of manipulatives, some evidence exists within the literature that manipulatives are not used as effectively or as extensively as they could be. Little is known about how trainees conceive, use and apply manipulatives in the classroom.

In response, this study explored eight primary PGCE trainee teachers' experiences of using mathematical manipulatives as they develop their professional learning during placement. A mix of methods (survey, interviews and video recordings) was used over the course of one academic year. In order to understand the participants' lived experiences, interviews were analysed using Interpretative Phenomenological Analysis (IPA).

Overall, findings indicated a silent set of institutional rules at play as to how manipulatives are selected, introduced and utilised, reinforcing habitual practices such as assigning manipulatives solely to the pupils classified as requiring further support. Study data also revealed the sensory experiences of the manipulative were used as a 'lifebuoy' to bridge the social gap caused by grouping by ability. Significantly, this study revealed that although trainees are novices, they appeared to be expected to cope and navigate difficulties with mathematics teaching in isolation. Participants reported that they drew on support for manipulative use from learning theories, textbooks and their own experiences. Mismatches existed between perceptions and accounts of use, and although manipulatives have many affordances, it was taken for granted the manipulatives and the associated language assigned would be universally understood.

This thesis concluded inquiry-based practices could help trainees challenge their traditional view of mathematics teaching and how manipulatives are assigned and used in the classroom. A balance has to be found between providing enough support

to nurture trainees in becoming autonomous professionals and setting policies that prescribe practices.

Impact Statement

The insights presented offer a greater understanding of how and why trainees use mathematical manipulatives as they develop their professional learning during placement. A summary of the key findings will be presented to the University where I am employed. The findings will contribute to the mathematics module of study as well as the professional and partnership components. More specifically, the data analysis will, hopefully, be used to find solutions to existing problems. At present there are two courses. Students are recruited based on qualification on one course and experience the other. There is a need to understand the challenges both camps face when embarking on teacher training. Consequently, this study can offer the starting point for change in course validation documents, programme material, as well as recruitment.

This thesis has broadened my understanding of the many challenges trainees face during placement and the implications for professional practice. Without a community of collaboration, trainees are isolated and cultural norms reinforced. I expect this research will encourage mentors to support trainees to move beyond routine practices and make use of the practicum to develop and employ the more experiential aspects of classroom learning. A balance has to be found between providing enough support to nurture trainees in becoming autonomous professionals and setting policies that prescribe practices.

I foresee this study will continue to assist in the production of creative, enthusiastic, innovative, qualified mathematics teachers that are willing to engage in liberatory practice, taking professionalism further. There are potential benefits in terms of attainment and personal communal wellbeing regionally, nationally or internationally should this research promote widened participation and shared decision-making. As a result, this study offers many benefits outside of academia and can contribute to social enterprise, professional practice and policy design. My long-term aim is to develop professional development cluster groups within the region. The experiential workshops can contribute to the drafting and publication of quality school-based action research relating to the ongoing developments of inquiry-based mathematics. As

research and scholarly activity remains an essential feature of university faculties, results can be published in educational journals, websites and conferences.

Interpretative Phenomenological Analysis (IPA) is a recently developed investigative methodology that originates in the field of psychology. However, it is now increasingly utilised within a range of disciplines that examine human and cognitive sciences. The use of story boxes as a way of reporting research results could potentially inspire future researchers to consider a similar format and make greater use of video recordings as a reflective tool. Studies that are written in an accessible style, may encourage audiences who are not used to reading research papers such as trainee teachers to access and engage in research about people similar to themselves, targeting a broader audience.

I consciously chose this study as it created a space to reflect, learn and make sense of my professional identity. The aim of a professional doctorate is for students to become creative, critical, autonomous researchers. As an active member of external professional bodies relating to mathematics, this study will enable me to publish publications, confidently contribute to policy, national debates and create further opportunities for cross-faculty development.

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Reflective Statement

I started the Doctorate in Education (EdD) programme of study in a quest to better understand secondary pupils' views of mathematics. Some of the pupils I taught held a negative view of mathematics and did not share my passion for the subject. This knowledge fuelled a personal desire to adapt teaching to suit their needs. At the time, I wanted to formulate a solution to what I recognised as a complex problem. I expected research, coupled with the practicalities of working with pupils, would enhance my professional knowledge and expertise in the field of mathematics education. I was, however, unprepared for how much the programme of study would transform my understanding of self (metacognition).

The day before the very first taught session, I recall a restless night of tossing and turning. I was sick with fear and self-doubt. I did not feel worthy of my place on the course, and I felt entirely out my depth. Although many members of my family are successful teachers and headteachers, I was the first to enrol on to a doctoral course. I suspected the course would be filled with exceedingly intellectual beings of a completely different world and class to me. I soon learnt my prejudices were ill-founded, and I had taken the first steps on to a beautiful new path where my life significantly changed, and new longstanding friendships took root and bloomed. The introductory session centred around the sharing of individual and unique stories; via these narratives, we commenced the process of building a community of practice (hooks, 2003). The stories provided the framework for contextual awareness (hooks, 2003).

Following a critical incident, my study evolved slightly from the initial proposed project of researching secondary pupils' views of mathematics. Inspired by the taught sessions relating to professionalism, I applied for an academic position at a university. I consciously chose to become an academic because it was the profession that allowed me to make sense of my reality and the world around me (hooks, 1994). I was also keen to appraise the role of a teacher from as many lenses as possible. It was

during the interview, I came to understand while I had gained a lot of experience in teaching, I knew very little about the field of mathematics education, including the range of manipulatives available.

Shortly afterwards, I undertook my first assignment Foundations of Professionalism (FoP) in Education. This module provided the perfect antidote to my episodic self-doubt. To construct a conclusive paradigm of the teacher as a professional, I initially reflected upon my childhood experiences beyond the constraints of my current perspective. I appraised the concept of the teaching profession through multiple lenses, drawing on critical professional incidents, and my ideological assumptions to better understand the context of professionalism. As I reflected on my own complex issue of professional identity, a desire to belong featured consistently (Kwhali, 2017). I came to understand the many informal learning opportunities my role had to offer (Cunningham, Andrews and Ball, 2008).

During the taught sessions, I was actively encouraged to develop my understanding of a range of philosophical perspectives surrounding the broader aims of education. The EdD group comprised of predominantly international students. I was fortunate enough to consider education from a global perspective, further refining my epistemological and to some extent, ontological ideologies.

I also critically examined my professional values as a teacher through the lens of compliance performativity and standards. This practice of introspection led me to the conclusion that my concept of professionalism is somewhat shaped by my holistic experiences of education in general. Through the process of reflexivity, I was able to locate myself in the picture of teacher professionalism and critically examine my limitations, while simultaneously appreciating how my practice and behaviour influences organisational practice (Cunningham, Andrews and Ball, 2008).

The FoP module proved an interesting, nonetheless challenging start to the EdD journey. During the discussions, I learnt the distinction between ‘reflection and reflexivity’ as well as ‘equality and equity.’ The context of ‘professionalism’ as a field of inquiry was relatively new to me. Still, it provided the perfect platform for me to engage with the process of academic writing following a four-year hiatus. I experienced a range of organisational issues. Academic reading and writing proved

problematic for me. At the time, I was unfamiliar with the subject matter and made the error of attempting to read everything. It was necessary to develop the self-discipline to read objectively, with a focal point in mind, creating a conceptual framework. Upon reflection, this was probably one of the most valuable lessons I have learnt from the EdD. I attended several writing workshops at the Institute of Education (IOE). The doctoral writing workshops supported me to overcome some of the angst I had with self-confidence and accept that I could contribute positively to sessions.

I approached Methods of Enquiry 1 (MOE1) with slightly more confidence. This module presented the possibility for participants to engage with a broader range of literature and identify a research topic. Students can explore political, ethical, and legal issues in educational research for the first time, as well as a range of methodological approaches when conducting and disseminating studies.

I enjoyed my sessions, particularly, the 'Theorising Key Concepts' debate. During this seminar, we were encouraged to develop our understanding of a range of philosophical perspectives through discussions surrounding the wider aims of education. I identified my epistemological and ontological positioning. The pragmatic view resonated with me where no single reality exists, and knowledge is constructed based upon the world that we live within (Robson, 2011). Therefore, theory can influence practice. I also embraced an interpretivist paradigm as an understanding of reality is grounded upon our experiences. This module assisted me in developing the confidence to present my research paradigm, while facilitating the opportunities to make use of a range of 'newly acquired' terminology.

During the Methods of Enquiry 2 (MOE2) module we engaged in the practical aspect of research and experienced the pitfalls. For the first time I managed to successfully design an online attitudes survey, a semi-structured interview and submit an application for ethical approval. As a consequence, my proposed study evolved considerably, and became much more focused and child-centred. It was during this time, I felt the familiar tug of the heartstrings, drawing me back to the primary classroom.

Shortly afterwards, I successfully gained a new class-based role for six months to gain a deeper understanding of the culture surrounding the use of manipulatives, and provide the foundation for future studies. Interwoven through this process, the methodological aspect of my research altered to an ethnographic focus. The aim was for the study to act as clarification of the phenomena, thus providing a rich description of the pupils' experiences. I completed a pilot study and used my key findings to develop a proposal for the Institution Focused Study (IFS). The extremely well-presented taught sessions, supervision meetings and the well-thought-out submissions exemplified the possibilities of linking the different stages of the EdD programme. Before these sessions, I struggled to visualise my journey through the EdD. The taught sessions were instrumental in providing a clear path for forthcoming studies.

Having completed the portfolio of assignments I then embarked on the IFS. The taught sessions were less frequent, and I transitioned to working more closely with my supervisors. My conceptual framework started to take shape. I knew I was interested in pupils' experiences of using manipulatives but had not decided the age group. My transition further refined my focus to the experiences of year 6 pupils as they also made their transition to secondary school.

The United Nations Convention on the Rights of the Child ([UNCRC], 2010) Article 13 endorses the right for all pupils to share their views relating to matters that affect them, yet it is debatable if researchers can truly represent that voice. I, therefore, adapted my study to be framed as an inductive, exploratory study design, involving mixed methodological approaches to triangulate the research subject. The aim was to derive a range of data sources to construct a detailed picture of the pupils' views. It was anticipated the aforementioned strategy could overcome the biases associated with using a single method and enhance the credibility of the study's findings.

The small-scale study significantly contributed to my professional knowledge and understanding of the range of manipulatives available and divergent ways of using manipulatives. One of the positive consequences of completing the IFS is the findings provided a natural focal point for the thesis. I had gained sufficient knowledge of the pupils' experiences of using manipulatives to warrant a shift of focus to teachers. My

desire was to build a holistic understanding of how manipulatives were used in schools. Once again, I transitioned from employment in schools to higher education.

During the completion of the IFS I noted some limitations. There was a risk in the very conceptualisation of aiming to capture the undifferentiated 'voice of the child' that I had glossed over the diversity of pupils' experiences, in particular cultural divergences. I found that far from providing pupils with greater audibility and visibility as social actors inhabiting a variety of different social worlds, I may have inadvertently disempowered their voice (Allison, 2007). As a consequence of my reflections, I decided it was important to me that when capturing teachers' perceptions, there should be a robust idiographic focus on individuals' experiences. I also joined the IOE Mathematics Education Special Interest Group. The seminars provided an invaluable opportunity to develop up-to-date subject knowledge within the field of mathematics and challenge my ideologies and orthodoxies further.

As I worked closely with postgraduate trainee teachers, I was keen to learn about their experiences of using manipulatives to better facilitate their learning. My own professional journey suggested we make sense of the world via stories and use the same medium to share our understanding with others. I therefore decided I would make use of interviews to capture experiences. Narratives can impose structure to the chaos of everyday situations (Gottschall, 2013).

One of the benefits of using IPA methodology is the researcher is analysing others while at the same time analysing themselves. I was ill prepared for the impact of how much I would learn about myself. During an interview, a trainee shared their very personal and painful story of how they came to love mathematics and teaching. It was only after I had listened to the transcripts and began the process of peeling back my own layers (bracketing) that I became aware of my own painful journey into teaching. My family and I have always been passionate about teaching, but I had never completely understood the root cause. The discussion with the trainee triggered childhood memories of my uncle whose life was taken at school at the tender age of fourteen.

A new level of self-awareness emerged. I have always considered the vocation of teaching to be a facilitative role where one has to listen intently to the learner's voice in order to guide. That hidden insight is contained within the word vocation itself as it is rooted in the Latin for voice. Vocation to me does not mean a goal I pursue, it implies a calling I must hear (Waddock, 2015). Engaging in this study and working closely with supportive supervisors has provided a space for reflexivity and supported me to find my own voice.

Looking back, I wish I had taken advantage of the many opportunities available to present my research to wider audiences. While I have gathered experience in presenting primary mathematics teaching to both large and small cohorts, I still remain fearful of presenting my research for the reasons outlined at the start. This is a skill I hope to refine in the future. I also intend to enhance my understanding of the use manipulatives internationally.

In summary, I have really enjoyed my studies so far at the IOE. I am incredibly grateful for the opportunity and remain indebted to all who have nurtured my journey.

Word count: 1998

Acronyms and Initialism

BERA:	British Educational Research Association
COVID-19	Corona Virus Disease 2019
DES:	Department of Education and Science and the Welsh Office
DfE:	Department for Education
GCSE:	General Certificate of Secondary Education
GDPR:	General Data Protection Regulation
EBSCO:	Elton B. Stephens Co., Information Services
EdD:	Doctorate in Education
ERIC:	Education Resources Information Centre
FoP	Foundations of Professionalism
IFS:	Institution-Focused Study
IOE:	Institute of Education
IPA:	Interpretative Phenomenological Analysis
ITE:	Initial Teacher Education
ITT:	Initial Teacher Training
JSTOR:	Journal Storage Digital Library
KS:	Key Stage
OECD:	The Organisation for Economic Co-operation and Development
Ofsted:	The Office for Standards in Education
PGCE:	Postgraduate Certificate of Education
PISA:	Programme for International Student Assessment
SEND:	Special Educational Needs and Disability
TA:	Teaching Assistant
UCL:	University College London
UK:	United Kingdom
UNCRC:	United Nations Convention on the Rights of the Child

Chapter 1: Introduction

1.1 **Overview**

This Chapter offers a brief overview of the thesis. It also provides the background and scope, as well as present the rationale for the research, including the decision to adopt an IPA approach. This study examined eight primary Postgraduate Certificate in Education (PGCE) trainee teachers' perceptions towards using mathematical manipulatives as they develop their professional learning during placement. A further aim was to examine if a disconnect existed between perceptions and the use of manipulatives.

The terms trainee, novice teacher, pre-service teacher, prospective teacher are used within the literature to describe a person who is new to, and inexperienced in a job or situation of teaching (Armador, 2017; Dayan, Perveen and Khan, 2018). They can be at various stages on the journey to becoming qualified. I will be using 'trainee' because it is the most frequently used expression in research and policy relating to the primary stage in the U.K. Primary education is typically the first formal stage of education.

For the purpose of this review, mathematical manipulatives are tactile resources that can enrich instruction. Teaching involving the use of manipulatives is not new, and a solid research base exists endorsing their use (Bruner, 1960; Montessori,1912/1989; Skemp, 1987; Vygotsky et al., 1978). Ideally, 'good' manipulatives are widely accepted as entertaining tactile objects that support the symbolic representation of abstract concepts, providing a conceptual framework for social collaboration and discussion. They are based on conventional techniques of using physical objects such as your fingers, stones and shells which have now been complemented with more specific mathematical forms such as interlocking cubes and fraction tiles. Although manipulatives can be handmade and produced relatively easily by teachers from paper or card (an assortment of materials), they are not worksheets diagrams or static representations that cannot be manoeuvred.

Figure 1: Numicon

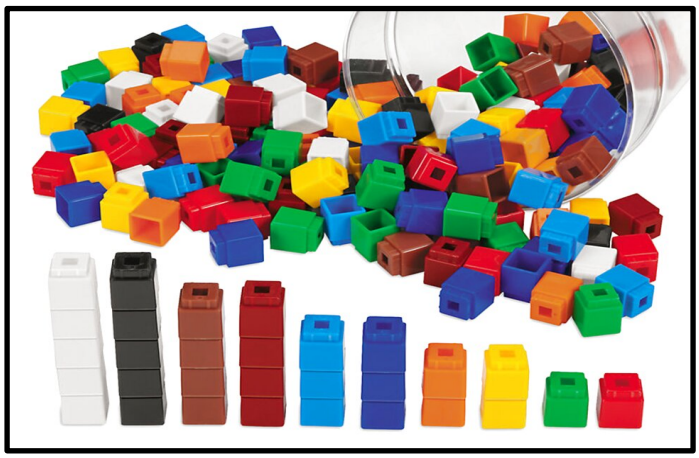


Figure 2: Unifix Cubes

Examples range from everyday objects such as cotton reels, buttons, straws or coins to objects that are specifically designed for use in mathematics lessons such as base-ten blocks, Numicon and Unifix cubes. At a simple level, items such as counters, straws and beads can be used to develop a sense of number to support understanding of basic arithmetic functions like addition and subtraction or multiplication and division. Manipulatives can also be utilised for more complex functions such as the use of

algebra tiles to model and solve an equation. Virtual manipulatives are a relatively new computer-generated version based on the physical kind. In primary school, concrete manipulatives are commonly used to illustrate and examine mathematical concepts; however, by the time pupils reach secondary school, the use of concrete manipulatives appears to give way to virtual and computer-based tools. Nevertheless, manipulatives are suitable for all learners and can be used with whole classes or individually. A comprehensive review of the term 'manipulative' is provided further on in Chapter 2.

1.2 **Introduction to the Research Topic**

The rapid technological changes that have taken place since the early twenty-first century have necessitated that learners acquire different and diverse skills to those required in previous generations. The Organisation for Economic Co-operation and Development ([OECD], 2019) has identified critical thinking, problem-solving, self-efficacy as well as the ability to work independently and collaboratively as the kind of skills that translate into success in current times. In a continually evolving world filled with increasing challenges, teachers have been tasked with the responsibility to prepare learners to live and work in a world where they will encounter a range of complex problems regularly.

The Department for Education (DfE, 2018) recently announced several funding provisions to increase the quantity and quality of mathematics specialist trainee teachers at the primary level. This includes teacher training bursaries of up to £6,000 for eligible candidates and an increase of £41 million in funding to enhance the teaching of primary mathematics (DfE, 2016). It is anticipated measures such as these will attract high-quality graduates into the teaching profession.

Yet, PGCE teacher training courses are short, intense programmes of study. They are designed to provide graduates with the correct balance of up-to-date theoretical study with significant school placement, enabling prospective teachers to embark successfully on the journey into their new-found teaching career. It can prove extremely challenging for trainee teachers to develop substantive knowledge, skills

and proficiency over one year, particularly while navigating the changing landscape of mathematics education. Despite the deployment of initiatives with vast funding reserves, together with the best efforts of university staff, research and personal experience indicate that routine practices exist that suppress opportunity for pedagogic innovation (Van Zoest and Bohl, 2002; Towers, 2010; Nolan, 2011). It can be challenging for trainee teachers to move beyond routine practices. My experiences have found there is a tendency for trainees to stick with what they are familiar with from their own learning during placement. Prospective teachers tend to deliver mathematics lessons as a sequence of facts and rules that are acquired in a particular order. However, mathematics, for me is the study of possibilities, and the freedom to explore outcomes.

Current educational practices related to the theory of how pupils learn mathematics such as 'concrete to abstract' posit that understanding is enhanced by connections between multiple representations of mathematical concepts (Clements, 1999; Post, 1981). These practices are based on established theoretical support for the use of manipulatives which date back to Dewey (1916) and other educational theorists such as Piaget (1952), Bruner (1966), Skemp (1977) and Papert (1993) who endorse the view that pupils learn best through hands-on approaches. The perception that manipulatives enhance the learning of mathematics has gained much validity from these learning theories. According to theorists such as Piaget (1952), pupils do not enter the world with the capacity for abstract thought intact, but rather must create abstract ideas through interactions with objects and their environment. Manipulatives provide such an opportunity and can bridge the gap between the concrete and abstract.

Nonetheless, merely exposing learners to manipulatives does not guarantee that learning will happen (Furman, 2017). Learners are required to draw together sensory input with prior experience. Interactions with, and connections between the pupils' mental models, their production of external representations and their talk during mathematical learning are perceived as fundamental to effective learning (Gifford and Thouless, 2016; Post, 1981). A comprehensive review of the theory I shall be using for this thesis is provided further on in Chapter 2.

Turning to teachers' perceptions of manipulatives, Askew's (1997) report exploring the knowledge, beliefs and practices of effective teachers of numeracy affirms the discovery orientation teacher holds the perception pupils must gain extensive use of practical experiences that are seen as embodying mathematical ideas. The discovery orientation teacher deems practical experiences present opportunities for pupils to notice methods themselves. The report also details how this type of effective teacher endorses learning about mathematical concepts precedes the ability to apply concepts.

An Office for Standards in Education publication ([Ofsted] 2012) which examined teachers' practices with mathematical manipulatives found too few schools used practical resources well to aid the teaching of mathematics. The study found that the quality of teaching varied considerably within schools and teachers typically adopted didactic approaches, demonstrating a standard method, rule or mnemonic to aid concepts being committed to memory (Ofsted, 2012). The report also highlighted inequalities in pupils' experiences of learning mathematics with manipulatives often reserved as a teaching intervention to support the lowest-performing pupils.

Yet, the National Curriculum in England (DfE, 2013) requires learners to "*move fluently between representations of mathematical ideas*." However, little guidance is available to educators with regard to how they can achieve this aim. Although the U.K. Government advocates the use of manipulatives, the National Curriculum in England (DfE, 2013) only stipulates the use of 'concrete objects' for Key Stage One (pupils aged five to seven years old). The use of manipulatives was also prohibited in the recent 2019 national tests giving mixed messages with regards to the suitability for pupils over the age of seven. Therefore, official guidance offers mixed messages about the desirability of the use of manipulatives, particularly for pupils aged over seven (Griffiths, Back and Gifford, 2017).

Research by Lesh, Post and Behr (1987); Moyer and Jones (1998) found manipulatives are often discarded when practitioners are unfamiliar with how best to use them or are fearful of losing control. It can be challenging for practitioners to adequately assess knowledge when manipulatives are used, especially when the pupils are better acquainted with the resources than they are. The ongoing problem of

selection (since 1970's) is made more difficult as it has become increasingly challenging to list all materials available and discuss the merits and disadvantage of each (Reys, 1971). Brown's (2014) study has revealed a sharp decline in the use of manipulatives in recent years, particularly during the latter stages of primary school possibly due to the advent of interactive whiteboards.

Sherin's et al. (2004) research also found the attitude of the teacher can contribute to the decline in use, should the teacher fail to acknowledge the value. Moyer's (2001) study determined that should the teacher perceive manipulatives as not necessary, or simply a diversion in the classroom, then students will fail to acknowledge the value. Thus, without considering teachers' perceptions about manipulatives and their effects on learning, the use of manipulatives in classrooms could fail to promote constructive learning (Golafshani, 2013).

Moreover, Suurtamm's (2007) study identified the gradual decline in manipulative use could be attributed to a lack of training. This investigation highlighted classroom practitioners might require some ongoing instruction in the use and application of resources. A recent survey by The Teacher Development Trust (2014) found that just over half of schools are now struggling to provide adequate professional development opportunities due to funding pressures. This can result in professional development opportunities relating to the use of new materials reserved solely for 'experts' or teaching professionals who are identified as struggling and requiring support, resulting in a self-perpetuating cycle.

Nevertheless, the decline in resources could be justified. As pupils progress through school, they become less reliant upon tactile methods of representation (McNeil and Jarvin, 2007). It is widely accepted in the teaching profession mathematics should proceed from the concrete to the abstract (Sarama and Clements, 2016). Yet, to develop mathematical knowledge, there is a need to provide experiences of actual problem-solving situations which is why manipulatives are still very much required. Furthermore, an unreflective application can lead to missed important nuances. This is not a new concern. Dewey (1933) is cited,

> *“The maxim enjoined upon teachers, 'proceed from the concrete to the abstract' is familiar rather than wholly intelligible. Few who read and hear it gain a clear conception of the starting point, the concrete; of the nature of the goal, the abstract; and of the exact nature of the path to be traversed in going from one to the other. At times the injunction is positively misunderstood, being taken to mean that education should advance from things to thought as if any dealings with things in which thinking is not involved could possibly be educative. So understood, the maxim encourages mechanical routine or sensuous excitation at one end of the education scale – the lower – and academic and unapplied learning at the upper end” (1933:220).*

Over the past sixty years, a substantial rise has taken place in the range of manipulatives available to schools which can make their selection more complex. Schools are bombarded with a wide variety of manipulatives and are often pressured to adopt the latest models through the process of endorsement via the newest media campaign (Griffiths, Back and Gifford, 2017). The head of the department usually manages selection. I held this department position for many years. I was responsible for the management and implementation of mathematical resources. Against my better judgement, I often felt hard-pressed by senior leadership to adopt the latest mass-produced initiative endorsed by the local education authority. I felt such decisions should be made in consultation with the teachers and pupils who would be making use of the manipulatives.

In my experience, manipulatives have an efficacious history of use. With sufficient training, these resources can be used to enable all to appreciate the enjoyable aesthetic aims of mathematics in a collaborative context that can bridge cultural and inclusivity barriers. The above suggestions require further investigation in order to develop a thorough understanding of the situation. As a consequence, there is a need for research that provides further details as to how trainees perceive and account for using manipulatives in primary classrooms.

1.3 **Professional Biography**

I write here from the perspective of a teacher with many years of experience. While my interest in this study started as an exercise to find solutions to a professional issue, it has evolved into a theoretical problem. The professional problem first arose while I was working as a teacher attempting to engage year six pupils in their mathematics lessons. In my quest to find a workable solution, I participated in a research project involving the creative use of a range of manipulatives, to reason and solve problems. Nurturing Mathematical Promise (2008) focused on empowering teachers with the confidence to develop a repertoire of effective strategies via enjoyable experimental activities making use of a wide range of tangible resources. It was fascinating to watch the pupils using equipment such as Lego and Dienes blocks to solve problems involving symbolic algebraic equations. What struck me is how much the pupils enjoyed their lessons when provided access to a wide range of tactile manipulatives, and the autonomy of choice. Yet, this inquiry-based pedagogic approach proved almost impossible for me to embed within my classroom. Every opportunity presented was stifled, due to the conflicting silent set of rules of the school. The silent set of rules are unspoken expectations which are considered disruptive to the ethos of the school. I struggled to maintain a sense of professional autonomy, producing a real atychiphobia (persistent fear of failing) due to the perpetual shifts to the boundaries of excellence associated with the teaching and learning of mathematics. This inspired me to explore contexts where teachers are encouraged to experiment.

Within my next role as a senior lecturer, researcher and link advisor, I was confronted with another unsolved professional issue. While on campus, trainee teachers seemed to relish the opportunities presented to explore and utilise a range of tactile manipulatives to enhance their repertoire of teaching and learning strategies. Yet, during placement, trainee teachers appeared to experience a crisis of confidence when efforts were made to transgress, experiment and develop their own professional learning with manipulatives. Initially creative, enthusiastic voices increasingly quietened as they became consumed by the specified content and grading systems. Trainees appeared to struggle to maintain a sense of professional autonomy,

developing a real fear of failure due to perpetual shifts in the grading boundaries of excellence. This is a similar experience to my own struggle (mentioned above). This inspired me to explore contexts where teachers are encouraged to experiment.

1.4 **Summary**

Few studies have been conducted into the ‘interchange’ between trainee teachers’ perceptions and accounts of the use of mathematical manipulatives. Trainees' perceptions towards manipulatives can be an important indicator of expected performance, attainment and achievement. There is considerable scope to investigate PGCE trainees’ perceptions and use of mathematical manipulatives during placement. Understanding trainee teachers’ perceptions and use of manipulatives could enhance previous work in this area and facilitate meaningful discussion surrounding initial teacher training programmes, particularly within the postgraduate sector. A balance has to be conceptualised between providing enough support to nurturing trainees into becoming autonomous professionals responsible for developing and delivering mathematics curriculum and setting policies that prescribe practices. I have chosen to focus on the trainees’ perceptions to pinpoint how this formation of mathematics manifests itself in their evolving practices as they become qualified. As this study sought to gain personal insights and accounts, a qualitative approach that focused on individuals’ experiences was required. IPA aims to explore in detail how participants make sense of their personal and social world.

This Chapter 1 has provided the backdrop for the thesis and discusses the importance of research that affirms the voice of trainee teachers, their perceptions, and accounts of the use of mathematical manipulatives during placement. Chapter 2 follows with a critical review of relevant literature and concludes with the research questions. Thereafter, Chapter 3 provides a detailed account of the methodological approach and data collection instruments employed in this study to capture the trainees’ lived experiences. Next, Chapter 4 consists of demographical data and story boxes that contextualise the participants' perceptions, and accounts of using manipulatives during the practicum. Chapter 5 presents a concise summary of the overarching

master themes found relating to the aims and two research questions illustrated by verbatim extracts. These findings are then synthesised into the discussion contained in Chapter 6. The discussion interprets and describes the significance of the findings in light of what is already known about trainees' perceptions and accounts of manipulative use. New insights that emerged as a result of this study are also accentuated. Finally, the thesis concludes with Chapter 7, which presents the new knowledge that has emerged from this study along with recommendations for future research.

Chapter 2: Literature Review

2.1 **Introduction**

This Chapter reviews relevant literature relating to the two main concepts that underpin this thesis: mathematical manipulatives and trainee teachers' perceptions. This is not an extensive review of the literature; rather, contributions have been presented according to relevance, and to develop a picture of the current state of research in these particular areas. As I will outline in Chapter 3, Interpretative Phenomenological Analysis (IPA) can take the researcher into new and unanticipated territory. The focus on participants' 'lived experience' requires the researcher to interpret that experience within a wider context. Some additional literature is discussed in Chapter 6 to frame new angles that emerged from analysis.

I begin by exploring existing definitions of the term 'mathematical manipulative.' Then, a critical discussion of the historical and theoretical basis in support of manipulative use is offered. Following this, a detailed analysis takes place of studies that examine the use of manipulatives in schools, and I highlight some of the main causes identified as affecting use. The remainder of the Chapter explores the significance of teachers' perceptions. Several crucial factors are identified as influencing perceptions and the outcomes of primary trainees' instructional practices. Conclusions regarding the literature review will be then summarised, leading on to a discussion of how this study builds on the existing literature base. Finally, the research aims, and questions are presented.

2.2 **Literature Review Search Strategy**

A wide-ranging search strategy was employed to access current, relevant and creditable sources. Major educational search engines were accessed including ERIC, British Education Index, EBSCO, and JSTOR drawing on articles and books. The

majority of the papers and books were from Canada, the U.S.A., Australia or U.K. and preference was given to those 50 years or less. At first, I searched for the word string '*trainee'* and *'concrete' a*nd '*mathematical manipulatives,'* which generated a limited result (155). I reviewed all 155 sources and found while some were relevant, many were related to the development of specialist knowledge in mathematics and mathematical competency in the U.S.A. rather than focused specifically on manipulative use. I wanted to examine the foundations of manipulative use in primary schools. This term '*practical mathematical manipulatives'* was then adapted in the hope of locating sources that focused explicitly on the use of tactile manipulatives. This search yielded a more significant outcome of 7,770 results.

More than 22,606 results relating to '*teachers' views of mathematics*' were identified. Of the sources viewed, quite a few were deemed inappropriate or lacked relevance to the search topic as they were focused on the developmental aspects of subject knowledge in mathematics as opposed to instructional practices involving manipulatives. Subsequent searches included '*mathematical manipulatives*' and '*trainee teachers' perceptions'* and *'instructional practices*.' These focused searches produced fewer responses (3,636). I further adapted my search to concentrate specifically on primary trainees' experiences, which returned far fewer results again (77). I also attempted to locate studies pertinent to postgraduate trainees. Preference was given to studies that were situated in the U.K. context.

2.3 **The use of the Term 'Manipulatives'**

The use of manipulatives in classrooms has been advocated for decades by educationalists to the extent that they can be considered ever-present in primary classrooms. It can be challenging to picture a primary classroom in the U.K. without some form of manipulatives. Yet, manipulatives are seldomly addressed by such nomenclature. Montessori's (1912/1989) work documents her creation of '*moveable cut-outs'*, and Cuisenaire and Gattegno (1961) refer to '*materials*' or '*colourful rods'*. Nowadays, manipulatives are more commonly known as '*practical equipment*' or '*resources*' in primary schools in England. Current terms such as '*tool'*, '*instrument*' of

learning, '*resource'* or '*artefact'* are also frequently used in primary classrooms. However, '*tool*' or 'i*nstrument*' is often referred to as an appliance that aids or accelerates work. Using this vocabulary can dispel any notion of interaction, engagement and enjoyment. In contrast, the term '*resource*' still fails to embody the multifaceted nature of the manipulative. A resource can be utilised as a term to describe stock or supply of materials/assets that can be drawn on by a person to function effectively or an action that can be adopted in adverse circumstances. Furthermore, while the term '*artefact*' highlights the longevity of the manipulative and the significance of socio-cultural and historical representation, this terminology is limited in the sense that it fails to acknowledge the embodiment of manoeuvrability.

The term '*manipulative*' is derived from the Latin word '*manus*' for hand to represent the versatile, tactile, manoeuvrable nature (Mahoney, 2002). It is widely accepted that our fingers are the primitive form of manipulative dependent on the field of mathematics observed (Jackson, 2012; Struik, 1987; Sousa, 2015; Griffiths and Gifford, 2016). Currently, the word '*manipulative*' can also mean the exercising of control over another. I use the word '*manipulative*' as I find it best describes learning through appropriate hands-on experience. The above illustrates the ambiguity surrounding demarcations within this area and also highlights some of the difficulties surrounding an agreed term of representation for manipulatives.

In recent years, there has been a significant rise in reference to manipulatives within mathematical textbooks, professional journals and commercial resource catalogues. The revived interest in manipulatives could be attributed to the renewed discussion surrounding East Asian 'mastery' currently trending in U.K. classrooms. In Chinese, the term 'mastery' can be translated as to grasp in the palm of the hand; the hand is the root of 'mastery' in both Latin and Chinese. However, Marshall and Swan (2005) suggest the introduction of virtual manipulatives in the late 1990s played a pivotal role in the revived characterisation and rekindled interest. As previously signposted, virtual manipulatives are considered to be digitalised resources that mimic the physical kind. Examples include virtual geoboards with rubber bands and large protractors. Although generally the term '*virtual manipulative'* is used to refer to any computer-generated image, they are typically available in two core representations. Moyer's (2002) research identifies static representations as mostly pictorial representations. Although

static representations resemble the physical kind, they cannot be rotated, manipulated and manoeuvred.

In comparison, the dynamic representations are visual images on a two-dimensional screen with the added advantage that they can be rotated. Moyer (2002) argues these representations are true virtual manipulatives as they offer an image of a three-dimensional object. Although virtual manipulatives may at first glance appear similar and are often inscribed with the same names as the physical kind, they offer very different teaching and learning experiences. Furthermore, they do not offer the same tactile responses as their concrete counterparts; therefore, it is difficult to agree that these representations are true manipulatives. When defining manipulatives Hynes (1986) argues it is not sufficient for students to observe a demonstration of the use of an aid. Reys' (1971) research also cautions that not all teaching aids are manipulatives. He defines manipulatives as real objects that pupils can handle feel and move, which have a social application. It can, therefore, be argued that these virtual types are not manipulatives at all.

2.4 **Defining Manipulatives with Pedagogical Criteria**

The use of manipulatives in mathematics classrooms grew considerably in the second half of the twentieth century. Around this time, the notion of a concrete to abstract pedagogic sequence emerged, and the idea of play as an integral part of learning was also embedded in educational research and practice. The perception that manipulatives enhanced the teaching of mathematics gained validity through theorists such as Piaget (1952), Bruner (1966) and Dienes (1967). Reys (1971) writes about an unprecedented period of proliferation in manipulatives during the sixties and the mass production of articles offering guidance for selection (Bernstein, 1963; Hamilton, 1966; Davidson, 1968; Spross, 1964).

Scholars such as Reys (1971), Sowder (1976) and Hynes (1986) have problematised the issue of defining manipulatives as their concept and function are not always clear. According to Hynes (1986), manipulatives are tactile concrete models that incorporate

mathematical concepts, appealing to several senses. This definition has been cited by Howard, Perry and Tracey (1997) in the past. Moyer (2001) similarly describes manipulatives as materials designed to represent explicitly and concretely mathematical ideas that are abstract. Griffiths and Gifford (2016) have recently defined manipulatives as objects that can be handled and moved to develop an understanding of a mathematical situation. Yet, the above 'anglophone' definitions can be difficult to comprehend due to linguistic accessibility. Concrete can mean hardened and stationary, yet manipulatives can also be malleable and moveable.

Furthermore, from a scientific point of view, it can be deemed necessary to define new terms in the form of operations for replication. Yet, Piaget (1952) did not do this; therefore, it is difficult to assess the significance of his general findings. A critical discussion of Piaget's concrete operational stage theory takes place further on within the literature review.

The above definitions also fail to take into consideration that manipulatives are not solely used for the purpose they are designed and can be creatively reconfigured. Manipulatives can be used beyond their basic purpose. Many natural materials such as potatoes and shells can also serve as manipulatives and be refashioned in many different ways. A potato can be used for counting or cut to produce geometric prints. Although customary mathematical materials such as Cuisenaire Rods were initially designed to aid arithmetic operations, they can also be used for a variety of purposes including for fractions, algebra, geometry, measure, as well as a bar model representation.

Uttal, Scudder and DeLoache's (1997) study attempted to discriminate between manipulative types by focusing on specific functions. Their work references objects that require dual representation (i.e. pupils' teddy bears). Dual representation is when the manipulative is as an object in its own right, but can also act as a symbol of a mathematical concept or procedure (McNeil and Jarvin, 2007).

Two classifications that emerge from the literature are structured and unstructured manipulatives. Drews, Hansen and Earnshaw (2007) describe structured manipulatives as those that embody one particular conceptual structure (i.e. Dienes

blocks). Whereas in contrast, the unstructured types are objects that are classified as much more versatile (i.e. Multilink). Unstructured manipulatives are not designed to focus on one particular conceptual structure.

A more recent study by Sarama and Clements (2016) cites Rao Ng and Pearson's (2010) research that found teachers define and describe manipulatives based on their sensory nature as physical objects that students can hold. The sensory nature is assumed to make manipulatives 'real' when allied with students' experiences of the world. Marshall and Swan (2005) cite Howard, Perry and Tracey (1997) definition which similarly describes manipulatives by their sensory nature as all materials both inside and beyond the mathematics classroom which can be experienced through the sense of touch or sound.

The idea that young pupils learn best through sensory stimulus such as concrete objects is derived in part from theorists such as Piaget (1952). Yet, Clements (1999) argues the concrete operational stage is often used incorrectly as a rationalisation for the use of manipulatives. The concrete operational stage is rooted in the idea young children reason concretely before they can reason abstractly. Nonetheless, even though manipulatives are physical objects, understanding how they represent concepts requires abstract thinking (Laski et al., 2015; Coles 2017). Pupils need time to notice the relationship between the concrete (physical) material and the abstract concept that they represent. Ball (1992) and Boulton-Lewis' (1998) research discusses the issue of transferability and found there are problems with this assumption as manipulatives are unable to carry meaning. Although manipulatives hold an important position in learning, their physicality alone does not carry mathematical meaning and pupils must understand how to use the materials for them to be effective. Baroody (1989) cautions that manipulatives can even be used in a rote manner if pupils are not provided ample opportunities to reflect on their actions. Simply using manipulatives alone without reflection can result in pupils acquiring skills as opposed to desired mathematical thinking.

A study by Fennema (1973) specified manipulatives should contain the added pedagogic function of stimulating pupils' interest and motivation. This study detailed how motivation is usually elicited via the physical characteristic of the material. The

material and colours used were identified as an important aspect of selection. This study, as well as Reys' (1971) report, defines successful manipulatives as durable, easy to distribute and withstand regular use.

In contrast, Hynes (1986) define manipulatives as simplistic materials that are easy to operate, and that should refrain from confusing or distracting pupils. Both Reys (1971) and Hynes (1986) stipulate manipulatives must have a clear representation of mathematical ideas and are appropriate for pupils' developmental level and learning style. Yet as previously discussed, manipulatives do not carry meaning alone.

Swan and Marshall (2010) have since redefined Hynes (1986) definition of manipulatives to include a pedagogic function. The redefined description of the manipulative now encompasses Fennema's (1973) idea that students need to engage with the manipulative and thinking should be stimulated. Within this definition, structured and unstructured manipulatives are recognised. For the purpose of this review, my definition of manipulatives reflects this current literature. Manipulatives are tactile objects that can enrich instruction when handled by an individual in a sensory manner, during which a conscious and unconscious change in mathematical thinking will be nurtured (Marshall and Swan, 2010:14). They provide a conceptual framework for social collaboration and discussion. This definition includes the notion that pupils need to engage with physical manipulatives in order to stimulate ideas.

2.5 **History of Manipulatives**

Ancient civilisations have drawn on the use of tangible entities to communicate mathematical meaning and solve problems. It is suggested mathematics initially arose from a need to count and record numbers (Joseph, 2011). As far as it is known, there has never been a society without some form of counting or tally (Joseph, 2011). Prior to the invention of writing, our ancestors had to rely on either memory, or external memory mechanisms such as diagrams, sketches, music, tangible objects or their hands to problem solve, encode and preserve important information. It is believed people in the past effectively extended the natural limits of human memory by making

use of clay tablets, stones, shells and bones to help preserve and organise information. Manipulatives were used as a method of displaying a vast amount of information the memory could not hold.

Central Africa is home to the worlds earliest tangible manipulative. The Ishango bone, a carved tool containing notches arranged in a definite pattern dating back to the period between 23,000 and 18,000 B.C., is believed to be the oldest manipulative recorded (Swetz, 2019; Jackson, 2012; Zaslavsky, 1999). Yet, it is difficult to be sure of the mathematical significance of the Ishango bone without knowing the artefact's cultural context. There are varying interpretations of the precise role and usage of this manipulative. For instance, the bone may have been an artefact used by people acquainted with the base-ten number system, prime numbers and the operation of duplication (Zaslavsky, 1999).

According to du Sautoy (2012) and Jackson (2012), time and distance were the first concepts people measured, and these notions are inextricably linked. In Ancient Egypt, it is documented every year the river would flood giving fertility to the land, and with each flood, the borders were washed away. When the flood subsided, the farmers required an accurate way of measuring boundaries and field size. The use of manipulatives aided in the learning process where people began to recognise if they carried out a particular action they could discover or predict the effect. A reliable and accurate standard unit of measure was required, and the solution was a wooden cubit rod, similar to a ruler used today. The cubit rod was also called a ‘Covid’ unit of linear measure used in Egypt in 3000 B.C. equal to approximately 18 inches (Grosser, 2002; Medhananda, 1978/2006). The ‘Covid’ was the same length as a Pharaoh's cubit (tip of the middle finger to elbow) however not all people are the same size; therefore, the length of each cubit rod varied. A unified standard of measure was then implemented. The ‘Covid’ was used to measure and create the Pyramids that still stand today. A range of manipulatives was developed from the ‘Covid’ such as a cord rope known as ‘ta’ (or Meh ta) which made use of a knot tied into the rope to indicate every cubit and was the length of 100 royal cubits (du Sautoy, 2012; Grosser, 2002). Engaging in this creative process with manipulatives enabled people to imagine new possibilities before deciding what to do.

Today we are aware of the tools the Ancient Egyptians used because these manipulatives have survived. It is documented that humans have used manipulatives since the beginning of time in their daily struggle to survive (Struik, 1987). Consequently, manipulatives in the past were designed and used out of necessity to solve everyday problems, convey information and gain a shared understanding. It can also be considered manipulatives were born from a desire to reduce the complexity and chaos of the world to just a handful of elementary units (du Sautoy, 2012).

All cultures have created systems to count, measure, design and locate places. The Mayans (from as early as 400 B.C.) and Aztecs (from 1300 A.D.) both had counting devices made from corn kernels strung on string or wires that were stretched across a wooden frame (Jackson, 2012). The Chinese Civilisation made use of a 'Suanpan' which was a type of Abacas made from wooden coloured beads dating back to the twelfth century, to communicate numerical data and act as a counting tool (Joseph, 2011). Whereas, the Inca Empire (1400 - 1560 A.D.) who inhabited Peru made use of the Quipu which was an assemblage of connected coloured knotted cords (Ascher, 1998). The relative placement of the cables and spaces between were all part of a logical, numerical recording (Ascher, 1998). This tangible, portable, artefact was of great importance to the Incas and played a crucial role in communication networks as this resource held numerical records (Germain-McCarthy, 2017). Clear messages were transmitted rapidly. It is entirely possible other perishable forms of mathematical communication existed in many different cultures in the form of wood, animal skins, accumulations of pebbles and shells that have all been lost over time (Zaslavsky, 1999). All of these systems are interwoven into individual cultural perspectives. "*The mathematical principles may not be in and of themselves 'cultural' but as soon as those principles are used by human beings, what is done becomes culturally influenced"* (Germain-McCarthy, 2017:37). Mathematical manipulatives are therefore a reverberation of the culture using them. Perceptions of what constitutes to a manipulative will vary according to time and place.

The use of manipulatives specifically for teaching can be traced back to early eighteenth-century philosophers such as Rousseau (1762) who was amongst the first to propose the importance of young pupils learning through their senses, he very much approved of kinaesthetic learning (Bloom, 1991). His voice was one of the earliest

and most prominent within education during the period of Romanticism, a movement within Europe that is symbolised by its emphasis on the emotions and aesthetic experiences. This period saw the expansion of manipulatives that appealed to several different senses and were specifically designed for teaching mathematical concepts.

Until the eighteenth century, it is documented tactile sensory learning remained valued. Mandrou's (1977) research into historical writings of early France found "*Until the eighteenth century at least, touch remained one of the master senses. It checked and confirmed what sight could only bring to one's notice. It verified perception, giving solidity to the impressions provided by the other senses, which were not as reliable"* (1977:53). Following on from this period, studies cite Pestalozzi (1782/1965), a Swiss educational reformer, as being influential in the endorsement of empirical sensory learning with entities (Silber, 1965). His methodology is believed to have been strongly influenced by Rousseau's (1762) theories. He created the 'Pestalozzi Method' of hands-on learning. Pestalozzi (1782) proposed the idea that all learners deserve an equal opportunity regardless of perceived differences and endorsed social play. Pestalozzi (1782) coined phrases such as 'Learning by Head, Heart and Hand' that intrinsically endorse the importance of pupils' learning through the sense of touch and drawing on concrete experiences before developing abstract concepts (Silber, 1965). Much of the research documents how during this period, perceptions towards manipulatives shifted from considering these objects as dispensers of knowledge whereby the manipulative must be used in a particular way, towards a more supportive role in learning.

Educators such as Fröbel (1837/2015) and Montessori (1912/1989) followed, developing educational play materials to support pupils' learning. Montessori (1912/1989) conducted extensive research with pupils who were identified as 'phrenasthenic' or pupils identified with 'special needs'. Her goal was initially to enable pupils to learn independently through personal investigation and exploration, and she founded a network of schools based on this educational philosophy.

Nonetheless, while Montessori's educational philosophy claims to involve a child-centred approach which encompasses child-initiated activities, these actions are often designed to take place in a specified location, with precise training. The idea behind

this approach is the adult is responsible for the environment and the child experiences it. Montessori teachers guide pupils towards seeing the connection that is expected. Loris Malaguzzi (1971/2016) founder of the Reggio Emilia's educational philosophy endorses the notion that pupils are born with a 'special type of knowledge' akin to the imagination (Cagliari et al., 2016). His approach supported a more lateral, as opposed to hierarchal, relationship between teacher and learner, favouring sensory learning (Wharton, 2015). He advocates topics ought to be explored dependent on the child's interest. Pupils were invited to explore learning through freedom of choice, endorsing heuristic play, maximising interest and imagination (Cagliari et al., 2016).

Theories relating to this historical period continue in pedagogic practice today. Early years educators still embrace and endorse the value of heuristic methods of learning (practical and discovery approaches). The ability to touch can be asserted as the most significant sense of all, as it is the first sense acquired and shapes experiences, particularly when learning (Linden, 2016). Scientific research now indicates humans process touch consciously and unconsciously (Eagleman, 2015). The largest organ on the body is the skin, and half the human brain is dedicated to processing sensory experience. Touch is the only sense which puts the individual in direct contact with the subject. This tactile sense forms a way of moving information between people. It is a really powerful communication tool, and interpretation can vary according to the mood of the individual at the time. It is an instinctive means of non-verbal communication that enables people to build an understanding of abstract concepts based upon interactions with physical representations.

The relationship between embodied cognition and learning has been researched for decades. It encompasses a diverse set of theories based on the notion that human cognition is established in the bidirectional perceptual and physical interactions of the body with the world (Wilson, 2002; Lakoff and Nunez, 2001; Tran, Smith and Buschkuehl, 2017). Research in education and neuroscience has shown that bodily movements improve retention of the learned concept by providing additional cues with which to represent and retrieve knowledge (Carbonneau, Marley and Selig, 2013). Chillot (2013 para. 1) is quoted in Psychology Today suggesting "*The physical sensations we experience early in life become a kind of mental scaffold that supports more metaphorical thinking as we grow older."* The Pacinian Touch Sensors within the

fingertips sparks an emotional response, creating memorable experiences (Linden, 2016). Therefore, embodied cognition can play an important role in communicating mathematical concepts as well as enable learners to experiment and evolve their ideas.

While tactile techniques can be fun and enjoyable; they also form the initial building blocks to what is known as 'associative memory.' Sousa (2015) describes the associative memory as a process where the brain operates by making connections. The long-term memories are stored and are awakened and refined by new thoughts. Sousa (2015) is cited, emphasising "*The limbic regions in the brain then sprinkle your memories with emotion*" (2015:39). Nonetheless, since our responses to tactile sensations are such an individual and unique experience, interpretations will vary considerably.

2.6 **Cognitive Representations Theory**

Theories about the role of representation in learning are central to any study of manipulatives. Although teaching with manipulatives is not new, much of the literature relating to the instructional practices with manipulatives has only taken place within the last fifty years. Piaget (1936) provided the initial epistemological foundation for manipulative use. Piaget's (1936) theories are consistently cited as the driving force behind many studies. His work outlines specific cognitive stages of development (sensorimotor, preoperational, concrete operational and formal operational) and stressed the importance of concrete operations in the primary stages of knowledge formation (Piaget, 1936). That is, pupils cannot comprehend abstract mathematics through explanations and require experience with models and representations to grasp mathematical concepts. He insisted that cognitive development always follows this sequence and each phase reveals new intellectual capabilities and a more complex understanding of the world.

In contrast to Loris Malaguzzi's (1971) view mentioned previously, Piaget (1936) argued pupils do not naturally possess the mental maturity to grasp abstract

mathematical concepts presented in words or symbols alone and they require substantial experiences with concrete materials and drawings first for learning to occur. This approach is still prevalent in primary classrooms today, where teachers provide a range of resources and teaching experiences for pupils to learn and reach predefined goals.

Nonetheless, while Piaget (1936) research has been hugely influential to the field of mathematical education, it is not without criticism, particularly concerning developmental processes and underestimates pupils' capabilities. Piaget's (1952) also believed that the physical manipulation of external objects was essential for natural cognitive development. Yet, studies (Dowker, 2009; Hilton, 2017) indicate pupils born without the physical capacity of outward action are still capable of cognitive development. Hilton's (2017) recent research about pupils diagnosed with Apert syndrome (where a child is born with their fingers fused syndactyly) concluded there was a strong link between pupils' finger awareness and their achievements in areas of mathematics involving arithmetic and numbers. The study found if pupils did not use their fingers, they had to rely entirely on known number facts and their ability to do calculations in their head. The physical nature of Piaget's (1952) theories fails to justify how pupils understand abstract words that do not necessarily relate to the physical object. Furthermore, Piaget's (1952) studies failed to take into consideration culturally specific influences on cognitive development. Studies by Kanjirathinkal (1990) and Matusov and Hayes (2000) have shown the Piagetian operational period and even the concrete operational period was heavily dependent on western education. The pupils Piaget studied grew up in Geneva within western culture and exposed to a particular way of thinking mainly in terms of the objects used. Yet, as previously mentioned, physical objects can be utilised for a variety of purposes and do not hold universal meaning.

The 'concrete operational' stage is the third in Piaget's theory of cognitive development. Piaget (1952) considered the concrete stage to be a crucial turning point in pupils' development because it marked the start of logical or operational thought. During this stage, pupils are considered mature enough to utilise logical

thinking but can only apply this logic with the use of physical objects (hence concrete operational). Still, as previously signposted Piaget fails to offer a specific operationalised definition to guide researchers to a link between observed changes and hypothesised changes in the mind. Terms such as 'accommodation' and 'assimilation' are used to indicate an alteration that occurs in pupils' thinking yet no specific guidance is provided of these behavioural or cognitive changes (Matusov and Hayes, 2000).

Brown and McNamara (2005) assert the apparatus of mathematics teaching is part of the culture of mathematics. They also suggest there is a danger of mathematics being portrayed through discursive approaches with manipulatives which can be open to miscommunication due to a lack of cultural understanding. This may differ vastly from the original purpose of the manipulative, where they were designed and used within the cultural context they were created. Culture here is considered to be a specific set of attitudes, values, beliefs, and behaviours shared by a group of people but different for each individual communicated from one generation to the next (Germain-McCarthy, 2017:305). As culture surrounds everyone, it impacts on many aspects of teaching and learning and influences how communication is received and processed whether one is aware or not (Germain-McCarthy, 2017).

Skemp's (1987) theories also support the notion that pupils' early experiences and interactions with physical objects form the basis for later learning at an abstract level. His theory also concurs with the Piagetian (1952) theory of assimilation (using an existing schema to absorb new information) and accommodation (modification of existing schemas to accommodate new information). Similarly, Skemp (1977) discusses the notion of the construction of schema when assimilating new information.

Schemas are used to connect what is already known to new learning. Therefore, it can be considered the richer and broader the input of experiences, the more the brain has to play with in terms of creative mathematical output. While schemas can be useful as they permit shortcuts to be made in the interpretation process of information, previous stages need to be revisited. Skemp (1977) expands on this theory and suggested that mathematics is taught and learnt instrumentally and relationally. He defined instrumental understanding as knowing the rules and procedures without

understanding the mathematics, or why these rules or procedures work (rote learning). On the other hand, relational understanding is defined as understanding how and why the rules and procedures applied work (Skemp,1977). Similarly, distinctions have also been made between procedural and conceptual understanding in mathematics. Conceptual knowledge relates to 'knowing why' and involves an understanding of the network of mathematical relationships. Whereas procedural knowledge involves 'knowing how to' and consists of an understanding of specific sequences of procedures to be carried out (Hiebert and Lefevre, 1986).

Leibeck (1984) discusses 'transmission' theory which centres around the teacher issuing precise instructions for the pupils to follow resulting in what Skemp (1977) describes as an instrumental approach to learning. While, instrumental approaches can produce quicker results for the teacher in the short term at the expense of verbal interaction. This can result in pupils leaving primary school without confidence and competence to articulate the reasoning behind their actions (Askew, 2011).

In contrast, relational teaching and learning is defined as a more meaningful process where pupils are able to establish links between mathematics structures, due to understanding not simply how, but why procedures are followed (Skemp, 1977). Whilst both theories raise distinctive issues, what is clear is the teacher is central to the teaching and learning of mathematics.

Although Bruner (1966) regarded Piaget (1952) as a great pioneer he did not always concur with many details of his theories, in particular the notion of school readiness and proposed that rather than neat stages, the modes of representation are integrated and loosely sequential. Furthermore, Bruner's (1966) epistemology can be viewed as a shifting process as opposed to a concrete phenomenon due to the ongoing development of empirical knowledge founded on the individual experiences. Bruner (1966) held the view learning is not a 'linear' process and the learning environment should have a specific goal that is not overtly structured.

Bruner (1966) also proposed that schools waste time trying to match the complexity of subject material to pupils' cognitive stages of development. He proposed the most

effective way for pupils to learn was through the concept of ‘discovery learning’ and the role of the teacher was to act as a facilitator in the process.

Bruner (1978) is cited,

> “*To do this a teacher must give students the information [and manipulatives] they need, but without organising for them. The use of the spiral curriculum can aid the process of discovery. '[Scaffolding] refers to the steps taken to reduce the degrees of freedom in carrying out some task so that the child can concentrate on the difficult skill s/he is in the process of acquiring*” (1978:19).

In his report on effective teachers of numeracy, Askew et al. (1997) as mentioned before also identified that the most effective teachers of numeracy were ‘connectionist’. Connectionist teachers demonstrated a sense making approach to mathematics learning. That is, they do not view mathematical learning as simply about the absorption and recall of facts but rather they consciously encourage pupils to develop understanding of the relationships and connections between concepts.

Bruner regarded pupils as active learners and not passive recipients of information. Bruner and Haste (2010) endorsed the importance of learners capitalising on pupils’ inherent instinct to touch, explore and discover. Bruner’s theories also discuss the possibility of learners enjoying their experiences and progressing beyond these stages towards the capabilities of producing fruitful predictions.

Moreover, Bruner and Haste (2010) acknowledges the importance of the location for learning, in particular the social learning environment and culture. This study argues the purpose of education is not simply to impart knowledge. The role of the teacher is to facilitate and ‘scaffold’ learning whereby lessons are designed so that pupils can uncover relationships between what is known and what is intended to be discovered (Bruner, 1960). Yet, Bruner (1960) held the notion that schools failed to bring about meaningful and lasting education because students’ are passive consumers of material and failed to make students active inquirers or strategist (Takaya, 2013). This directly contrasts with the origins of the manipulative where they were designed and utilised to solve problems in real context.

Zoltan's 'blocks,' and Gattegno and Cuisenaire's (1954) 'rods' were designed to support the application of Piaget's (1952) theories of learning. Researchers such as Moyer and Jones (1998) also made significant contributions to this field, during the 1980's, where they drew attention to the relationship between 'teachers and pupils' usage of manipulatives and constructivist theories. Constructivist theory states that knowledge is actively constructed by the learner (Moscardini, 2009). However, constructivism is not without limitations due to lack of structure. It can be viewed as a form of learning requiring experts in pedagogy to understand students' response due to the less structured environment (Marshall and Swan, 2010).

Furthermore, Ball's (1992) research questions the idea pupils can independently develop an understanding of mathematical concepts by interacting with the materials alone. She is cited "*although kinaesthetic experiences can enhance perception and thinking, understanding does not travel through the fingertips and up the arm"* (1992:47). This suggests the teacher's role is central. Yet, little research is available exploring perceptions and accounts of use of manipulatives.

2.7 **Tensions Between Structures and Cultures**

The National Curriculum for Mathematics (DES, 1989) and subsequent statutory assessment procedures was introduced into England, Wales and Northern Ireland as a consequence of official accounts documenting poor mathematics performance of English students in comparison to the international context (Brown and McNamara, 2005). The purpose was to standardise the content taught across schools and raise standards of attainment. At the time, official reports attributed the poor performance to the primary pedagogies of the 1970s and early 80s where teaching staff were depicted as facilitators administering and supervising pupils through individualised learning programmes (Brown and McNamara, 2005). The introduction of teacher-proof programmes as well as specific pedagogic approaches was considered by the U.K. Government as a pragmatic solution to counteract poor performance (Brown and McNamara, 2005).

The year 1998 also saw the introduction of a detailed curriculum and assessment portfolio for Initial Teacher training and prescribed partnership arrangements between training providers and schools (Brown and McNamara, 2005). Vast reforms have taken place in recent years, in how teachers are trained, and the various routes into teaching. Subsequently, there have been decades of recurrent statutory changes to curriculum assessment regulations and the implementation of unpreceded large-scale reform programmes (Brown and McNamara, 2005). Over the past twenty years, teachers in England have been working within a culture set by accountability and target setting, in a quest to improve standards in mathematics, fostering what can be considered as a mind-set characterised by compliance and conformity. More stringent accountability measures have been enforced, resulting in an increased demand for control and performance, hence less room for risk-taking and mistakes (Flutter and Alexander, 2009). As a consequence, a deepening crisis of mistrust exists as trust has to be placed without guarantees.

Schools today are placed under immense pressure to respond to the rapidly changing internal and external environments while meeting the needs of an evolving global economy. It can be argued the new accountability measures, and high stakes testing has now endorsed teaching to tests (Burghes et al., 2012). This pedagogical approach is at odds with the purpose of using manipulatives in the classroom. The use of manipulatives is based upon the 'discovery learning model' where the teacher acts as a facilitator of learning. Learners are encouraged to engage actively, and the teacher creates opportunities for learners to explore concepts, facts and relationships for themselves. In contrast, teaching to the test endorses the ‘transmission learning model’ that involves a more teacher-centric approach. The purpose of learning in this model is to memorising facts, and the teacher (the source of knowledge) transmits the information to the students. Learners adopt a passive role in this model of learning.

More recently, the U.K. Government has been influenced by high performing jurisdictions such as Singapore and the use of mastery approaches. There are numerous interpretations of mastery and I have not adopted any particular interpretation myself. I have considered mastery in-depth as in some forms it includes recommendations for using manipulatives and it is a framework in which most primary teaching is currently judged. Teaching for mastery involves employing approaches to

support pupils to develop a deep and secure knowledge of mathematics. According to Newell (2019) a mathematical concept or skill is considered to be mastered when an individual can represent it in multiple ways, makes use of the mathematical language to communicate related ideas, and can independently apply the concept to new and unfamiliar situations. This archetypal mode of learning mathematics was inspired by Bruner's (1966) three modes of cognitive representation.

> *Enactive stage 1 - involves representing events through motor responses (physical motions and gestures);*
>
> *Iconic stage 2 - involves the storage of information as images or diagrams;*
>
> *Symbolic stage 3 – where information is stored through written symbols codes or language permitting mental manipulation. (Bruner and Haste, 2010)*

While the notion of mastery learning is principled, the reality of implementation within large classrooms can be complex. Furthermore, although teaching for mastery supports the National Curriculum in England (DfE, 2013) aims (fluency, reasoning, problem-solving) and U.K. Government inspectors advocate the use of practical resources or manipulatives, there is little guidance on how educators can achieve this. Griffiths and Gifford's (2016) study found there is an absence of guidance available to teachers surrounding the use of manipulatives, particularly in terms of supporting learners when moving fluently between representations of mathematical ideas.

Practical aids are described as helpful and often necessary to the development of pupils' mental images of mathematical concepts and mental strategies (Moyer, 2001; Drews, Hansen and Earnshaw, 2007). Nevertheless, research by Sowell (1989) found pupils need time to notice the relationship between the concrete object and the abstract concepts they represent. This study also found learners make progress at different rates (Carbonneau, Marley and Selig, 2013).

Mastery is frequently misinterpreted in schools as salient, repetitive, mechanical procedures with little variation (NAMA, 2015). Much confusion remains relating to the

terminology and nature of mastery and approaches vary considerably amongst primary schools. Some schools have interpreted mastery as a methodology where differentiation cannot take place. All pupils are expected to work through at broadly the same pace supporting the aims of the National Curriculum in England (DfE, 2013). In contrast, other schools have interpreted mastery as a form of differentiation.

While mastery approaches are inspired by Asian teaching methods, there exists some similarities and fundamental differences between Shanghai and Singapore teaching. These variations are highlighted in the diagram below.

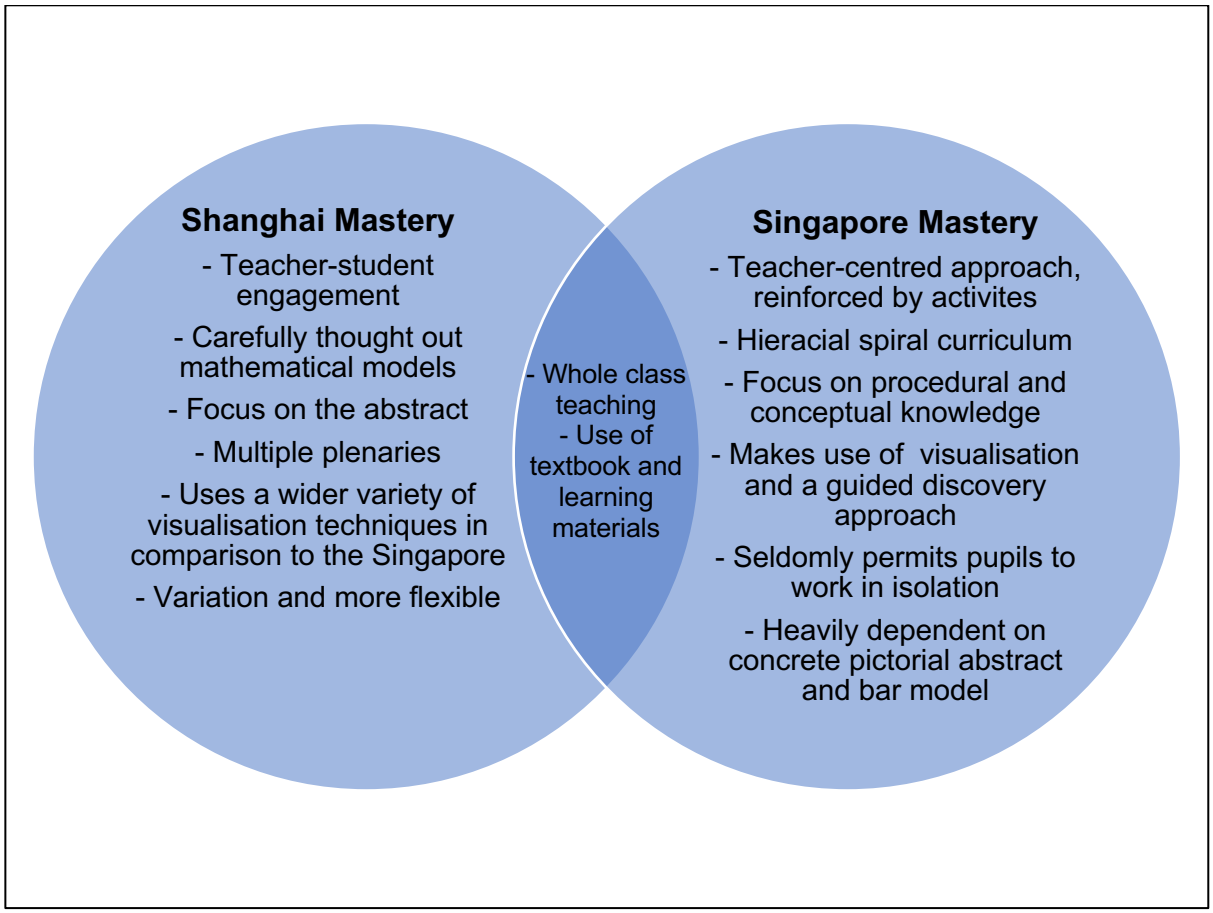


Figure 3 : Differences between Shanghai and Singapore Mathematics Mastery

Drury (2014) has assisted in founding the U.K 'Mathematics Mastery Scheme' that is inspired by the teaching methodologies of both Singapore and Shanghai. The intension with this technique is to challenge the pupils identified as exceeding national expectations and offer further support to pupils considered as achieving lower than anticipated (Stripp, 2014).

Although the content and principles of mastery programmes mirror those of international high performing education structures, typically those of South and East Asia, the concept of mastery is not new. Bloom (1968) first developed the mastery model during the sixties and proposed a range of complexities surrounding this approach; some of the concerns raised are still relevant now. For example, it can prove problematic for teachers to adopt new pedagogic practices within the same policy structures. The manner of implementation within schools can also impact on productivity.

Habitually, teachers have assumed intelligence and aptitude determine the potential for learning. Bloom (1968) argues that intelligence and aptitude scores have determined opportunities, and even the quality of interaction between student and teacher. He further contends that the teacher-student relationship is substantially altered in the mastery learning model. Hence students with high scores tend to be the ones who benefit from the most direct attention. It is unusual for teachers not to know the outcome of the lesson, and these experiences can generate an expected result. Valid questions can be raised as to what mastery entails and whether it is indeed achievable, given that knowledge can be viewed as an accumulative process. Horton (1981) contends that "*mastery is an optimistic model for learning which requires wide-scale agreement upon the specific goals for attainment"* (1981:29). How the teacher delivers mathematics can have an impact on pupils' views of learning (Dweck, 1999).

The current administration (U.K. Government) has implemented some alterations surrounding teaching, learning and assessment with changes to the National Curriculum in England (DfE, 2013) and assessment. Primary school assessment level descriptors have now been removed and replaced with age-related goals, implemented to make appropriate use of classroom teaching (McIntosh, 2015). It can be considered these measures encourage primary schools in England to make greater use of professional autonomy.

Queries have been raised surrounding the value of mastery (NAMA, 2015). Evidence from Hodgen's (2017) review found only marginal variations in terms of attainment. This report also suggested eight practical evidence recommendations,

one of which is that pupils should be encouraged to make use of manipulatives and representations. While the report acknowledged the importance of the use of manipulatives, it contained few references relating to the significance of the teachers' role. How the teacher considers manipulatives can significantly impact on how they are deployed and used. The Sutton Trust (2014) found teachers' perceptions can impact on students' outcomes.

2.8 **Classroom Challenges**

Teachers are now incorporating both virtual and physical manipulatives; however there remains an absence of theoretical and empirical grounds confirming which are more effective in mathematical teaching and learning (Moyer, 2002; McNeil and Jarvin, 2007). Educators are now expected to integrate technology into the delivery of mathematics lessons. Yet, little research exists into the scope, or indeed the limitations of using virtual manipulatives (Moyer, 2002; McNeil and Jarvin, 2007). As previously mentioned, although virtual manipulatives are inscribed with the same name as their physical counterparts and appear comparable, they offer a very different teaching and learning experience. Therefore, it is difficult to agree that these representations are actual manipulatives.

Generally, much of the literature relating to teaching and learning with manipulatives has been positive. Research about the use of manipulatives in teaching and learning indicates students who use tactile materials tend to perform better in tests than those who do not (Kablan, 2016; Raphael & Wahlstrom, 1989; Sowell, 1989; Suydam, 1986; Harshman, Wells & Payne, 1962). These benefits are demonstrated across topics, and studies such as these have demonstrated using manipulatives also increases attitudes towards mathematics. The literature supports the notion manipulatives are well suited for mainstream mathematics teaching, and in teacher professional development workshops, yet a few studies have noted inconsistencies regarding their efficacy for learning mathematical concepts. Carbonneau, Marley and Selig's (2013) recent meta-analysis of fifty-five studies comparing teaching with and without manipulatives concluded tactile materials can benefit pupils dependent on the

conditions and context in which they are used and the level of teacher knowledge. This study also found when manipulatives are used consistently over a long period, they are advantageous (Laski et al., 2015; Carbonneau, Marley and Selig, 2013).

McNeil and Jarvin (2007) examined if manipulatives adequately support pupils in building conceptual understanding or if they merely serve as a distraction from the formation of symbolic notation of mathematics. Skemp's (1987) theories also discuss the stages of symbolisation and the hierarchy of concepts. He examined the process of abstraction and considered if symbolisation only occurs once knowledge is established through constant exposure, or if knowledge is an ever-evolving process revised continually (Skemp, 1987). Nonetheless, Fennema (1973) argues that unless knowledge of abstract mathematical symbols is based on meaningful, concrete experiences learners will remain unable to use symbols except in a cursory manner. She posits manipulatives can provide real situations that enable learners to understand and effectively use symbols.

Studies have also found there is a danger that manipulatives can be used mechanically by pupils (Cobb, 1994; Clements & McMillen, 1996; Threlfall, 1996; Clements, 1999; Moyer, 2001) Studies indicate while pupils may want to draw on manipulatives to make sense initially, it is insufficient to use manipulatives solely to carry out a procedure (Moscardini, 2009). Yet, instructional texts and research set out specific guidelines for teachers to employ, detailing which manipulatives to use to show learners how to carry out mathematical methods (Bernstein, 1963; Spross, 1964; Reys, 1971; Threlfall, 1996). However, providing pupils with specific guidance to employ when solving problems is arguably undesirable (Baroody, 1989).

My recent study (Charles-Cole, 2017) found mathematical manipulatives were not used as widely as they should be and are often reserved for pupils classified as lower attainment who are usually taught by the teaching assistant. This downgrades their intrinsic value. This research revealed there exists a veiled social stigma attached to the use of manipulatives, and some inequalities occur in the deployment and use of these materials. As the use of manipulatives is associated with intellectual difficulties, when they are used, this reduced the individual's worth or status within the context of the classroom. These findings suggest that the use of the manipulatives can also

restrict social mobility, even result in social exclusion and can leave the individuals who rely on these resources feeling devalued and demotivated. Should the teacher fail to influence pupils positively in the use of manipulatives, it can have a detrimental impact.

Still, as previously described, manipulatives have a history of efficacious use and are suitable for all learners, providing the platform for enriching conceptual understanding, problem-solving skills, enhancing vocabulary, reasoning, fluency, resilience as well as self-efficacy skills. The literature has disclosed manipulatives are valuable when they are introduced as an integral part of the lesson to challenge pupils' thinking (Germain-McCarthy, 2017). To make sense of problems, pupils need time to reflect on their actions (Clements, 1999). Lessons with manipulatives must be carefully designed to advance students thinking.

As stated, the diverse range of quality manipulatives available, the cost of the materials (both in time to produce and purchase), size, manageability and ease of storage can make it challenging for teachers when planning and structuring lessons. Furthermore, teachers can face a real dilemma where they are committed to respecting pupils' ideas yet are also responsible for covering the curriculum. Howard, Perry and Tracey's (1997) study indicates manipulatives benefit the teaching and learning of mathematics, but teachers' use of manipulatives needs to be strengthened through appropriate professional development within the overall context of the students' learning of mathematics.

2.9 **Significance of Teachers' Perceptions**

There is a wide breadth of research dedicated to understanding and defining the concepts of 'beliefs, 'perceptions' and 'views' in mathematics education. Green (1971) refers to the term 'beliefs' as a judgement that is accepted as true by the individual holding the belief. Green (1971) delves further, describing 'beliefs' as a psychological concept that is different from knowledge, which implies epistemic warrant. 'Views' can be thought of as an outlook, a consideration or a personal opinion, whereas 'beliefs'

can be thought as holding a far deeper reaching impact. Real conviction, trust and confidence can all be placed within beliefs.

Research conducted within this field problematises the disparities between ‘beliefs’ and ‘knowledge’. Lester, Garofalo and Kroll (1989) describe the distinction between ‘beliefs’ and ‘knowledge’ as:

> *"An individual's beliefs may or may not be logically true or may be externally justifiable, whereas knowledge must have both characteristics in addition to being believed by the individual” (1989:77).*

This is justifiable, as one can hold a very strong conviction that may not have any basis at all. Nespor (1987) and Abelson (1979) refer to ‘beliefs’ as a weaker condition than knowing. The difficulty is associated with understanding where knowledge ends and belief begins (Parjares,1992).

Numerous studies have been conducted into what is meant by 'perception,' a term which is hard to define and even more difficult to research. Social psychologists, anthropologists and philosophers have contributed towards an understanding of what perception entails and the effect on actions. Lotto (2017) refers to ‘perception’ as a type of mental impression that is sensory driven. It is an expression closely associated with many aliases such as views, attitudes, values, judgments, theories, as well as understanding (Parjares, 1992). The core distinction between ‘beliefs’ and ‘perception’ is that a ‘belief’ is mental acceptance of a claim as likely to be true, while perceptions are organised identification and interpretation of sensory information.

Still, few studies specifically report on teachers’ or trainees’ perceptions of manipulatives use. Nespor (1987) contends it is vital to conduct research from the teaching professional’s perspective to better understand how they define their work. The perception of the teacher is important because it underpins the particular practices adopted, the purposes they aim to achieve, and overarching theories of what learning is, or should take place. Teachers’ perceptions of using manipulatives are strongly associated with their beliefs about how useful manipulatives are.

A report led by Askew et al. (1997) found teachers considered as highly effective in the delivery of mathematics were characterised by a specific outlook which led to a corresponding set of teaching approaches. Askew et al. (1997) claims "*The mathematical and pedagogical purposes behind particular classroom practices are as important as the practices themselves in determining effectiveness"* (1997:5). Put simply it matters why teachers implement the practices they choose, as existing perceptions can influence actions.

> *"The cultural routines and patterns associated with schools, teaching and learning are firmly embedded in our culture from a very young age and thus, highly resistant to change. Simply put, every adult knows what teaching and learning should look like because he or she has spent thousands of hours as a student in school" (Bullock & Russell, 2010:95).*

Moyer and Jones' (2004) study which examined the use of manipulatives in the classroom referred to 'controlling choice' as instructional practices that exhibit control over the use of manipulatives during teaching. This study discusses how teachers exert different control orientations during lessons, conveyed through a range of instructional behaviours. Restricting the choice and use of manipulatives can remove the element of fun and engagement from learning. In this study, engagement was referred to as the degree of attention, curiosity, interest and passion that learners showed towards motivation to learn. Deci and Ryan's (1987) research reported that a student-controlled choice can significantly impact on pupils' intrinsic motivations and concluded that enthusiasm increased in lessons where pupils were provided with high autonomy.

Furthermore, Yackel and Rasmussen (2003) assert the extent to which pupils diagnosed with specific needs are afforded opportunities to use manipulatives in ways that are meaningful to them to support the construction of mathematical relationships can be linked to teachers' knowledge and beliefs. This makes sense intuitively as pupils should gain a deeper understanding of abstract concepts when these ideas are related to the real world (McNeil and Jarvin, 2007). Thus, if teachers' perceptions

about practical aids are not explored, constructive learning opportunities will be missed.

As concrete manipulatives are tactile by nature, and visually appealing, their appearance can reinforce the notion of play (Moyer, 2001). It is not uncommon for teachers to hold the perception manipulatives are a source of amusement and simply a ‘fun’ way to teach mathematics (Moyer, 2001). Nonetheless, embedded in this reference to fun is an important notion about how and why they are used (Moyer, 2001). McNeil and Jarvin's (2007) research also found teachers sometimes use manipulatives as a reward for appropriate behaviours adding variety to the lesson, or as a hook before pupils begin the ‘real mathematical learning’. This study also implies this perception can undermine the effectiveness of using these resources. This insight fortifies the belief of ‘fun’ at the expense of mathematical conceptualisation (Bouck and Flanagan, 2010).

As previously signposted, play is considered an integral part of learning in early years education. Therefore any form of 'fun' or excitement can be regarded as potentially disruptive to the atmosphere deemed essential to the learning process in the classroom beyond the foundation stage due to preconceived notions of what learning should look like (hooks, 1994). Furthermore, manipulatives do not carry actual mathematical information. In the absence of clear information, knowledge and understanding of the potential role of manipulatives as tools that can be used autonomously by pupils to build conceptual understanding, there is a danger that teachers will persist in maintaining a default position where materials are used to demonstrate procedures for pupils to re-enact (Moscardini, 2009).

2.10 **University-school Training Partnership: Rhetoric or Reality?**

A wealth of literature exists documenting the analysis of effective mathematical pedagogy, and the types of support deemed necessary to engage trainee teachers to develop effective teaching skills (Van Zoest & Bohl, 2002; Lewis et al., 2012; Amador et al., 2017). Barber and Mourshed (2007) investigated twenty-five of the world’s

training systems, ten of which were identified as best performing by The Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA). These top school systems highlighted several fundamental factors that impacted on performance, such as it was deemed key to identify the ‘right people’ to become trainee teachers from the onset. Barber and Mourshed's (2007) study categorise how the 'right people' possess three essential characteristics, 1) the ability to gain an understanding of the best practices, 2) being self-aware of the specific weaknesses in their practice, 3) being motivated to make changes. This research emphasised the importance of recruiting trainees who possessed the ability and motivation to identify and act upon areas for development, together with effective mentoring. This report also outlined the role of the mentor was to provide adequate exploratory experience to enhance the pre-service teacher's development (Hyde and Edwards, 2014).

Research (Ball, 1990; Nolan, 2011; Hyde and Edwards, 2014) indicates the relationship between mentor and trainee is fundamental in teacher education, and the quality of the relationship has a significant impact on the professional learning of both the trainee and mentor. Akkerman and Bakker (2011) supports this notion and discusses how in training programmes that emphasise school experience, tutors, trainees and their mentors engage in the process of boundary-crossing. The pre-service teacher is moving from peripheral participation in the school practice of teaching to becoming a recognised member of a community of practice in schools (Wenger, 1998). At the same time as the trainee is shifting from being a student to becoming a teacher, the mentor crosses a boundary from schoolteacher to teacher educator. Hyde and Edwards (2014) propose that although teachers are knowledgeable professionals who shape instruction, a significant number of teachers find themselves as a mentor without the necessary preparation and experience. Furthermore, trainees bring experiences to these interactions influencing what teachers can do (Nipper and Sztajn, 2008).

The supervising link advisor from the accredited provider (university) is also involved in the process of negotiating the boundaries between the institutions and has to undertake the role of quality control for both mentor and trainee and may undertake the role of evaluating the quality of mentoring. In practice-based programmes in

England, trainee teachers and link advisors find themselves negotiating a conceptual boundary between the competency-based training and monitoring that is found in schools, and the reflective mode of professional learning that is promoted by universities (Hyde and Edwards, 2014). These boundaries can be sources of tension, but also potential sources of learning. hooks (1994) discusses the importance of collaborative discussion that crosses boundaries and creates a space for intervention.

Hiebert et al. (2005) consider instruction as a complex activity in which different pieces are brought together. Instruction takes its shape from the knowledge teachers and students bring to the situation, the tasks on which they work, discourse structures, assessment practices, the physical material available, and so on. It is the interactions amongst these elements, the system, rather than the individual aspects acting alone that define the learning outcomes for pupils.

Nolan's (2011) study argues existing research focuses a lens on what a teacher educator and link advisor can learn from trainee teachers as they negotiate their field experience amid officially sanctioned pedagogies of mathematics classrooms. She discusses her frustrations with this type of research as it appears to fail to acknowledge the disconnect and disparities between university courses and placement. Furthermore, the existing research fails to acknowledge the culturally-based assumptions of how mathematics is shaped between the individuals' grasp of the subject and the institutions' definition of it. Nolan's (2011) study claims trainees experience negotiations of conflicting habitus-field fits (a process leading to patterns that are enduring and transferrable from one context to another) during their teaching practice. Teaching with manipulatives is not just a matter of pedagogical strategy and technique but requires a significant reframing of instructional practice (Cobb, 1994).

Clay and Kirtley's (2005) research discovered two critical factors in bringing about positive change which were ‘the opportunity to experience mathematics in a new way’ and ‘continued engagement in professional learning’. Studies such as these indicate not only is it the trainees’ engagement with professional development that brings changes to their instructional approaches, but also the nature of the placement. Success is more likely to take place if the ongoing partnership between the external

agent and trainee is strong, and the trainee is provided with adequate opportunities for reflection.

Nolan's (2011) research has also indicated that despite the introduction of inquiry-based pedagogies during teacher training courses, traditional textbook and teacher-directed approaches prevail. She goes on to state,

> *"An unfortunate outcome of thousands of hours that all students serve in the 'apprenticeship of observation' (Lortie, 1975) is that prospective teachers enter teacher education programmes already feeling quite at ease with their knowledge of what teaching and learning look like" (2011:202).*

Freire (1970/1996) and hooks (1994) both discuss the notion of liberatory practice which involves deepening the learner or trainees' consciousness about his or her situation. Liberatory pedagogy, also known as problem-posing education or inquiry education, uses the process of inquiry to transform oppressive structures by engaging learners to draw on what they already know. Freire (1970/1996) began to develop an educational praxis due to the inequalities experienced while learning as a child. He argues deepening the individual's consciousness about his or her situation stimulates the process of inquiry and develops critical thinking.

The liberatory pedagogic style is based on a set of teaching and learning strategies that focuses on student-centred approaches which encourages metacognitive discussion and collaboration (hooks, 1994). This is an approach to education that proposes a transgression takes places against boundaries so that a new relationship between teacher-student and society can materialise.

There is a large body of literature complementing the above that explores 'good practice' and research on 'exploratory' or 'inquiry-based' mathematical pedagogy; many of these studies are from the trainee secondary teacher's perspective (Nolan, 2011; Antropov, 2014; Wirth, 2014). This research base typically discusses the importance of moving away from textbooks and making use of inclusive pedagogic

approaches such as digital technologies (Amador et al., 2017; Hyde and Edwards, 2014; Armador, 2017; Bouck and Flanagan, 2010). There is an absence of literature surrounding trainee teachers' use of manipulatives, consequently, a gap exists in the knowledge.

Nonetheless, inquiry-based pedagogy has two facets that are relevant to my study. It can be defined as an approach to classroom learning that emphases exploration and individual experience. Inquiry-based pedagogy can also be defined and related to trainee teachers' professional learning. Professional learning is adopted at my institution, where trainee teachers are expected to inquire into their practice to develop further. The reflective element of the course seeks to enhance the postgraduate trainees' experience towards a realisation of themselves as a successful learner, offering opportunities to reflect at a more profound and critical level. The assessed reflective opportunities are in line with the Master's level of study and the Teachers' Standards (DfE, 2013). The Teachers' Standards (DfE, 2013) is statutory regulation detailing a set of expectations of effective teaching practice.

Wheelahan (2007) argues a key concern with inquiry-based learning is it can leave students without access to understanding the relational connections that make up the field or the relations between fields and sanctions a focus on portions of knowledge rather than a sense of how knowledge is produced in a discipline. Ashwin (2017) counteracts this concern stating it is important to refrain from overstating the power of traditional curricula in providing students with access to these connections and argues that just because the educator may cover the connections, it does not mean the learner will gain access to them.

Freire (1970/1996) discusses the significance of dialogue in education, as well as to human nature. He argues critical dialogue seeks to unearth meaning, uncover challenges and consider ideas through new perspectives. He discusses how dialogue should not be imposed on the learner, nor can it be assumed that only the student has something to learn. Freire (1970/1996) asks: "*How can I dialogue if I always project ignorance on to others and never perceive my own?"* (1996:71)
hooks (1994) also considers the importance of dialogue as a source for establishing a communal space between people with different backgrounds and perspectives which

can enhance the likelihood of collective effort in creating and sustaining a learning community. hooks (1994) is cited,

> *"To engage in dialogue is one of the simplest ways we can begin as teachers, scholars, and critical thinkers to cross boundaries, the barriers that may or may not be erected by race, gender, class, professional standing, and a host of other differences" (1994:130).*

As teaching is both a physical and cognitive process, where varying and ever-evolving interactions take place at such a fast pace, it would prove impossible to provide a manual of procedures and definitive guidance for all possible interactions (Sellars, 2017). Robins et al. (2003) describes reflective professional learning as a valuable tool permitting teachers and trainee teachers to understand themselves, their personal philosophies and the dynamics of their classroom more deeply. The benefits of the cyclical action of metacognition, reflection and learning from experience is well documented (Gibbs, 1998; Schön, 1983).

Arguably, exploratory and reflective experience should only take place with the support of an experienced mentor with appropriate learning experience so that effective skills are developed (Antropov, 2014; Ball, 1990). Hyde and Edwards (2014) assert that although the mentor may assume responsibility of assessing if the trainee has achieved the required standard during placement, this responsibility should be shared and negotiated with the trainee. Trainees are then encouraged to develop personal strategies of formative assessment guided through reflection.

2.11 **Similar Studies**

A few studies have been identified that address similar elements to the proposed study. Golafshani's (2013) research about teachers' beliefs and teaching practices with manipulatives reported a significant increase in the number of teachers that desired to use manipulatives in teaching as the project progressed. This study made

use of questionnaires and observations. While the findings of this study have been useful in offering a glimpse into the use of mathematical manipulatives in classrooms, the research was conducted from the perspective of the qualified teacher and took place in Canada.

Jones (2010) conducted a similar study documenting secondary mathematics teachers' views and use of manipulatives. This qualitative study examined six participants' views using a structured interview. The findings revealed the use of manipulatives were influenced by the teachers' beliefs and experiences with manipulatives. Although this study recommended a need for further work in this field, the research was again conducted with qualified teachers who were secondary trained as opposed to primary. This study also took place in Canada and it is not reflective of the U.K. context.

Unlike the above, Howard, Perry and Tracey's (1997) study involved a comparison of primary and secondary teachers' views regarding manipulatives use. This study investigated the opinions of more than nine hundred primary and secondary qualified teachers in the southwestern suburbs of Sydney and the North Coast of New South Wales. The findings revealed the use of manipulatives in secondary schools was significantly lower than primary school, and manipulative use was primarily for checking results and remedial support.

Thus, there is a need to investigate teachers' perceptions and accounts of using manipulatives in the U.K. from the trainees' perspective. Expanding this kind of research could enable educators to identify if any other challenges may exist.

2.12 **The Rationale for the Current Study**

As described in the preceding sections, many studies have shown that although manipulatives can be valuable in building and strengthening mathematical understanding, there is a need to investigate how trainee teachers account for their use. The critical relationship between the perceptions of teachers and the application

of instructional decisions require more attention. I have witnessed that it can be challenging for postgraduate trainees to identify opportunities for development, challenge assumptions and utilise the experiential aspect of classroom learning, especially when trainees are observed and graded. Professional learning opportunities are an essential aspect of teacher training courses. Every effort is made to foster a child-centred approach that encourages metacognitive strategies, self-efficacy and resilience during university training. Yet, observations detail, once trainees are on placement, a more didactic approach prevails, with fewer opportunities to make use of manipulatives.

The review of the literature identifies a gap in the knowledge relating to postgraduate professional learning and the use of manipulatives. There is considerable scope to investigate if primary trainee teachers should be afforded greater autonomy to appreciate the interconnected nature of mathematics through the full range of manipulatives. It is clear that research in education should be concerned with taking account of the trainee's perspective while perceptions are forming, and that there is much to gain from a study in this area. Given that there exists a substantial academic history into the gathering of teachers' perceptions and instructional practices in mathematics, it is surprising that there are at present few studies examining the use of manipulatives, particularly from the trainee's perspective within the U.K. The Initial Teacher Education (ITE) year influences future teachers' and mentors' practices.

At present, there is little guidance regarding how these materials should be used with trainees. More research is necessary to inform teachers' choices about which, and how many representations to use. Understanding trainee teachers' perceptions and use of manipulatives could broaden the scope of work in this area and facilitate meaningful discussion surrounding initial teacher training programmes, particularly within the postgraduate sector.

Gonzalez Thompson (1984) is cited,

> *"If teachers' characteristic patterns of behaviour are indeed a function of their views, beliefs and preferences.... then any attempt to improve the quality of mathematics teaching must begin with an*

understanding of the conceptions held by teachers and how these relate to their instructional practice" (1984:106).

2.13 **Research Questions**

This study aimed to explore PGCE primary trainee teachers' perceptions towards the use of mathematical manipulatives, and understand how they accounted for their use. I defined accounts of manipulatives as any lessons, discussions, personal or professional learning opportunity related to manipulatives with which trainee teachers identify, acknowledge, utilise or have any interactions that would result in the formation of a perception. I decided to focus on perceptions as this includes what is physically embodied, as well as cognitive. The perception of the trainee is crucial because it underpins the particular practices adopted, the purposes they aim to achieve, and overarching theories of what learning is, or should take place. As I work closely with postgraduate trainees, I wanted to explore their experiences of using manipulatives and find out if a variation existed between training and practice.

The current rhetoric of including the student's voice has grown in prominence within the field of education and considered an essential goal for universities (Ashwin, 2017). I believe it is vital to afford trainees with the right to have their perceptions taken into consideration, especially when decisions are made that affect them. Involving trainees in the decision-making process demonstrates their opinion is valued and can improve self-esteem as well as self-worth. By utilising trainee teachers' perceptions, it can enable opportunities to untangle some of the complexities that occur in the profession and ultimately transform the learning experience in the classroom for teachers as well as the pupils. My role was not merely to just let the trainee speak and present the findings; it was to explore the unique contributions of the trainee's experience so that decisions can be made with their best interests at heart.

The literature highlights where studies have collected teachers' perceptions and accounts of using mathematical manipulatives. Thus, there is a need to investigate teachers' perceptions and accounts of use of manipulatives in the U.K. from the trainee

perspective. To the best of my knowledge, this study is first to use a phenomenological approach to provide deeper insights into the experiences of trainee teachers' use of mathematical manipulatives. Consequently, the following two research questions were identified.

1. What are PGCE trainee teachers' perceptions of mathematical manipulatives?

2. How do PGCE trainees account for their use of manipulatives during placement?

These two questions were operationalised by the following sub-questions:

a. Why do they take that approach, if, with or without manipulatives?
b. What are the barriers and incentives to using manipulatives?
c. If a disconnect exists between the training and current use, why?
d. What do trainees think would be a productive way to increase this connectivity?

Chapter 3: Methodology

3.1 **Introduction**

The ensuing sections contain a description of the chosen design and methods used to gain an insight into the trainees' perceptions and accounts of using manipulatives. A summary of the strategies used to recruit the participants then follows. I then offer a rationale for the selection of semi-structured interviews as the primary data collection instrument, and the subsequent use of video clips as a focal point for responses. The process I undertook to develop the interview schedule around the research questions is outlined, alongside a detailed account of how the data was collected and analysed. This section concluded with a description of how this study meets the research quality guidelines.

3.2 **The Rationale for a Qualitative Approach**

According to Cresswell (1998), the choice of research approach heavily influences the research design. With this in mind and considering how best to address the research questions of this study, it was decided to adopt an inductive approach as at present little guidance is available detailing trainee teachers' accounts of using manipulatives. Inductive methods are concerned with generating new theory emerging from the data. Such approaches enable the emergence of unanticipated findings.

As this study is related to an aspect of teaching and learning practice, a suitable explorative research design was also required. I identified a qualitative methodological research design as the best means to gain an understanding of the trainee teachers' perceptions, thoughts, feelings, and reflections. Qualitative research focuses on general meaning and knowledge through rich description. It is a particularly useful approach to studying educational problems that are not easily quantifiable, especially those that require the researcher to develop an understanding

of complex social environments and the meaning the people within those environments bring to the experience (Behal, 2018).

I chose a phenomenological approach in order to give the participants the opportunity to express themselves and gain an insight into how they make sense of, and understand their experiences. This choice reflected my own epistemological and theoretical orientation regarding the nature of knowledge, and what can be truly known. Phenomenology is a philosophical approach to qualitative research that aims to describe the meaning of lived experiences of a phenomena for several individuals (van Manen, 2016), which in this case is the experiences of trainee teachers. However, phenomenology should not to be confused with case studies, ethnographies, narrative inquiries, or empirical studies that aim to generalise their findings to a certain group or population (van Manen, 2016). There are a range of different emphases and interests, but they all tend to share a consideration of peoples' lived experience. The 'lived' experience is regarded as the past event, or experience of an individual. This fitted well with my aim to go beyond existing research by attempting to understand what it is like for trainee teachers during placement and shed some light on their experiences of using manipulatives during placement. I describe below how Interpretative phenomenological analysis (IPA) approaches this.

3.3 **Interpretative Phenomenological Analysis (IPA)**

Interpretative phenomenological analysis (IPA) is a qualitative approach to research that aims to offer insight into how individuals in a particular context make sense of a specific phenomenon (Smith, Flowers and Larkin, 2009). I selected IPA as the chosen qualitative approach for the following reasons. Firstly, IPA is consistent with the research aims in that it is committed to the examination of how people assign meaning to their experiences and seeks to understand the complexities of our social world. IPA is phenomenological in that it wishes to explore an individuals' perception or account of an event as opposed to producing an objective record of the event or state itself. I aimed to try to make sense of the experiences as it was narrated by the participants. This approach does not attempt to hypothesise, validate or refute, define or

taxonomise the experiences shared (Behal, 2018). It, therefore, focuses on the commonality of the lived experience within a particular group 'exploring experience in its own terms' rather than attempting to reduce it to 'predefined or overtly abstract categories' (Smith, Flowers and Larkin, 2009).

The uniqueness of this qualitative inquiry is its experiential understanding of complex interrelationships and its direct interpretation of events. Therefore, the emphasis is on seeking to explore the patterns of unanticipated and unexpected relationships between phenomena. Thus, in examining this under-investigated experience, such as trainees' accounts of manipulative use, new light could be shed upon the phenomena and how to comprehend this lived experience of the classroom, opening other avenues of exploration.

Secondly, while IPA is useful for understanding experiences that are challenging to explain and can provide a rich and detailed understanding of the phenomena in question, it also involves interpretation and consideration of changes in culture and context (hermeneutics). Caution must be exercised with this approach. Inferences that are drawn from the data must be conducted with an awareness of the context and culture within which the study is situated (Reid, Flowers and Larkin, 2005). This approach demanded that I take into consideration the timing, the culture and context during the process of interpretation as people, customs and context change. An awareness of changes in culture and context was an integral part of the study as the trainee's experiences of teaching with manipulatives evolved. Hermeneutics focuses on 'how' understanding is achieved as opposed to 'what' is understood by interpreting texts related to the lived experience.

IPA also involves a double or triple hermeneutic cycle as I was making sense of the participants' past recollections of experiences, while they were making sense of the phenomenon. When the reader is added to this process, the reader is making sense of the researcher who is making sense of a participant, who is making sense of the phenomenon (Behal, 2018). There are multiple layers of understanding and interpretation. IPA therefore, inevitably involves interpretation on the part of both the researcher and participant. To capture the trainees' personal lived experiences, the objective was for the trainees and I to become co-creators and form a bilateral

relationship in this sense-making process. Due to the passage of time, memories of experiences can fade. Notably, my role was to support the participant to recollect that experience. IPA considers that it is not possible to get close to the participants' personal world directly without acknowledging the researchers' own conceptions which are required to make sense of the interpretation (Reid, Flowers and Larkin, 2005). Thus, IPA is the exploration of the lived experience, coupled with a subjective and reflective process of interpretation.

Thirdly, IPA's strong idiographic approach was in keeping with the research aims. I aimed to understand the participants' retrospective accounts on their own terms and capture insights into how a given person in a given context makes sense of a phenomenon. IPA methods intend to avoid premature generalisations about large populations and arrive at more general claims cautiously and only after meticulous analysis of individual cases (Behal, 2018).

The inductive nature of this approach meant that I did not have to rely on existing literature to drive the analysis. Instead, the approach allows for the possibility of novel and unexpected results to arise. Smith, Flowers and Larkin (2009) consider it is the nature of IPA that the interview and analysis will take the researcher into new and unanticipated territory, therefore, it is likely some additional literature will be required after the analysis is completed to frame the new angle that has emerged. Introducing new literature into the discussion can, therefore, help to generate an enriched meaning. I have done this in section 6.2.6, 6.2.7 and 6.2.8.

Although a recently developed investigative methodology that originates in the field of phenomenological psychology, this approach has increasingly branched out into other areas that examine human and cognitive sciences (Smith, Flowers and Larkin, 2009). I would contend that through the use of IPA, researchers can gain an understanding of experiences within an educational context as it is a valuable approach to adopt, particularly within remits that lack previous exploration. This seems pertinent to this study as investigations aiming to explore trainee teachers' perceptions of using manipulatives appears to be scarce.

3.4 **Rationale for IPA**

In this section, I present a rationale for selecting IPA over three other types of qualitative analysis methods that were initially considered as possible alternatives that capture lived experiences: Grounded Theory, Discourse Analysis and Narrative Theory.

IPA was selected over Grounded Theory as this methodology can be considered a sociological approach that makes use of large samples to support wider conceptual explanations (Willig, 2001). Grounded Theory investigates social processes and appears to emphasise understanding at the group level as opposed to the individual. One of the attractions of IPA for me was the idiographic focus. IPA, by contrast, is more concerned with the more detailed nuances of personal experiences of a smaller sample (Smith, Flowers and Larkin, 2009). Also, the focus on IPA is on the nuanced lived experiences of participants rather than the development of explanatory models as is the case in Grounded Theory (Mcleod, 2013). Thus, I deemed IPA was in keeping with this study's aims.

Discourse Analysis was also rejected as this approach focuses on how effects of truth are created in discourses (Brinkmann and Kvale, 2015). As mentioned in the previous section, the objective within this study was not to call into question the facticity of the experience, but to provide accounts of the participants' experience on their own terms, and in their own words.

Narrative Analysis was initially considered, this method was also rejected as the fundamental idea behind this approach is people primarily make sense of their experiences and communicate these experiences to others in the form of stories. The stories shared form the unit of analysis; consequently, can be treated as the primary source of data. This approach focuses on the specific actual stories that have been told and seeks to deepen understanding of the meaning and interactional significance by focusing on how it is structured, the type of language used and the way that is shaped or co-constructed (Mcleod, 2013). In a linguistic sense narrative analysis is a chronologically told story with a focus on how the elements are sequenced (Brinkmann

and Kvale, 2015). It is, therefore, feasible to include a much larger sample size. Nonetheless, narrative is just one way of understanding experiences (others include discourse and metaphor). I felt IPA also included consideration of the narrative as a means of exploring the experiences of participants without being constrained by this focus (Smith, Flowers and Larkin, 2009).

Although there existed some overlaps between approaches, each offers a distinct method of gaining understanding (Willig, 2001). IPA allows for flexibility and draws from across phenomenological traditions. I have chosen to pursue IPA as I felt an interpretative and idiographic understanding was the most valid means to access and understand the trainee teachers' experiences. This has led me to reject other methods. Nevertheless, I acknowledge that such approaches, as mentioned above, could well be appropriate as an alternative means of documenting the lived experiences of trainee teachers' usage of manipulatives.

3.5 **Design**

I considered that it was essential to select a methodological framework and data collection instruments that enabled me to capture the trainees lived experiences. Cresswell (1998) is cited "*The researcher is an instrument of data collection which gathers words or pictures, analyses them inductively, focusing on the meaning of participants and describes a process that is expressive and persuasive in language*" (1998:14).

A survey was initially considered as a means of gathering data about the trainees' perceptions. I have used surveys in the past to gain an understanding of how pupils use manipulatives in lessons and found them to be easy to administer. While this format was convenient and well suited to gathering the trainees' perceptions, it was rejected as the primary method for data gathering. Although surveys permit a large population to be assessed with relative ease, it can be challenging to build a rapport with participants. Furthermore, the results produced offer a more generalised account. I was seeking an in-depth personal perspective. Therefore, to hear the trainees

describe their personal experiences with mathematical manipulatives, I deemed it was vital to meet the trainee face to face.

I also considered the method of direct observations. I contemplated requesting willing participants work in a room with manipulatives and demonstrate to me how they would usually use these materials in mathematics lessons. However, this approach was also rejected as the trainees may have interpreted my study as an additional means of mathematical assessment. As mentioned in the introduction, I had witnessed that it can be challenging for postgraduate trainees to identify opportunities for development, challenge assumptions and utilise the experiential aspect of classroom learning, especially when trainees are observed and graded.

Furthermore, my dual role of researcher and senior lecturer could have caused an inherent power imbalance. There was a danger the trainees would demonstrate approaches that I expected to see as opposed to revealing their authentic actions, choices and experiences. Taylor and Bogdan (1984) recognise this tension "*The lack of first-hand knowledge of how people act can make it difficult for the researcher to sort out the difference between purposeful distortions and gross exaggerations on the one hand and genuine perspectives on the other"* (1984:99).

Taylor and Bogdan's (1984) study suggest that the researcher can usually obtain a precise amount of information about past events and current activities by creating an interviewing atmosphere. This study claims within this atmosphere, the participants are likely to talk freely when the researcher encourages the subject to describe as precisely as possible what they experience and feel with specific concrete examples of practices. Descriptions of specific situations and actions are elicited, consequently not general opinions (Brinkmann and Kvale, 2015). Brinkmann and Kvale (2015) define an 'inter-view' as literally an interchange of views between two persons conversing over a theme of mutual interest. They suggest interviews should involve a balanced power relation where a professional conversation between equal partners takes place. Knowledge is therefore constructed in the interaction between the interviewer and interviewee (Brinkmann and Kvale, 2015).

As I desired to minimise the risk associated with obedience compliance, and desired

to obtain true accounts that involved descriptions of practice and justifications, it was essential for me to build trust. Furthermore, it was also important for me to understand the phenomena from the subject's point of view to bring about a social production of knowledge (Brinkmann and Kvale, 2015). To gather the trainees' personal narratives and encourage them to speak freely, I considered one to one interviewing to be the most appropriate tool. The flexible design of interviewing is commonly used in small scale qualitative research as this method provides opportunities for spontaneity and direct contact with research participants. I selected this method as it supports the phenomenological nature of reality, whereby multiple views of the same phenomena can be explored. This creates a particular sense of detailed depth to the analysis (Smith, Flowers and Larkin, 2009). This process does not involve eschew generalisations, but rather prescribes a different way of establishing those generalisations (Harre, 1979).

I aimed to engage with the participants in collecting the data. I refrained from approaching this study with a fixed hypothesis to test, but rather two broad research questions to form and scaffold the exploration. The resulting analysis is therefore described as inductive, driven by the data as opposed to deductive, which is driven by existing theory and literature. To ensure the data gathered contained a depth of detail and included time for reflection, I also decided to include video clips. This approach afforded a focal point for responses, enabling the participants to describe their experiences in more detail introspectively. This strategy also provided powerful authentic examples of typical actions and behaviours in real-time. It was anticipated that this tactic could overcome the biases associated with using a single method and enhance the reliability and credibility of the study's findings (Robson, 2011).

3.6 **Recruitment Strategies**

I made use of purposive criterion sampling (also known as a judgement or selective sampling) to recruit participants. I used this method of sampling as it generated a group of participants that have all experienced the phenomenon of using manipulatives. Therefore, I was able to describe the significant impact of the findings.

Although I teach across many programmes of study, I decided to focus specifically on the PGCE trainees. This effective method of sampling is deemed efficient when only a limited number of participants can serve as the primary data source. Smith, Flowers and Larkin (2009) highlight researchers should attempt to recruit a fairly homogenous (similar) sample for whom the research questions will be meaningful. There were two PGCE models available: a full-time university-based course and a School Direct model (employment-based route into teaching). The university-based model took place on campus in the south of England, while the schools direct programme was delivered in the north of England. By choosing more than one route from which to select participants (two culturally different institutions), I hoped to avoid the results from the research questions being limited to one particular context. I will refer to the route when analysing trainees' accounts where I think it is relevant to the analysis.

I decided the interviews would take place on-site within the secure confinement of the campus in a quiet private room. It was important for me to create a comfortable environment for the interview to keep the participant calm and at ease in an atmosphere that they were familiar with. It was also crucial for me to establish a rapport with the participants so that they would feel comfortable sharing their authentic experiences.

Due to the participant anonymity afforded within the survey, the comparative element of choosing university-based postgraduate trainees (site A) and school-based trainees (site B) could only be determined and assessed during the follow-up interviews.

3.7 **Instrument Design**

A non-obligatory anonymised online survey was disseminated to all willing PGCE participants at the start of the academic term before the first placement (included as Appendix 2). Due to the time constraints of the PGCE course, I decided to circulate the survey at the start of the term to ensure sufficient time was made available for the follow-up interviews to take place. During the invitation, I introduced myself, provided a brief description of my research and explained how the results would be used to improve the programme of study in the future. I reassured the recipients that

participation was entirely voluntary and that they would be free to withdraw from the study at any time without penalty or prejudice to minimise the risk associated with obedience compliance. This sweep survey was carried out to identify primary participants, and the responses received assisted in the formation of some of the questions posed in the semi-structured interviews. This sharpened the focus of the ensuing interviews.

The survey included a five-point Likert scale, with some questions included that required the respondent to produce a more reflective response. A Likert scale is an ordinal psychometric measurement of attitudes, beliefs and opinions. A series of statements were presented, and each respondent was asked to indicate the strength of agreement or disagreement in a multi-choice format (Bell, 1999). The survey results provide a snapshot of the trainees' background experiences of using manipulatives. This highly versatile type of survey does not force the participant to take a stand but permits the freedom to reply in a degree of agreement which makes it easier and less threatening for the respondent. The survey also permits a neutral or undecided response to be recorded. The answers allowed a quantifiable method of collating accumulative data.

I created the Likert scale through a range of practices. Retrospection, preliminary literature readings, reviewing the findings of my IFS, and my research proposal aided in the identification and creation of important areas for investigation. Engaging in this process helped me to make improvements to the initial research questions, aims and assisted in the production of a flexible list of topics to be covered within the interview (Bryman, 2012).

The semi-structured interview schedule (included as Appendix 3) was developed, refined and updated through a process of reflection with my supervisors and colleagues. The schedule, therefore, underwent many stages of revision. This process was fundamental as I believe the first few drafts were influenced by my perception of trainees and what they should be doing (for example I assumed all trainees would have made use of manipulatives in the classroom). However, the final draft refrained from prepositions about the expected practice and instead invited the trainees to discuss their experiences as they wished. The final schedule included ten

questions with probes and follow-up questions to encourage participants to elaborate or clarify responses. The semi-structured schedule contained an introduction that included instructions for opening the dialogue with the participants. This was followed by some key open-ended questions that centred around gauging the trainees' background experiences of using manipulatives, experiences of using manipulatives at university and accounts of use on placement. It was anticipated that more specific questions would be added as the interview progressed in response to themes that emerged.

At the end of the survey participants were given the option to provide contact details should they wish to partake in the follow-up interviews. The follow-up interviews were conducted with a convenience sample (based on who was available at the time) to avoid bias surrounding selection and participation.

The respondents who indicated they would like to participate in the second stage of one to one interviews were contacted via email within two weeks of the dissemination of the survey and issued an information sheet and consent forms (see Appendices 4, 5 respectively). The information sheet included a brief introduction detailing the study and how the results will be disseminated. A consent form was also issued for the school gatekeeper for the video recordings to take place (see Appendix 6).

All respondents who provided consent were included irrespective of gender, race or perceived ability. I did not expect the research to raise sensitive material, however, as a precaution the information sheet stated that the researcher might not be able to guarantee complete anonymity should the participant disclose a safeguarding issue that impacts on the safety and well-being of anyone involved in the study. All participants were again reminded of their right to refrain from responding to any questions without penalisation should they feel the questions posed were of a sensitive nature (e.g. ability set). I complied with safeguarding procedures in accordance with current best practice. The participants were informed their identity would not be disclosed and pseudonyms assigned. All issues related to confidentiality was in keeping with the British Education Research Association (BERA), General Data Protection Regulation (GDPR) and Data Protection Act (Great Britain, 1998). The recruitment process of interview participants is discussed in significant detail below.

3.8 **Video-stimulated Inquiry**

Trainees were invited to bring along video excerpts involving the use of manipulatives on practice as a stimulus during the interview. I deemed this strategy would enable the trainee's to be more articulate and thoughtful in their reflections. The videos were not used as a data collection form, but rather a discussion prompt during the interviews. Substantial support can be found in the literature for utilising the medium of video recording as a supportive agent (Coles, 2014; Coles, 2013; Armador, 2017; Blomberg et al., 2013). They hold the potential to play a vital role in enhancing effective reflection. This is known as an inquiry-based process to classroom learning that empathises exploration of the individuals' experience, as set out in the literature review.

According to Fichtman Dana and Yendol-Hoppey (2002), video recordings are a useful means of collecting descriptive information, better understanding natural interactions (or unfolding behaviours), capturing verbal and non-verbal instruction, group dynamics, and the influences of the physical surroundings of the learning situation. Video footage captures a single snippet of action (in this instance, between two and four minutes of video) in the classroom over a set period. According to Coles (2014) between two and four minutes of video provides just enough scope for fruitful discussion, enabling the researcher to retain a positive focus and avoid going off task.

I gave the participants the option to select any clip they wished to bring that involved the use of manipulatives. I anticipated this process would increase trust, confidence and eliminate conforming testimony. To ensure I was able to meet with all the participants, I provided guidance relating to the length of footage (maximum of four minutes) and requested that the recordings were of the participants' hands only. This guidance (See Appendix 4) also outlined the reason for the use of video clips.

One of the challenges I faced in getting this method to work related to the access arrangements of video clips. I had no advance knowledge of the clips the trainees would select, or if they would attend the interview with a video clip at all. The footage varied in length, size of groups and was filmed from different angles of the classroom.

During the first two interviews, it became apparent how difficult it was for the trainee to focus solely on the positive aspects when confronted with video evidence of themselves. The trainees initially responded quite judgementally towards the video footage and attached labels for what was taking place. Those labels were then linked to actions, e.g. pupils were off task. Coles' (2014) study reports the difficulties of using videos and found participants can initially respond quite judgementally to the use of videos as a reflective tool. He discusses the challenges associated with steering the participant away from using predefined negative labels to judge the video towards forming generalised descriptions. Coles (2014) is quoted "*A common problem is reported in the difficulty of keeping teacher discussion of video away from judgement and evaluating*" (2014:267).

Coles (2019) reasons in the classroom environment the teacher has to make judgements quickly and therefore assign labels for what is going in the classroom such as 'engaged' or 'disengaged'. These labels are then often used to interpret the video footage. As these labels are very strongly linked to actions, there are actions the teachers will take in response to those behaviours. The teacher can then develop a pre-programmed way of responding to these labels (Coles, 2014). Therefore should a participant engage in evaluation and judgement (positive or negative) the opportunity for change is limited. Lesseig et al. (2017) is cited,

> *"A critical factor in promoting productive teacher discussions is the ability to maintain focus on evidence-based interpretations and avoid premature judgements or evaluation. Evaluation leads to classifying and explaining away events, closing down opportunities for teachers to consider mathematical ideas deeply or reason pedagogically" (2017:593).*

It was my role as a researcher to ensure the student did not lapse into the evaluative or judgemental mode. During each playback, I established discussion norms by highlighting explicitly my expectations each time the trainee attempted to lapse into judgement mode, and ensured the talk remained reflective and questioning (van Es and Sherin, 2008). During the reviewing of the clips, my role was to act as a facilitator for the discussion. As I was the facilitator, I also made some of the decisions about how to pace the discussions, what to review, when to move on, and when to pursue a particular point.

According to van Es, (2010), noticing involves identifying noteworthy events during classroom interactions, making use of the knowledge of the pupils, curriculum content and the school context to reason about these events. Mason (2002) offers two key distinctions between offering '*accounts of*' phenomena and offering '*accounts for'* phenomena. The position I have adopted - '*accounts of*' phenomena aims to avoid judgement or evaluations, whereas '*accounts for'* phenomena aims to explain what is perceived or interpreted (Mason, 2002).

As this study aimed to capture and explore the meanings that participants assign to their experiences, the initial task was to simply describe what was happening as a starting point. The clips were played twice during each interview where video recordings were present, first to identify anything positive they noticed of interest. The second time the clip was played to determine sections where the participant identified as important and wished to discuss in greater depth. This is an important feature of current frameworks for using video footage to focus the teacher/trainee discussion on the detail of events and avoiding untimely evaluation and judgement (van Es and Sherin, 2008).

During the deconstruction of the video clips, some of the trainees commented on how much action they missed during the process of teaching. During the second viewing, the discussion took on a renewed focus surrounding possibilities, and the discussions became much richer. The trainees relaxed and became more receptive to interpreting new actions in the classroom too. van Es (2010) posits videos can help trainees/teachers learn to notice because it captures much of the complexity of the classroom interactions, providing multiple perspectives, as well as allowing the participant to interrupt their typical routines. I also found the video clips could be used to create a 'safe space' for discussions to take place and transgress the usual boundaries (hooks, 1994).

3.9 **Data Collection**

Narrative interviews centre on the stories the subjects tell and the structures of their accounts (Brinkmann and Kvale, 2015) therefore, I perceived that this would be the best interview technique to adopt. Narrative interviews can occur spontaneously or be elicited by the interviewer. I used Brinkmann and Kvale (2015) text to help structure the use of probing questions that elicited an in-depth, rich response.

Although the information sheet suggested that each interview would last for thirty minutes, each interview lasted approximately forty minutes. In each of the interviews that overran the allocated time frame, the participants were happy to continue discussions. I collected all data for the study from the eight single semi-structured interviews conducted with the participants. The eight interviews were conducted between June and July before the trainees' exit day. Hermeneutics of IPA specifies the timing of questions can impact significantly on the responses issued. For example, if the participants were interviewed immediately after an observation while on placement, the answers elicited may differ and avoid the depth of reflection required. I decided it was important for interviews to take place after the trainees had completed their placements and had time to reflect on their experiences.

Interviews were conducted at a time and place on campus that was most convenient for the participant. Linden's (2016) research indicates the temperature and conditions where the interview takes place will invoke different feelings and characteristics in rooms that are cold in comparison to hot. I ensured that I kept a log, remained mindful, and documented the environmental factors as accurately as possible during the interviews.

I found the first two interviews to be the most challenging to conduct; however, I felt my technique improved with each interview as I was able to use my previous experiences to manage the conversations. The dynamic between interviewer and interviewee inevitably varied, and I adjusted my interaction style to suit the interviewee.

For me to concentrate on the trainee's perceptions and accounts of use during the interview, I made use of a digital recording app on my mobile phone and laptop. I recorded on two devices should one recording fail. Taylor and Bogdan (1984) suggest recordings can alter what participants say in the early stages of the interview, however, a recorder allows the interviewer to capture so much more than they could retain via memory. During all the interviews, I made sure I had a note pad and pen to write brief notes of significance points, and further questions that I felt may be useful in the subsequent interviews. For instance, during the interview with David, I scribed "White Rose Hub strict". I used this response to solicit further information about the use of manipulatives in conjunction with this programme of study through additional probing questions. I also kept a copy of my semi-structured interview questions alongside the notes to seek further elaboration in a natural conversational manner.

During the review of the footage there were moments when I wanted to act one way, as a tutor, and a different way as a researcher and the participant and I held different interpretations. I careful noted these occurrences for consideration later. While the interviews were taking place, I decided against making detailed notes to ensure the discussions progressed naturally. I did, however, refer to the semi-structured interview guide frequently to ensure that each of the main topic areas was explored and specific questions asked, although not necessarily in the order I had initially identified. On occasions, the participants were encouraged to take the lead influencing the direction of the discussions. Topics that appeared important to their unique experiences were explored further. For example, Sacha wanted to discuss the lack of flexibility and assessment within mathematics lessons which influenced her choices in the selection of materials.

According to Brinkmann and Kvale (2015) the requirement of sensitivity to, and foreknowledge about the topic of interview contrasts with the presuppositionless attitude. Knowing or just identifying some of the prospective participants' key terms in advance can help form questions, and put the research participant at ease creating an opportunity for them to convey their story without interruptions (Charmaz, 2014). A lack of shared understanding of key terms can also significantly impinge on the data produced. This process of introspection also enabled me to remain focused during the interview and avoid interruptions such as the posing of questions for further detail while

the trainee was in mid-flow. At times it was almost like I was in the front row seat of a theatre watching the action unfold while at the same time I had access to the back-stage experience knowing what it takes for the performance to unfold. I was able to make novel connections between their experiences and mine. This experience informed the questions that the trainees were asked as I was keen to avoid biases and assumptions.

Following the collection of data, all participants were debriefed to ensure that they had not been adversely affected. Participants were also given the opportunity to reflect upon their contributions allowing reasonable attempts to address misconceptions, ask questions and were thanked for their contribution (Morrow and Martin, 1996).

3.10 **Ethical Issues and Risk to Participants**

The UCL Institute of Education necessitates that all students gain ethical approval before conducting research. I applied to the supervisor and advisory committee prior to the initiation of the study. Ethical approval was granted for the study by the IOE Research Ethics Committee. The completed Doctoral Student Ethics Application Form is enclosed as Appendix 1. I also ensured the study was compliant with ethical and safeguarding procedures in line with current best practice and procedures. This was to avoid a breach of privacy, legal consequences, anonymity and confidentially, as well as potential ethical harm to the reputation of the organisation.

Understanding power relations and the implications has become increasingly more critical when conducting research (Coles, 2014). I needed to acknowledge the extent to which the research could potentially impinge on trainees. The dual roles I undertook while carrying out this research could have also potentially caused tensions in areas such as psychological harm, privacy, anonymity and confidentially and had to be addressed accordingly (Brooks, Riele and Maguire, 2014). I therefore continued with my practice of learning from the trainees and creating participatory spaces as part of my teaching.

Informed consent is closely aligned with the ethical principle of respect for persons.

Participants who provide informed consent were also afforded the right to withdraw at any given time. It was perceived informed consent could lead to a more balanced or equal relationship between researcher and respondent (Brooks, Riele and Maguire, 2014). This brought about a positive impact surrounding the quality of the data collated as the respondents felt more confident and willing to share their perceptions.

As this research was conducted by me and the accounts dependent on my perspective as the person conveying the information, every effort was made to ensure that the perceptions and accounts transcribed were a true and fair reflection of the participants' experience. While narratives can be used to empower and humanise, they also have the power to repair. As I chose to refrain from using a single story about the trainee's experiences with manipulatives, it was anticipated a wider perspective, and a truer account would be gained (Adichie, 2009).

A small potential risk of physical and/or reputational harm to the researcher existed. As it is important that all potential risks were identified and planned for, all interviews took place in locations deemed safe where the students could not be overheard. The supervisors I have assigned also offered guidance and mitigated the study.

I held an ethical obligation to consider the voice of pupils who were also part of the study as pupils are considered vulnerable, placing forward various procedures to protect them when conducting research. The Children and Families Act (Great Britain, 2014) enforces that pupils should be consulted about matters that affect them. Although video recordings are often associated with naturalistic approaches to collating data, as this research was carried out with minors, informed consent was sought in accordance with the policy of the school (Opie and Sikes, 2004). The trainees retained the footage as the aim was for the videos to serve as a prompt.

I also informed the participants a professional transcription service would be used, and any external services that were utilised would be compliant with confidentiality agreements. I notified participants quotes would be utilised within the write-up for the thesis; however, all identifying information (such as names and places) would be removed. The participants were informed that my supervisors and representatives from academic, professional bodies could only access anonymised scripts.

3.11 **Data Storage and Security**

UCL necessitates that researchers must pass the GDPR course before conducting research, and students must apply for a UCL Data Protection Registration reference. I ensured that I was compliant with both before undertaking the research. The reference code obtained was No Z6364106/2018/04/113.

The BERA (2018) written guidelines were also adhered to when storing data. The online survey results will remain cloud encrypted to private access and stored for a maximum period of five years and destroyed when no longer required. All data from the survey, interviews and visual methods was anonymised (each participant assigned a pseudonym) with the allocation of codes and password encryptions. To avoid loss of encrypted data, or in case of the failure of encryption software, an unencrypted copy of the data collected has been placed in a secure environment.

3.12 **Insider Research**

'Social situatedness' can be viewed as a concept relating to the idea that the development of individual intelligence requires a social and cultural influence (Vygotsky et al., 1978). It also denotes that multiple perspectives are required in order develop a thorough understanding of a given context (Tedlock, 2000) and 'situatedness' arises from the interplay between the researcher, the situation and position held by the researcher (Lave and Wenger, 1991). Therefore, my prior experiences in the classroom can have an impact on the validity of the research. However, by using the 'insider' approach, the trainees became more comfortable, established trust and spoke more freely of the usual social interactions (Tedlock, 2000). This strategy provided a wealth of knowledge an outsider would not necessarily be privy to, seeing as I could talk more freely and openly with the participants.

3.13 **Researcher's Background**

I had met all the participants before the study as I deliver mathematics sessions to them. At the start of my teaching sessions, I insist everyone's presence is acknowledged, and everyone's contribution is valued. This approach reflects my educational philosophy, where I deem teaching and learning is a collective effort. I do not expect the trainees I teach to take risks that I would not undertake, or share experiences that I would be unwilling to share. In all of my taught sessions, I shared reflections of my experiences/critical incidents of teaching and learning. I encouraged students to engage in this process of reflection, contributing where possible their experiences. Therefore, it came as no surprise to the trainees that my passion and interest in their experiences continued outside of the professional learning environment. hooks (1994) is cited *"When professors bring narratives of their experiences into the classroom discussions, it eliminates the possibility that we can function as all-knowing, silent interrogators"* (1994:21).

I found I shared several commonalities with the participants that enabled me to immediately establish a level of trust and rapport, encouraging the trainees to share their insights and perspectives willingly and openly. My educational background was, in many ways, very similar to many of the participants. I believe as I already knew the participants and had already established a rapport, the interview atmosphere was less intimidating, therefore more relaxed and pleasant. I believe this helped remove the potential concerns that their practice would be evaluated or judged during the interview.

3.14 **Procedure**

Smith, Flowers and Larkin (2009) characterise a set of common processes in IPA to encourage reflective engagement with the participants' accounts, and these were used flexibly to help guide the process. The process outlined below was designed to encourage reflective engagement; therefore, the analysis is a joint product between the participants and me.

The developing heuristic framework for analysis involved moving from a focus on the individual to a more shared understanding and from descriptive to more interpretative. I have presented a table below describing the stages involved (adapted from Smith, Flowers and Larkin, 2009). Antaki et al. (2002) state that in making use of clear and succinct guidelines means that the 'anything goes' critique of qualitative research is avoided. It also ensures an insightful deep representation of the data takes place.

Although the table is presented in a linear format, the analysis involved a more iterative process of engagement with the transcripts. I approached the analysis with a hermeneutic circle in mind. This iterative process involves understanding the text as a whole and this is established by reference to the individual parts and understanding of the individual parts is by reference to the whole.

Table 1: Steps to Analysis

Steps	Description
1. Reading and re-reading	Transcribe the first transcript while listening to the audio. Become immersed with the data.
2. Initial noting	Identify emergent themes and patterns using specific phrases that carefully capture the essence of the phenomenon. Include exploratory comments. Run word frequency queries to identify unexpected themes from the data.
3. Developing emerging themes	Analytical shift to working primarily with emergent themes. List the emergent themes without too much concern about connections between themes. Each theme must be accompanied by short verbatim extracts from the actual interview.

4. Searching for connections across emerging themes	Cluster the themes making sure to avoid redundancy and repetition. Group the themes into “superordinate” (most important) and “subordinate” (less important but relevant) based on the research questions.
5. Moving to the next case (next interview transcript)	Repeat the process with each case carefully noting the emergent themes and clusters. During this stage, it is important to treat each case in its own terms and ‘bracket’ the ideas from the analysis of the previous case. New themes will emerge from each case.
6. Looking for patterns across cases	Condense themes into 'master' themes. Select compelling extract examples for final analysis, relate to research questions/literature and produce a well-defined concise report of the analysis.

The table below is an example of the initial level of analysis which involves examining the semantic content and language.

Table 2: Extract from David's Interview Transcript (case)

Emergent theme	Original transcript			Exploratory comments
	Interviewer:	00:00	Can you tell me about how you came to learn mathematics?	
Negative feeling learning mathematics Textbook Status quo	David:	00:15	A lot of my school life wasn't a particularly good experience, um, throughout school my teachers, which basically gives you a textbook and ask you to read the paragraph and then you would answer the questions.	Negative experience because of the use of textbooks for learning?

Alternative name for manipulative Denied use of manipulative as a child Theoretical meaning abstract Independent learning Confidence from structure Love mathematics Pattern Teacher orientated/ directed Abstract			Um, and this was kind of done in maths as well. There was very little use of apparatus or any kind of... Um, it was very theoretical so it was difficult to learn because obviously you didn't have the things in front of you and you kind of learnt by yourself , uh, which is good in some respects, but obviously when you first try to do something, you need a little bit of guidance. Um, so I would say my initial.... I loved the concept of maths because it's all so logical, systematically, looking at patterns, figuring out patterns. And I love that type of work, but actually school myself, the experience I had wasn't particularly good due to not having the correct kind, of teaching ethos really. Uh, the teacher would just like sit down and say, right, we're reading through textbook page fifty-five. Um, and then we're answering the questions on page fifty-six.	Interesting use of the term apparatus. Theoretical meaning abstract? Work- toil, exert effort, Possible lack of confidence?
	Interviewer:	01:33	How did you feel about that?	
Struggle Textbook Feeling of dread Positive learning experience at home Negative feeling when learning mathematics	David:	01:36	And um, well it didn't really interest.... Because for one I was interested in maths and wanted to learn, but I didn't look forward to the maths lessons. Um, I actually look forward to it more when working through mathematical problems with my dad at home because we would use various bits and piece at home. I'm trying to think of what we used to use, um, because he was a computer programmer, so he did lots of solving mathematical equations, um, and was able to sort of help me through. But school wise I would say a feeling it wasn't a particularly good experience. So, I wouldn't say I look forward to my maths lessons.	What does interesting mean to David? Should have asked what bits and pieces he used at home. Preference for mental calculations?
	Interviewer:	02:22	What are your goals in relation to teaching mathematics now?	
Desire for pupils to avoid their experience Learning objective	David:	02:28	Um, goals wise it would be not to have the pupils go through what I went through. I would like them to be looking forward to each maths lesson that I teach, you know, and finish maths lesson and know what we're doing in the next one. Yeah, I think that would be my	What is interesting and enjoyable for David? Systematic? Sense of vocation?

Interesting and enjoyable			overall goal. Making it as interesting as possible and enjoyable as possible but obviously learning at the same time.	
	Interviewer:	02:54	Why did embark upon a career within the teaching profession?	Correct past pain?
Metaphors for learning Positive feeling Vocation	David:	03:01	Um, I love pupils, I love working with pupils is probably the main thing. I think that the best way to describe the reason for is the light bulb moment. Um, never ever get a feeling the same as when you teach something to somebody, especially a child for the first time, and it suddenly clicks. And the recognition in their face is like, wow, I actually get that now. You know, there's not another feeling like that. Um, so I think that's kind of the reason why I aspire aspired to be a teacher.	Strong positive feelings from the joy of watching others achieve
	Interviewer:	03:38	Do you feel confident about teaching mathematics?	
Confidence from structure Scheme of work Learning as tidy	David:	03:42	Um, in some respects, yes and in others no. But the maths that I've taught over teacher training where I have been exposed to in my current position, we follow like a strict kind of programme, The White Rose, which kind of starts with the basics in works through systematically. So, I think any of any parts that I wouldn't be, wouldn't be confident with....	Unspoken set of rules? Uncertainty Systematically What does it mean? Comfort in the rigidness of structure.
	Interviewer:	04:18	Yes.	
Confidence from structure	David:	04:19	This is a place where I can kind of look and be able to teach myself or brush up on it. Um, you know, so the confidence side, yes. You may not be as comfortable with certain things, but there is always somewhere you can kind of look.	See/look
	Interviewer:	04:34	So can you tell me a bit more about the White Rose hub?	
Concrete Learning styles theory Description of practice with manipulative	David:	04:41	Um, well, from my experience, um, it likes to teach basically concrete first so that the pupils get to physically manipulate things kinaesthetically, uh, so using Dienes blocks, using counters and you can do that with anything.	Descriptions of manipulatives Bruner's Stages? Dienes blocks – place value Counters for place value

The audio recordings from each of the interviews were transcribed into a single data set. The interviews were transcribed verbatim using Temi, an audio transcription service. All cases (interviews) were imported into NVivo (qualitative data analysis software) for analysis. Following the import, all cases appeared in alphabetical order. David's transcript was first.

I started with the first transcript (David) and noticed the data set produced was not wholly accurate. I listened to the audio while reading through the transcript line by line correcting omissions and inaccurate phases. I had to listen to the audio recording many times to ensure I fully understood the nature of what was being said and to move beyond a subjective interpretation of the text. I compared the transcripts against the audio and edited until the final version was word perfect. During this process, I became immersed in the original data and was able to identify initial emergent themes and probe areas of interest (Bryman, 2012).

Although the transcription and reading process is time-consuming, decelerating the habitual tendency of reading, permitted me to condense information and offered opportunities for reflection (Smith, Flowers and Larkin, 2009). I read and re-read his transcript (occasionally reading the transcripts backwards to rupture the narrative flow). Within subsequent readings of the transcript, I could imagine the interviewee's voice and actions (Smith, Flowers and Larkin, 2009). I labelled relevant descriptions of actions, activities, concepts, opinions or whatever I thought was relevant. Further themes were identified based on journals and books I had read, conversations with staff, and attendance of mathematics conferences or workshops. I read back through old journals I had read previously and noticed potential themes I had missed and included them. Themes were also identified when an entry was said more than once or surprised me. For example, I always start my sessions at the University by eliciting what is already known and reminding students of the significance of this phase in the teaching and learning cycle. Yet, eliciting prior knowledge appeared to be absent from the transcripts. As I read through and started to construct my theoretical framework for the study, it became apparent the complexities surrounding understanding experience and the human psyche. It was challenging at times to determine if what I

had coded as a theme was interpreted in the way intended. Annotations were included for further investigation.

New themes were introduced as a consequence of the ongoing process of reading. Themes were also revised based on readings of literature. For example, following the reading of hooks (1994), I preferred to use the term ‘lack of freedom’ as opposed to ‘control.’

Occasionally, parts of the text did ignite my interest (e.g. tender memories relating to my teaching career and how I had experienced mathematical learning as a child). It became apparent that some long-term (flashbulb) memories are stored and an emotional connection can spark the memory to replay. Yet, the very act of remembering can change or alter the memory (Duvarci and Nader, 2004). I did not code these memories as a theme but simply annotated with a note/memo for further investigation once I had completed the final read through. In this instance, I had to block out what was already known to capture the reality of the experience first-hand with a fresh view, while simultaneously acknowledging the privileged position of intuition (Heron, 1992). I engaged in the process of peeling back the layers gradually until the foundations appear. This strategy was informed by IPA methodology.

Once I had identified as many emergent themes as possible from David’s case that most closely captured the essence of the phenomena, all emergent themes were listed in alphabetical order in a table (see Appendix 7 for a list of themes for David). I then began to closely examine the themes, distilling and grouping them into superordinate and subordinate taking care to avoid redundancy and repetition using the research questions and aims to guide the process. On occasions, I placed like with like and developed a new name for the cluster. There were some themes such as (concrete) which could be used in response to either research question. Each theme was accompanied by short verbatim extracts from the data (see Appendix 8 for a table of subordinate and superordinate themes for David).

In keeping with IPA's idiographic commitment, each case was first analysed in-depth individually (Smith, Flowers and Larkin, 2009) following the same process as described above until all eight interviews had been analysed. Once I had completed the above-outlined steps for all cases, carefully noting the emergent themes and

clusters, I then looked for patterns across cases. This was achieved by drawing up a list of themes for each group and clustering them into a comprehensive master listing representing shared higher-order qualities. The master table of themes for the group can be found in Table 4 in the results section.

3.15 **Validity and Quality**

Assessing the validity and quality of qualitative research differs in criterion in comparison to quantitative research (Barker, 2002). While there are a number of guidelines available (Yardley, 2000; Elliott, Fischer and Rennie, 1999), Smith, Flowers and Larkin (2009) recommend Yardley's (2000) four principles: sensitivity to context, commitment and rigour; transparency and coherence; and impact and importance. I have chosen to present my research in accordance with these principles.

3.16 **Sensitivity to Context**

Yardley (2000) discusses the significance of sensitivity to context accomplished through contemplation of existing literature and theory, the socio-cultural milieu of the study, and the material gained from the participants. I endeavoured to demonstrate sensitivity to context in providing a rationale for my choice and through awareness of the pre-existing literature included in Chapter 2. The current literature underpinned the research itself and the study's findings are also related to additional relevant literature (in line with IPA methodology) in the discussion.

I also aimed to demonstrate sensitivity by close engagement with the idiographic, descriptions of the sample, and the manner in which the data was collated and analysed. I took great care with the collection of data and ensured the grounded analytical claims were consistent with a strong IPA study. All arguments were supported with verbatim extracts in the subsequent Chapter, and interpretations are presented as possible readings, and more general claims are offered cautiously. I also provided a thorough account of the stages of analysis (in section 3.14). I showed

empathy during the interview by ensuring I put all participants at ease recognising interactional difficulties. The power relations between myself and the participants (ethical issues) were all considered sensitively at all phases of the study. Smith, Flowers and Larkin (2009) contend that this process provides participants with a voice and permits the reader to check interpretations made.

3.17 **Commitment and Rigour**

I aimed to demonstrate a commitment and rigour through attentiveness to all participants during data collection. I personally committed a considerable amount of time and care to analyse each case separately at first to attend carefully to what each participant said.

I engaged in sufficient idiographic engagement moving beyond just a simple description. I intended to reveal details of importance to the reader about the individual participants as well as about the themes they shared.

3.18 **Transparency and Coherence**

Transparency refers to how clearly the stages of research are described and the level of coherence between the research that has been carried out and the underlying theoretical assumptions of the approach being adopted (Smith, Flowers and Larkin, 2009). In section 3.3 to 3.4, I demonstrated the degree of the fit between my study and IPA rather than wishing to adhere more closely to the expectations of a different qualitative approach.

I have also aimed to enhance the transparency of my analysis by including an audit trail above and within the Appendices, ensuring when presenting the data all ambiguities or contradictions are dealt with clearly and sensitively. Smith, Flowers and Larkin, (2009) suggest contradictions may be presented as they are often the richest part of the text. Still, the analysis of the contradictions should not be in itself contradictory.

Yardley (2000) also includes a consideration of reflexivity within the principle of transparency, and a discussion of this has been presented in section 3.13 and elsewhere.

3.19 **Impact and Importance**

The final principle reflects that however well or sensitively research is conducted, the real test of validity lies in whether it tells the reader anything interesting, essential or useful. I have included a consideration of the educational relevance of this study in Chapter 6.3.

Chapter 4: Data

4.1 **The Participants**

The participants consisted of five women and three men who were all enrolled on the PGCE course (refer to table 3 below). Pseudonyms were assigned to protect the participants' confidentiality. The length of prior teaching experience varied, nevertheless met the requirements for enrolment on to the course. Surprisingly, although many of the participants had gained experience of teaching prior to enrolment, this experience did not necessarily involve the delivery of mathematics lessons or the subsequent use of manipulatives.

Table 3: Characteristics and Demographics of Participants

	David	**Donna**	**Sacha**	**Sarah**	**Samantha**	**Sean**	**Sophie**	**Steven**
Course Type	School Direct	School Direct	Full-time PGCE	Full-time PGCE	Full-time PGCE	Full-time PGCE	Full-time PGCE	Full-time PGCE
Ethnicity	White British	White British	Black British	White British	White British	Indian British	Chinese British	White Irish
Video	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Prior Teaching experience	Full time TA KS2	Full time TA KS2	3 years (TA) KS1 and KS2	1 year (TA) KS1	15 days KS1 and KS2	Observed KS2	1 year (TA) KS1 and KS2	Observed KS1 and KS2
Type of school	Primary	Primary	SEND and Primary	Primary	Primary	Primary	Primary	SEND
Placement	KS2	KS1	KS1	KS1	SEND KS2	KS2	KS2	KS2

I have made use of the 'story boxes' below to assist with contextualising the sample. These story boxes demonstrate some background information about each participant such as their prior experiences of teaching and learning with manipulatives as well as a brief synopsis of the video footage.

4.2 **Story Box Situating Each Participant**

David

Prior Experiences of Using Manipulatives

David had enjoyed a long and successful career as a teaching assistant supporting predominately Key Stage Two (KS2) classes in the North of England before enrolling on the School's Direct programme. He decided to embark on a career in teaching as his family were of an age where they required less support. During the interview, David shared his own personal journey into teaching, motivated by his desire to support his son who had been diagnosed with autism.

David described himself as having gained some limited experience in using manipulatives both at home and school. He listed using conventional materials such as Dienes blocks, counters, number lines and Numicon. David explained his classroom had five tables; two lower ability tables, two middle ability, and one higher ability table. Within his classroom, each table had designated trays. The tables labelled as “lower ability” contained the majority of the manipulatives. David described a preference of ‘break the learning down into steps’ when teaching.

Video Clip

David decided not to bring a video clip but was still keen to participate in the one to one interview and share his experiences.

Donna

Prior Experiences of Using Manipulatives

Like David, Donna had spent three years as teaching assistant supporting mostly KS2 classes in the North of England before enrolling on the School's Direct programme. A few members of her family were also teachers. She described having gained some limited experience teaching with manipulatives. Donna listed manipulatives (such as clocks, Numicon, shapes and counters). Her goals for her pupils centred around building confidence with manipulatives. She clarified it was important to her that pupils gained a "concrete understanding."

Video Clip

Donna brought a short clip of her teaching a year two class of approximately twenty. The pupils were exploring commutativity - doubling and halving in pairs; each pair sharing a ten-frame and counters. In the example, Donna was stood at the front of the class modelling how one grouping context can be represented by two multiplication equations. E.g.

$3 \times 2 = 6$ *'Three twos are six.'* $2 \times 3 = 6$ *'Two, three times is six.*

Donna modelled the commutative properties on the interactive whiteboard with a range of movable red circles. The process of unitising was also modelled with these circles, which involved thinking of a number in terms of groups.

During the review, Donna struggled to focus solely on the positive aspects of the lesson at first. Once she concentrated on the positive characteristics of the lesson, she became more aware of how many interactions were missed by assuming a position at the front of the classroom.

Sacha

Prior Experiences of Using Manipulatives

Since completing her undergraduate degree, Sacha had spent three years employed as a primary school teaching assistant prior to enrolling on the full time PGCE course. The majority of Sacha's teaching experience involved delivering music lessons. On a few occasions she had managed to make use of conventional manipulatives such as beads, counters, Unfix and Dienes blocks. She described the significance of breaking "down tasks into smaller steps" to make learning accessible for pupils.

Video Clip

Sacha brought a video clip of herself delivering a mathematics lesson to four year two pupils she later identified as "lower ability." Sacha explained the video recording had taken place in the library in accordance with the usual procedures for this group of pupils. Each child had a set of beads coloured in yellow and blue. They appeared to be learning subtraction facts. She first explained the coloured beads were grouped in sets of ten. Sacha demonstrated the procedure of counting out seventeen beads, and then modelled how to take away or move nine beads to the opposite side from the seventeen. Sacha then explained the remaining beads were the answer. The calculation (17- 9 = 8) was then scribed on to a large whiteboard for the pupils to see. The pupils were directed to follow her example with the beads. Sacha explained her aim for the lesson was to move the pupils from a physical understanding to a "mental understanding."

Samantha

Prior Experiences of Using Manipulatives

Samantha had just completed an undergraduate degree before embarking on the PGCE course. She had enjoyed a short placement of at a nearby school and had decided to embark on a career in teaching. During her placement, she had gained the opportunity to make use of a small range of manipulatives such as Numicon, counters and Multi-link cubes. Samantha described her goals were to build confidence with manipulatives and ensure all the pupils' needs were met.

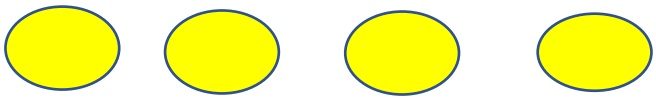
Video Clip

Samantha brought a short video clip of herself working alongside the class teacher in the classroom (SEND provision school) delivering a mathematics lesson to four pupils. Samantha was sat at the table as the teacher stood at the front of the table next to the whiteboard. A range of double-sided counters, pencils and mathematics books were placed in the centre of the table in preparation for the lesson. The pupils were all seated around the table observing the class teacher.

The lesson objective appeared to involve subtracting negative integers with double-sided counters.

First activity

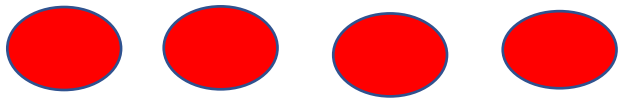
4 - 2 = with counters



The above subtraction had been carefully scribed onto a whiteboard. Samantha's teacher carefully counted out four yellow counters into the middle of the table, with one to one correspondence. She then explained to the group the yellow counters represented positive amounts. The teacher then removed two yellow counters and explained the remaining two yellow counters represented the answer. The pupils watched the activity carefully. The pupils did not touch or replicate the activity with the counters.

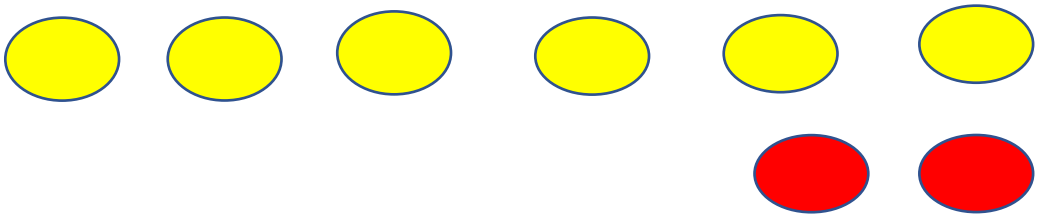
Second activity

-4 – (-1) =



The class teacher carefully counted out four red counters this time and described how these represented negative integers. Samantha's teacher modelled how to subtract negative integers. In the example above negative four minus negative one is negative three. This time the pupils were asked to handle the counters and replicate the activity the teacher had demonstrated.

4 - 6 = - 2



In final example, Samantha appeared to model the concept of zero pairs. The pupils were handling the double-sided counters as Samantha stood at the front and scribed the above calculation on to the whiteboard. The class teacher, who was sat beside the pupils, requested the pupils stop what they were doing and observe Samantha's activity. An array of counters, some red and some yellow were sprinkled around the table. Samantha pushed the majority of the double-sided counters to one side of the table. She appeared to be creating space for her activity. Like her mentor, she started carefully counting out four yellow counters which she identified as positive counters and explained to the pupils that she did not have enough counters and would require an additional two. The pupils immediately asked questions and discussions commenced around the table. Two of the pupils started to handle the counters.

Samantha appeared to be extremely nervous and continued to explain over the pupils' voices how she required two more yellow counters to make six and then added another two red. The class teacher stood up and resumed the rest of the lesson.

During the reviewing of this clip Samantha appeared distressed and initially responded quite judgementally. During the second viewing, she relaxed.

Sarah

Prior Experiences of Using Manipulatives

Like Samantha, Sarah had just completed an undergraduate degree before embarking on the PGCE course. While enrolled on her undergraduate degree, she had gained some experience of working part-time as a teaching assistant supporting a year one class with reading. Samantha described observing the class teacher she supported using of a wide assortment of manipulatives such as “money, Multilink, chimneys (Numicon) and shapes (hexagons).

Video Clip

Sarah brought along video footage of a year two class using a wide range of manipulatives (counters, beads, 5p coins, Numicon, Unfix) to multiply in groups of five. All the pupils were working at tables with what appeared to be different tasks. The camera footage moved directly forward to one child in the group who miscounted the number of counters. The class teacher could be heard questioning the child if they were sure they had the correct answer. The child counted again with Sarah's assistance and adjusted his response.

The camera footage moved back to the group. Sarah was modelling the aggregation procedure of grouping the numbers before forming a union set, making use of the interactive whiteboard. A graphic was on the screen of frogs sat on a Lilly pad. The small group seated at the table in the front of the interactive whiteboard were making use of Dienes blocks. The video footage went on to show a large group of pupils independently scribing in their books.

Sean

Prior Experiences of Using Manipulatives

Sean had enjoyed a long and successful career before embarking on the PGCE course and had decided on a career change into teaching to fulfil his sense of vocation. He had no experience of teaching beyond a short placement before entering the course. Sean did not have any experience of delivering mathematics lessons before the start of the PGCE course.

Video Clip

Sean brought a short clip where a year five child was working one to one with him outside the classroom using Dienes blocks to answer word problems and develop mental mathematics strategies. One of the activities involved the question "*If one hundred and fifty-two pupils each give two pennies to the school fair collection, how much would the teacher have in total?"* Sean explained to the child this task was related to doubling and the two times tables. During the interview, Sean handled the red Dienes blocks and modelled to the child how to use the Dienes which were split into denominations of hundreds, tens and ones to answer the associated problems. The child was then invited to replicate.

Sophie

Prior Experiences of Using Manipulatives

Sophie had just completed an undergraduate degree before enrolling on the PGCE course. While enrolled on her undergraduate degree, she had gained some experience working part-time as a teaching assistant. She recalled, during this time, she particularly enjoyed planning and implementing extracurricular activities such as food preparation lessons and questioned if these materials were types of manipulatives.

Video Clip

Sophie decided not to bring a video clip to the interview. While she was keen to participate in the one to one interview, she explained she felt too self-conscious and nervous to share footage of herself teaching.

Steven

Prior Experiences of Using Manipulatives

Steven had just completed an undergraduate degree in Ireland before embarking on the PGCE course. He had no experience of teaching beyond a short placement before entering the course. While Steven had observed several teachers make use of mathematical manipulatives such as “cubes and Dienes” to deliver the sessions, he did not hold experience of delivering mathematics lessons before the start of the course.

Video Clip

Steven brought a short video clip of him delivering a mathematics lesson to a year two class. The lesson appeared to be related to division and the pupils were tasked with sharing various items. Steven modelled the first few examples at the front of the classroom on an interactive whiteboard.

Steven made use of paper plates, and there were various manipulatives such as multi-coloured interlocking cubes and multi-coloured plastic fish. On the interactive whiteboard, there was a digital image containing ten brown buns and two white plates with the prompt "divide the buns onto each plate" scribed underneath. Steven read the task to the pupils first. He then asked the pupils seated on the carpet in front of him how he could solve this problem. Steven first modelled the sharing activity with buns on the interactive whiteboard prior to modelling sharing with cubes and paper plates with volunteers from his class.

Chapter 5: Results

5.1 **Overview**

Interpretative Phenological Analysis (IPA) of the eight semi-structured interviews resulted in the emergence of four master themes. These were as follows:

Purposes of using manipulatives

Practices of using manipulatives

Feelings

Teacher learning

In this Chapter, I present a concise summary of the overarching master themes found relating to the research questions. Examination of these master themes and their constituent superordinate themes (see Table 4 below) will form the basis of this Chapter, with each theme illustrated by verbatim extracts from the interviews.

Table 4: Superordinate Themes and Related Master Theme

Superordinate Themes	Master Themes
Inclusivity Build confidence Manipulative as a meaning-making tool	**Purposes**
Remedial use of manipulatives Pupils' lack of choice Chunking up information Institution rules	**Practices**
Confidence and competence Sense of vocation Metaphors for learning	**Feelings**

Concrete to abstract Reflection	**Teacher learning**

It is acknowledged that these themes offer one possible account of the trainees' experiences of mathematical manipulatives while on placement. They do not cover all aspects of the participants' experience. Superordinate themes were first identified based on their relevance or commonality to the research questions and aims. Superordinate themes were also identified if unusual or unexpected in comparison to the existing literature base. With IPA at this stage, the researcher must use their own interpretation framework and understanding to make sense of what has transpired in the study, while simultaneously capturing what has been shared by the study participants in their own words. It is conceded that my interpretation may be considered subjective, and other researchers may have focused upon dissimilar facets of these accounts. While these themes were common to the eight accounts, there were also other areas of divergence and difference, some of which are commented upon. I will say a theme is recurrent or pervasive if coded for more than 6 out of 8 participants and common or a majority view if reported by 5 or 6 participants.

During the presentation of the verbatim extracts, some minor modifications were made to improve readability. Trivial hesitations, utterances, repetition of words have mostly been omitted. Any missing material is indicated with dotted lines within brackets (…) and where material has been added to help make sense of participants' words (e.g. subject-specific vocabulary) square brackets are utilised. Dotted lines at the beginning or end of an extract demark the participant was talking prior to or following the extract. Given the idiographic focus of IPA, each participants' account was treated and written about in its own merit with specificity in mind. The data was then distilled and presented to create a group narrative.

Each section focuses on one master theme and related superordinate themes in turn. On occasions, subordinate themes were drawn on for added detail.

5.2 **Purposes of Using Manipulatives**

All trainees shared their perceptions that pupils benefit from using manipulatives while learning mathematics. However, there was a range of opinions offered as to whether certain groups of pupils benefited more than others. This master theme aims to capture the main purposes for using manipulatives during placement as described by the trainees.

Inclusivity

The participants commented upon the theme of 'inclusivity' when asked about the purpose for using manipulatives during placement. This recurrent superordinate theme was represented by seven of the eight participants rather than all eight but was still a strong one. Donna described, as a matter of fact, how she felt manipulatives were useful for all pupils. David's account, on the other hand, detailed his passion for making sure 'everyone had an input' in mathematics lessons.

Donna: I think they [manipulatives] are useful for all pupils.

David: I think everybody would take something away, but you know, some would take more than others and certainly with the concrete side of maths.

Steven was the only participant who questioned if manipulatives were useful for all pupils. He preferred to use manipulatives at the start of the lesson.

Steven: I wouldn't say all pupils. I'd say, certainly I think in terms of grasping the first part [of the lesson] I think they are essential.

When Sacha and Samantha were asked if they perceived manipulatives as useful for all pupils, they provided the following responses. While they also concurred

manipulatives could be helpful for all pupils, their accounts also detailed the challenges involved in achieving this aim.

Sacha: That's a brilliant question. My gut wants to say yes with a fervent nod, but I don't exactly know why yet. I think physicality supports thoughts and I think movement is thought.

Samantha: I think (...) if you're somebody like myself being like a trainee, sometimes it can be quite difficult to make math accessible for all (…) So, watching back videos like this helps you (…) to basically teach it yourself. You can get ideas on how to break down concepts.

The majority of participants articulated inclusivity as an important reason for using manipulatives, although there seemed to be some feeling that this was aspirational.

Build Confidence

Participants also described manipulatives as purposeful for 'building' confidence while learning mathematics. This pervasive theme detailed how the trainees felt the benefits of manipulatives accrued from consistent use after pupils became comfortable with using them. Steve described how using manipulatives simplified the process of mathematical learning, whereas Samantha's account details how using manipulatives enabled learners to build a repertoire of strategies.

Steven: I suppose they're just giving them the confidence, making it. Simplify it is as much as I can.

Samantha: So, they [pupils] get more confident, coming up with new ways around working something out.

The recurring subordinate theme 'engage pupils in learning' frequently appeared in response to questions about the purpose of manipulatives. This engagement referred to the degree of attention, curiosity, excitement and passion the pupils showed when they were learning or being taught.

Sacha: Unifix cubes. I don't know why, and I haven't even got a constructive answer to that. Why? Because they're colourful. So therefore engaging...

Sean: So here she is engaging. So here she's worked out the answer already in her head. And this I found fascinating because what was very clear to me, she could do nine times three [excitement].

Donna:…So that it is [mathematics lessons] fun and engaging for the pupils so that they don't find math at all boring and they actually want to do it.

The Manipulative as a Meaning-Making Tool

This recurrent superordinate theme addressed the extent to which the participants referred to the manipulative as a tool for sense-making. There was an expectation for pupils to 'see' mathematical relationships via the use of the manipulative. The trainees took for granted the pupils would see what they saw and understood about the connections between physical objects and mathematical concepts. Below, you will find a sample of powerful extracts from the transcripts that detail the trainee's perception of the manipulative as a meaning-making tool.

Steven: The first bit was trying to get her engaged in the process, and that wasn't easy as I thought it would be. I was looking to see whether she could translate the Dienes into numbers. Something as simple as that.

Samantha: Yeah it [the manipulative] helps them understand why that is the answer, like why it always come to that answer.

Sophie: So, we were using the Dienes to teach about tens and ones, and without it, I think they would have really struggled to understand it but using Dienes they managed to understand tens and ones and place value.

Donna: I would say if I asked a child a maths question without a real resource and they couldn't get the answer, I would then give them a manipulative to use and then

they could get the answer. You would know obviously, that the resource has had an impact on their learning.

Steven's account appears to describe his desire for pupils to move quickly from enactive mode to iconic. Although the above narratives confirm and describe manipulatives as purposeful for pupils' learning of mathematics, several of the trainees also expressed concerns about using them.

Sean's and Sacha's accounts below detail a concern that pupils could perceive the manipulatives as baby toys and become distracted from the process of 'real' learning. Sarah's transcripts revealed her determination to use the manipulative in what she deemed 'the right way.'

Sean: Because they [manipulatives] are used by lower year groups, (…) particularly if there are other pupils in that class who are not using them, and you're giving them manipulatives to use, it immediately, you know, highlights the difference. They think, oh gosh, I'm being given these baby toys because I'm clearly a baby and not like the others. And understandably that would set the child's mind against using it.

Sacha: I think they are just disregarded as some sort of toy, you know, (…) at a certain age like year five or year six. They kind of already relegated to the lower abilities within these year groups and are seen as a crutch.

Sarah: If they are not using them [manipulatives] correctly, (…), then it can't be used as evidence because they've not been taught the right method and how to use them.

Sacha described how during both practicums, the pupils enjoyed activities with the manipulatives and appeared to learn through play, although, she felt playing may be considered unacceptable or inappropriate for pupils. If learning did not take place in a manner that was required, the manipulative could be identified as the cause and further intervention imposed. Sacha gave an account of this perceived failure of the manipulative.

Sacha: So that's a very interesting thing is that in the failure of a resource (…). If a resource is not explained properly, and pupils do not know how to access a resource mathematically, then they will revert to just playing with it and just experimenting like kids do.

Although the accounts detail manipulatives were used as a meaning-making tool, the participants also described a desire to ensure the pupils who utilised manipulatives did not become too reliant upon them. This theme was pervasive. Sophie commented:

After they had used the Dienes, I took them away and then they were able to draw visually...

In contrast, Steven considered pupils did not need manipulatives at all, and it was best for pupils to stretch themselves.

Steven: I suppose sometimes they just don't need it. I've seen them using their hands for counting instead. I feel like if they get too reliant on counting that way then (...) they'll never feel the need to stretch themselves further…

As highlighted in the extract below, the manipulative was, on some occasions, utilised as a tool to reinforce behaviour management. There existed an expectation that the pupils follow the instructions precisely. If the pupils did not utilise the manipulative as modelled, they would be removed. The removal of manipulatives during lessons when pupils appeared to be playing was present in many of the transcripts.

*Sarah: …Some pupils get highly distracted by manipulatives, and you've got to really pinpoint exactly what you want them to do and put the expectation, and if this isn't done by such and such by x, y, and z [*deep breath*]. So, I think there's a boundary with manipulatives, how many you have, what they have access to.*

The transcripts revealed manipulatives were used by the trainees for purposes such as a meaning making tool. The participants commented on the visual aspects of the manipulative as being particularly helpful for pupils to make connections between enactive and iconic representations. There was an expectation that pupils follow the instructions precisely and it was taken for granted the pupils would 'see' what the trainee saw.

5.3 **Practices of Using Manipulatives**

This second master theme draws upon the shared practices with manipulatives as described by the participants and also observed in the video clips. This theme includes what appears to be habitual practices (although the trainees are novices) such as reserving the use of manipulatives solely for the pupils classified as requiring further support.

Remedial Use of Manipulatives

This superordinate theme represents the trainees' descriptions of how they accounted for manipulative use during the videos and subsequent interviews. Surprisingly, while the above narratives detailed the trainees' perceived manipulatives as an inclusive tool for all, there existed an unconscious connection between the use of manipulatives and remedial support. This is highlighted in the following table below. A table has been used to enhance readability.

Table 5: Superordinate Theme Remedial Use of Manipulatives

Superordinate Theme
David: We can all use counters and have that kind of support there for the lowers. I would hover around their table. *Donna:…I would then look at a different way of trying to support the lower pupils and their learning and perhaps try and produce a resource or looking online, asking other people how they have maybe taught that lesson using what resources are available.*

Samantha: …I would always try and give something for the lower ability definitely to help them.

Sean: Well, again, because so many of the class were gifted and talented, they didn't really need them [manipulatives]. These pupils could solve double digit multiplication questions in their head. (…) *there's a very high proportion of gifted and talented, but at the other end of the spectrum there are pupils who are probably working at year three. So, for those pupils, what I created was a laminated place value board....*

Sarah: Pupils who are higher ability pupils I find don't need manipulatives, and they're able to just visually see what's going on. So, with that concept of not having something they could quite easily get on with it, but lower down in the ability scale in the classroom. They need [manipulatives], they rely on those sorts of things, so it's letting them have them maybe for the first two or three lessons.

Not only were the manipulatives predominantly reserved for the pupils classified as requiring further support, but the transcripts also revealed increased adult presence. This result is in direct contrast to the approaches promoted at the University. At the time of the interview, while examining the video, Sarah stated in a matter of fact way:

The teachers put them into separate groups, which is good because they all have different resources to use, which is quite nice. And left them to it.

Analysis of the transcripts also revealed the pupils classified as requiring additional support were frequently removed from class and taught by the teaching assistant. An extract from Sacha's transcript can be found below.

Sacha: So basically I'll take them [pupils identified as lower attaining] out of the classroom, the main class to work with them or the TA [teaching assistant] in the library, one to one in the library or one to two in the library and just explaining how to use the number beads, telling them that the different colours are groups in tens…

The use of language describing grouping by ability was a prevailing superordinate theme. The trainees referred to word choices such as 'high ability' as an indication of higher knowledge value and low ability as encompassing 'lower value.' The label

of separate and difference was an overall powerful theme when discussing pupils who required additional support.

Pupils' Lack of Choice

The video recordings and subsequent transcripts disclosed the majority of interactions with manipulatives were trainee teacher orientated with a prevailing use of didactic approaches. The trainees always selected the manipulatives and directed the pupils in how they expected the resources to be used.

Sean: So, as you can see it's always me giving her the Dienes…

Samantha: I gave them some [manipulatives]; I gave them some questions to all do first…

Sarah: I would give out resources for the pupils to use but the more able they wouldn't necessarily need to use them.

David: You can pinpoint the pupils that you could ask questions.

Aside from David's comment above, there was little evidence of the trainee making use of the manipulative to aid or support mathematical discussions and effectively develop learner's communication skills.

When asked to describe how manipulatives were used on the practicum, the trainees responded they modelled how to use of the materials first as they were afraid pupils would not 'see' the connections. There was a sense of compliance from the pupils in the transcripts and video recordings. There was no evidence that the pupils were offered any choice in the selection process and were mostly restricted to the use of Dienes, Unifix cubes, or counters.

Steven: The Dienes have been useful, and I used them at the start. I have used the counters, but there are so many different ones I could use.

Sarah: The Multilink or the Unifix is always very good for everything to be honest, which is quite nice because you can split them…

Interestingly, although trainees are guided at University to always start lessons by actively engaging with the pupils and eliciting their prior experiences, there was little evidence of this practice taking place too. The transcripts detailed numerous references to what the trainee thought the pupils knew (a subordinate theme). Few references were made to the sharing of learning aims to ensure knowledge was accessible. An extract from Sean's interview is found below.

Sean: She was just making a pretty pattern. Yeah, she was just sorting them.
Interviewer: Did you ask her what she was doing?
Sean: She was just trying to put them. Keep them in some type of order. Making the blocks the same size.
Interviewer: Did you ask her?
Sean: No, I didn't…

Although all the participants stated they experienced freedom in the choice of manipulatives they could use for their lessons, the transcripts revealed that a small number of resources were assigned for remedial use. A possible reason for this practice is provided by Sophie below:

I try to [use different manipulatives], but it's difficult, um, because a lot of the time I can't find the resources that I need.

The transcripts revealed the trainees organised who were permitted to touch the materials, and when, in a manner that seems to be habitual. There was a sense the pupils classified as requiring support were patrolled through stages of learning.

Chunking up of Information

The third superordinate theme described practices where the trainees guided pupils towards a desired objective, making use of manipulatives to support the depositing

of ‘chunks of learning.’ The accounts below detail how the participants engage in this process of knowledge transmission.

Donna: I would start off probably making it [lesson objective on time] into small chunks so covering maybe the hour and then moving onto maybe half past, then a quarter to. So really just doing it in small chunks so that the pupils get confident with learning all the time. Constantly recapping then perhaps using things [manipulatives] to test them on it so that they're seeing it in a fun way, rather than something that they need to be frightened of.

Sacha: Well they do [pupils], I think find maths very sequential or basic maths anyway, or primary maths quite sequential in a way. It's like step one first you do this, step two, then you do that. So, it's almost you know, ABC and quite instructional in that respect…

There appeared to be conflicting aims in the above quote from Donna's transcript. Donna mentions the necessity of ensuring that pupils are not anxious in the process of learning, and yet appears to be utilising manipulatives for testing.

Institution Rules

The transcripts detailed a silent set of institutional rules at play as to how the manipulatives were introduced and used. The rules appeared to suggest that manipulatives should be used for lower attaining pupils, for modelling concepts that have been previously taught.

Donna: Hmmm [pause]. I would say it has been very important to use manipulatives. So, I've had positive praise when I've used a resource for the lowers [pupils perceived as lower attaining] to help them in their mathematics. Previously when teaching and I haven't used a manipulative in my math lesson, it has been noted. Could you have done this? You definitely could provide them with a resource to help them. So, I think it's widely known that manipulatives are a really important part of

the pupils' learning, because it just helps those abstract contexts become concrete for them. They need that demonstrated for them.

It also became apparent, from the accounts the trainees considered, that they ought to adopt a systematic approach that appeared to inhibit the creative, or longitudinal use of manipulatives. This is highlighted in the following extracts.

David: … But the maths that I've taught over teacher training in my current position, we follow like a strict kind of programme, The White Rose, which kind of starts with the basics and works through systematically.

Sophie: *After they had used the Dienes, I took them away and then they were able to draw visually the two lines for 20 and the five dots or circles...*

Sacha: My objective was to basically move them from a physical understanding of counting to a mental.

The trainees felt it was necessary to embrace the silent set of institutional rules. When Sophie was asked if she thought she could perhaps experiment and make use of inquiry practices, she replied *"I don't feel I'm currently in a position where I can. No, I can't."*

Sacha's description below details her frustration of these silent set of rules.

Sacha: *Because you have the [*pause*] you have. Because some schools have a certain policy (…) Because maths is a core subject. So, what that means is that it's under a lot more scrutiny than other subjects. And so normally a lot of schools will have set ways on how they teach mathematics, and it's troubling if you come in with that kind of mindset of manipulatives or shaking things up. They have a very prescribed way of teaching math because it gives them certain results so that they're not kind of sweating over Ofsted or sweating over, you know, their outcomes, their percentages for maths because it's a core subject. It's difficult to implement.*

This second master theme provided an account of the common practices with manipulatives as described by the participants and also observed in the video clips. This theme includes what appears to be a silent set of rules reinforcing habitual practices such as assigning manipulatives solely to the pupils classified as requiring further support. The pupils who were assigned to use manipulatives lacked choice, and the objects were used to support the depositing of 'chunks of learning.'

5.4 **Feelings**

This third master theme aims to capture the intense feelings the participants described in association with the delivery of mathematics lessons and subsequent use of manipulatives. The transcripts revealed the way trainees felt often drove their thought processes and behaviours. Several of the participants described having experienced strong reactions to manipulatives when they encountered them. These reactions ranged from strong positive to strong negative.

Confidence and Competence

This superordinate theme represents the feelings of uncertainty experienced by the trainees when asked to classify manipulatives. The compelling descriptions detailed the participants experienced an overwhelming sense of confusion when it came to identify manipulatives.

Samantha: I got observed during, (…) and we were doing addition, with money. I used the coins, I'm not sure if this actually counts as a manipulative, but I also brought in packaging, items of food. Does that count?

David: Even just something as simple as a place value mat you can use.

Sean: I'm not sure if you'd call them manipulatives, but I was doing a lesson on the lowest form of fractions and percentages…

The participants referred to visual diagrams or static representations on the whiteboard as manipulatives. Many of the trainees felt pupils benefited from the visual aspects of using manipulatives as it helped the pupils to develop a repertoire of mental pictures of the operations performed. The expectation was then for pupils to subsequently draw on these mental pictures to solve more complex problems. This was a surprising result as the trainees are informed at University that it is not sufficient for pupils to observe a demonstration of the use of manipulatives, and pupils should handle real objects.

The participants also provided accounts of their lack of confidence in delivering mathematics lessons. This theme includes both overt, and even covert expressions of fear and vulnerability. Donna shared how she would like to overcome her anxiety and enjoy the teaching of mathematics lessons by feeling confident.

Donna: Just to be more confident in mathematics myself. I think sometimes mathematics is a bit of a feared subject for some and I've never really been strong in mathematics myself. Thinking back to secondary school actually, now that I think about it, I did use to struggle a little bit in maths, and I think that's kind of followed me up into my career. So just to be really confident in myself, so that I show the pupils that we don't have to be frightened of maths and that maths is enjoyable.

Interestingly, all participants described the teaching of mathematics as a hierarchical process and expressed a fear attached to the delivery of content to older pupils. Donna's account below conveyed her discomfort at not having enough strategies with manipulatives to deliver the content.

*Donna: Obviously there's a lot of different ways of say, for example, different methods for multiplication or division and obviously then they are using larger numbers as well. And times tables. I'm not necessarily very quick with my times tables. A lot of the pupils could do a timetable sheet in probably half the time that I could. Hmmm [*long intake of breath*] I think just by having a range of different things where I can [*pause*]. I feel almost a little bit like perhaps you always have to be one*

step ahead of the pupils and I don't feel necessarily one step ahead in mathematics, especially for example, in year six. So, I think that's what the fear is for me.

Sacha and Sophie both also mentioned a fear of taking risks within their accounts. An extract from Sacha's transcripts can be found below.

Sacha: I think that pressure is really detrimental because there's no freedom (…) there's a fear of doing anything different because, you know when in doubt you kind of just go for the least line of resistance. You kind of go to the surest, um, you know, the one with guaranteed success, which is perceivably worksheets and that kind of thing, you know, getting to the mental side of it really straight away isn't it? Whereas, you know, there's this fear if you do anything differently, there's that risk that you can fail or, but then what is failure? So, I feel like because maths is a core subject, the way it's been taught has also been choked and kind of really narrowed because people are too afraid to kind of step outside the box and say, okay, well let's try it this way. So, I think it's sad because then the student that comes in and he's like, oh I want to try this, I want to try that. And normally it kind of gets stamped out of them.

Remarkably even though the trainees are novices, no evidence existed in the transcripts of the possibility of trainees asking or contacting others for support when dealing with these uncertainties and fears on placement. The trainees appeared to be expected to cope and were given schemes of work to navigate these difficulties. David mentioned he was given the White Rose scheme of work to develop his teaching. It was a surprising result that none of the trainees requested to borrow manipulatives and instructional guides to use at home. The trainees did, however, indicate that gaining the confidence and competency to use manipulatives in the classroom did not come naturally to them. The development of confidence and competence was, therefore, ongoing often taking considerable time and repeated attempts.

David: …The White Rose, which kind of starts with the basics and works through systematically. (…) This is a place where I can kind of look and be able to teach myself or brush up on my confidence.

Samantha: I'm reading Haylock's maths. He helped. It was a really good resource that book. It was really good and just sort of reading around the curriculum really just making myself confident with it. So, I wouldn't teach a lesson if I didn't feel confident. Obviously, I would always read around the topic first before I taught it. So just keep developing my knowledge by revising it and keep going over it.

Remarkably, all participants described having experienced negative feelings and a real fear of failure when learning mathematics. Samantha's account below contains a compelling description of the fear and shame she experienced in the past when learning mathematics. Samantha's description of her childhood experiences of mathematics typifies those of the other participants. She describes a traditional teaching approach that did not involve learning with manipulatives.

*Samantha: I actually found maths really difficult when I was at school, and I actually struggled even at secondary school. I just about managed to scrape a C at GCSE (General Certificate of Secondary Education), [*nervous laugh*] but I always found it difficult and I think that's because I didn't have a lot of the resources that pupils have now. And for me, maths has always been such an abstract concept. I don't understand why we've got A's and B's in algebra, and it's not easy [*sigh*]. Yeah, I always struggled, and I think if I'd had the resources to help, that probably would have helped me a bit more.*

All participants described their childhood experiences of learning mathematics as having been predominantly based on a traditional teaching style which centred on the authority of the teacher and the use of textbooks. A teaching approach that preferentially favoured memorisation of symbolic rules and procedures. Except for Steven, the participants reported some limited, nonetheless, enjoyable experiences of using manipulatives during their primary years. However, these descriptions centred around fond memories of using manipulatives at home.

Sarah: Mum would go through them all [word problems], or work with us [at home] using different things like sugar lumps. In those days we didn't a lot of things to use, but sugar lumps or coins or post it notes, we would have loads of different things on the table, and it was just like repetition all the time.

Sophie: *I started very young when I was at home. My mum often did maths with me counting with sweets. She'd give me five sweets, I'm going to give you two more, how many altogether? I'd need to count them. Using them as objects, and then I use to get to eat them afterwards [*laugh*].*

Steven is the only participant who did not recall using manipulatives during his school years. Often Steven described manipulatives as somewhat superfluous to learning.

Steven: I think some students in my class have it in their head, and once they have that understanding, they don't need them. They shouldn't get too reliant on resources.

Beyond primary school, none of the participants specifically speak of using manipulatives except at University. Six of the trainees described their first experiences with manipulatives stemmed from University workshops. These sessions were described as positive, and a catalyst for encouraging them to relearn and rethink. Sarah described these workshops as opportunities "*to put what we have learnt into practice."* Incidentally, David described the workshops as an opportunity to *"see the different ways that students learn."*

David felt he could not use unfamiliar manipulatives until he felt comfortable with and very familiar with them. David: *I think it's because it's such a new resource. I'm trying to get to grips with it [Numicon] myself before I delivered it [*pause*]. I was first*

introduced to Numicon in the nursery of my previous school where they just kind of subscribed to it. We kind of touched on the basics, so I didn't get a full-on understanding of how we use it, and what we use it for.

In the experiences of Sean, Donna, and David they describe the workshops at the University as offering them different ways to present and think about mathematics and manipulatives. Consequently, they found the lectures more interesting and engaging.

Sean: We had a lot of maths lessons where items were put in the middle of the table, and you know, we were shown how could use them from those angle measurers to strings with beads on. Lots of things.

Sarah: *Lectures are more based about putting what we have learnt into practice in terms of using manipulatives and how to plan around them and getting ideas from people in your cohort rather than just subject knowledge.*

The trainees spoke about how their initial perceptions of manipulatives changed after experimenting with using them, and, in some cases exploring the wide range or materials available. While Sophie, Sacha and Samantha did not offer specific details of the variety of manipulatives available at University, they did acknowledge the time constraints of the programme did not allow them sufficient time to get to use them all. Further analysis of the transcripts revealed the common theme of trainees requesting a bank or a list of all manipulatives available together with supplementary guidance. Remarkably the participants seemed to be unwilling to learn from the pupils how to use unfamiliar materials and did not allow pupils to use them unless they were familiar with them first.

During the playback of the videos, both Samantha and Sarah described how observing the footage was particularly helpful in increasing confidence and competence as she could now observe what she had initially missed.

Samantha: So, watching back videos like this, helps you (…) to basically teach it yourself. You can get ideas on how to break down concepts.

Sarah: Oh, my goodness! You only watch the pupils which you are working with. You don't realise the impact you are having beyond them.

The videos helped the trainees to challenge their traditional view of mathematics teaching. It was during the playback that Sacha described a new way of noticing. She commented on her change in perception after reviewing the footage. Sacha acknowledged what she had initially deemed to be a true and fair assessment of a child's perceived capabilities may not be reflective of the reality at all.

*Sacha; …What was interesting, because she counted twelve and then I said take away five and she continued to count past five all the way to... Moving all the beads back. Either she wasn't listening or maybe it's interesting, isn't it? Like kind of the same. There are so many things going on, on so many levels at that time. So right now, I'm kind of wondering whether she actually heard what I said. Maybe even from the start she didn't [*pause*]. Maybe she just saw the resource and didn't understand the maths that went with it or didn't hear the maths that went with it, which is interesting. So, it's almost like that makes me wonder when a child gets a maths resource to work with whether this be number beads, or coins, do they just blank out once they have a toy, and just zone into the actual kinaesthetic process. Almost like the other senses become subdued and that you're not even listening or correlating or connecting the language with that resource*.

This superordinate theme aims to capture the intense feelings the participants described in association with confidence and competence in mathematics lessons and subsequent use of manipulatives. The transcripts revealed the way trainees felt often drove their thought processes and behaviours. While the trainees could identify areas of development, they did not feel confident enough to act. The relationship between the mentor and trainee is vital in creating competent and confident teachers. There appeared to be a lack of support for the trainees in relation to using manipulatives during placements.

Sense of Vocation

This superordinate theme addresses the theme of a 'sense of vocation'. David, Sacha and Samantha explicitly described a desire to prevent pupils from experiencing the same type of fear of learning mathematics that they had experienced in childhood. Many of the trainees describe having been drawn into the teaching profession to preserve pupils' confidence while learning mathematics. Sacha's interview extract can be found below.

Sacha: That's a really good question (…). Why do I say that? Because I understand pupils. (…) So, because there's an element of myself that has remained a child and sees things in a very kind of like, you know, in a childlike way. A preservation of the child I think is why I'm going into teaching. It is not necessarily a preservation of the physical child. But a preservation of a way of being. A way of looking at the world which is [pause] I associate a childlike perception of looking at the world is through constant fresh eyes.

*Samantha: Um, from having such difficulty with it [mathematics] when I was younger and struggling with it and always hating it and being nervous about tests and, all sorts of things to do with maths. I'd like to give pupils, well try and make sure they do not feel that way about it, or scared, when it comes to tests and things. Like I did and if they do [*sigh*]. Just give them ways [to cope].*

Samantha goes on to describe how she wanted to intervene and help pupils overcome fears before they grew up. This was a prevailing theme in several of the transcripts where the trainees describe not wanting the pupils to feel as they did, therefore, making use of manipulatives as an aid to help the pupils they teach 'grasp' concepts. Sacha's account also described how she used the manipulative to help pupils become 'unstuck.' This prevailing theme was not uncommon. It appears as if the manipulative was being used to reinforce co-operation and foster emotions of gratitude and trust.

Metaphors for Learning

This superordinate theme addresses how the trainees used a range of metaphors to describe a wide range of emotions and actions in terms of touch. The transcripts revealed the way the trainees felt often influenced the way they thought or behaved. In Sarah's and David's description below, she describes having used manipulatives to help pupils 'grasp' learning.

Sarah: And you can quite clearly see, the pupils grasp Numicon from reception early years.

David: So then through questioning, you could ascertain whether they have grasped this, but I think that's what I kind of was trying to look for.

Touch metaphors such as 'grasped' illustrated in Sarah's and David's account above may reveal how everyday language is a reflection of neural processes. It is possible the participants were searching for a language that fits the experience. Language such as 'get to grips' or 'hard' was used to describe the difficulties and frustrations involved in attempting to achieving the desired result. Sarah's descriptions below described how the manipulative felt often influenced the selection.

Sarah: I remember from my previous experience with SEND pupils, they have to, they have to feel the physical money that coldness the hardness, the roundness, the thickness and stuff.

Elsewhere Sarah's account appeared to detail through the social organ of skin, manipulatives were used to bridge a social gap created between pupils who were deemed lower attaining. The trainee's hands would make contact with the child, and this brief experience appeared to promote personal warmth and a feeling of reassurance. Sacha made use of texture metaphors regarding cubes as strong and firm and seemed to be reassured by their use. In contrast, Sophie detailed her discomfort with cubes, hard edges, and vertices. She describes finding comfort and

value in smoother or rounder surfaced manipulatives for counting as she did not feel the hardness and sharpness of edges were child friendly.

*Sophie: I felt that it really helped. Like I use the hmmm [*pause*]. I don't know if you know the plastic teddy's use for counting. I remember using them in infant school, and I've seen them being used on placement as well, so I feel they really help as they are really child friendly. I think I remember them because they really helped me with my counting. It's just, they are a lot more child friendly than using cubes, in my opinion.*

Incidentally, these preferences were also mirrored in her childhood descriptions of enjoyable manipulatives, where she recalled fond memories of having enjoyed using teddies and sweets. Sophie's account goes on to describe how she felt she was not in a professional position where she could exercise her preferences with learning. She describes how she felt learning should not be "*done to a standard*" and should be exploratory, perceiving learning as a circular process.

Sophie's transcript also details a desire for pupils to completely reconstruct the manipulative when shifting from concrete to pictorial representations. Her aversion to the use of squares is found below.

Sophie: After they had used the Dienes, I took them away and then they were able to draw visually the two lines for twenty and then five dots or circles.

Remarkably Sarah described learning with manipulatives as a process where she could "*double-check learners were on the right lines*" and manipulatives helped "*putting it all together.*"

All of the trainees referred to culturally constructed metaphors such as "*build upon that,*" "*get them hooked,*" "*have it in their head,*" and "*step up*" to verbalise interactions that took place with manipulatives. On occasions, the participants described assigned pseudonyms and metaphors. For example, Sarah referred to Numicon on several occasion as "chimneys." It was taken for granted that pupils

would interpret the language as intended and glean the same universal understanding from these physical interactions with manipulatives.

5.5 **Teacher Learning**

This final master theme aims to capture the connection between the language used to describe learning with manipulatives and teacher learning. Abstraction theory was drawn on to describe the aim of moving what pupils do with their hands to their head. It appeared the trainees' perception of the theory was generally seen as a set of ideals or general principles which can be used to explain a fact, event or opinion. Still, theory can also be viewed as a set of rules which have the potential to guide the action.

Concrete to Abstract

All participants commented on starting with the manipulative (concrete), then moving to visual or symbolic representations and finally abstract. It became apparent from the transcripts the significance attached to utilising manipulatives in aiding pupils to move towards abstraction. The mastery approach adopted (refer back to section 2.7) appeared to be reinforcing specific stages in cognitive representation. This is highlighted in the following salient extracts found below:

Table 6: Superordinate Theme Concrete to Abstract

Superordinate Theme
Sacha: My objective was to basically move them from a physical understanding of counting to a mental which by mental understanding they [the pupils] could workout things mentally. That seems pretty lofty in just one session, but that's, that was the long-term goal of these sessions. (…) Basically, practice makes perfect is what I believe. (…) A seamless movement from an enactive to iconic to symbolic.

Samantha: University helped me realise how to identify the needs of children, you know, make it concrete, pictorial and all that. I mean not so abstract. So, I think the University definitely like opened my mind to that because I hadn't really thought about it before, and then I was trying to put it into practice when I was teaching.

Sarah: In terms of with the pupils, I think it would be a case of making sure that they're concrete and move on to visual then abstract.

This powerful subordinate theme was recurrent. The trainees also described utilising the manipulative to 'cement learning'. When asked what concrete means to her, Sacha mentioned how concrete involves construction, like a block at a time (laying down concrete slabs of learning) that are stuck in place. Both Piaget, (1952) and Bruner make reference to the term 'concrete' by way of an explanation of stages in cognitive development. From the analysis of the transcript, it became apparent that the word concrete could have been interpreted to represent the tangible nature of the manipulative and the enormity of the task associated with the desire to make learning stick.

This superordinate theme aims to capture the descriptions of abstraction theory utilised by the trainees to describe the perceived journey of moving mathematical learning from hands to head. It appeared the trainees made use of existing abstraction theory to explain and potentially guide their teaching to help learners make sense and strengthen their understanding of mathematical concepts.

Reflection

This superordinate theme captures the participants' explicit reflections about their use of manipulatives, and the recommendations they have based on these experiences. The trainees described a number of techniques to increase the connections between University and placement.

David was asked to identify how teacher training courses could be improved to aid his and other trainees' understanding of how to make use of manipulatives during placement. He contemplated that trainees should be provided with more

opportunities to reflect, talk and explore, particularly during the practicum. This powerful theme is captured below.

*David: I know the training that I had last academic year when training to be a teacher was fantastic! For all [*rub hands together*]. And we were able to experience a bit of a lesson. I think that's a good thing to be able to learn because you can then take that skill away and tweak it how you want to do it and you know, make it better. Not make it better, but certainly, put your own spin on it. So, I think definitely trainees need to have that experience. Not just kind of be talked at [on practicum]. I think we should, you know, going back to the White Rose Hub, use the concrete first and then talking about it and then say, well hang on a minute I might have done it this way and have a discussion.*

The comparative element of utilising university-based postgraduate trainees (site A) and school-based trainees (site B) was deemed at first to be a significant aspect of the overall study design. Interpretation of the transcripts revealed the above interesting finding. David attended a School Direct model (employment-based route into teaching) where the majority of his time is spent on placement. He found the University workshops empowering, whereas, in contrast, he describes having experienced a lack of freedom during placement.

In contrast, Sarah, who attended the full-time course, described how she felt she needed more time on her practicum.

Sarah: I think in terms of teacher training and the requirements for teacher training doing that ten days or expected ten days is not enough experience in schools to really understand what is going on in front of you, and what goes on behind the scenes as well.

Sacha who attended the full-time course also describes University lectures as facilitating reflective inquiry.

Sacha: Because it's enabled me to become so reflective about mathematics and actually question. It's permitted me to question things on a deep level and actually my, master's essay was on maths and resilience.

This superordinate theme captured the participants' reflections associated with manipulative use, and recommendations they have based on their experiences. There existed a contrasting view between Site A and Site B with regards to the amount of time required on placement. Yet, all students agreed that reflective time was paramount to a successful placement.

Chapter 6: Discussion

6.1 **Overview**

This study examined PGCE trainee teachers' perceptions and accounts of using manipulatives as they developed their professional learning during placement. This was conveyed through an analysis of semi-structured interviews using Interpretive Phenomenological Analysis (IPA).

This Chapter begins with a summary of the key findings from the study and their connection to the research literature. Within this section, I discuss how my findings illuminate or problematise what has been found in existing studies.

Sections 6.2.1 and 6.2.2 addressed the first research question: *What are PGCE trainee teachers' perceptions of mathematical manipulatives?* Whereas sections 6.2.3 to 6.2.5 addressed the second research question: *How do PGCE trainees account for their use of manipulatives during placement?*

Following on from this, sections 6.2.6 and 6.2.7 also addressed the first sub-question: *Why do they take this approach, if with or without manipulatives?* Whereas sections 6.2.8 addressed the final sub-question investigated: *What do trainees think would be a productive way to increase this connectivity?*

It is not unusual with IPA studies during the data analysis to uncover phenomenon which at first seems to have no bearing on the research and yet adds excellent value to the project. The beauty of IPA lies in its ability to facilitate and capture each emergent phenomenon enabling further and more in-depth exploration. The inductive nature of this approach means the researcher does not have to rely on the existing literature to drive the analysis to allow for the possibility of novel and unexpected findings to arise. Therefore, in line with IPA methodology (Chapter 3,

section 3.3 and 3.4), some additional literature will be included to frame the emergent findings that have been developed.

After I addressed the research questions and the emergent findings, in section 6.3, I considered the significance of this study to educational practice and the implications of the results. This is followed with an evaluation of the study. I considered the positive aspects of the methodology as well as areas of improvement (6.5). In section 6.6, I presented some suggestions for future research.

Finally, section 6.7 concluded with my personal reflections on this study. I considered what I learnt, and how I might undertake a different course of action in the future.

6.2 **Discussion of Findings**

While each participant described a different path to their current understanding of the value of manipulatives, several common themes appeared during the analysis providing valuable insights about how trainees perceive and interact with manipulatives. Bearing in mind, the participants had little, if any, experience of manipulatives before placement, the overall findings indicated:

- the trainees acknowledging the many benefits associated with using manipulatives, yet a silent set of institutional rules were at play as to how the manipulatives are selected, introduced and utilised;
- the trainees adopted habitual practices such as assigning manipulatives solely to the pupils classified as requiring further support;
- the trainees were left alone to cope and navigate the difficulties with developing their teaching in isolation;
- trainees took for granted the meaning they ascribed to manipulatives would be understood;

- a mismatch between perceptions and accounts of use. This resulted in trainees making use of the sensory experiences of the manipulative to bridge the social gap caused by grouping by ability.

This study found the use of video recordings and inquiry-based practices could help create cohesion, therefore, challenging the traditional view of mathematics teaching. Videos can create opportunities for reflection and the possibility to learn creatively from failure.

Trainees Perceive Mathematical Manipulatives as Inclusive and Engaging

Analysis of the transcripts revealed the recurrent theme that all participants held the perception that manipulatives are efficacious for pupils to learn mathematics. Nonetheless, there was a range of opinions offered as to whether certain pupils benefited more than others. The tactile nature of the manipulative was described as purposeful and inclusive, making learning accessible for all.

The above finding correlated with the existing research base where using manipulatives are described as an accepted technique to enhance pupils' learning of mathematics (Bruner, 1960; Montessori, 1989; Skemp, 1987; Vygotsky et al., 1978). The participants also described how, although they felt manipulatives were inclusive, this was an aspirational aim as there existed considerable challenges in using them.

Although it is true manipulatives can be useful under some conditions when learning mathematics, several studies have shown there exists some challenges in use, particularly for pupils who are diagnosed with varied sensory disabilities such as Apert syndrome (a rare condition where pupils born with their fingers fused). Pupils diagnosed with this condition experience greater difficulty with learning mathematics (Hilton, 2017).

Examination of the transcripts revealed the trainees described manipulatives as 'engaging' and a fun way for pupils to learn mathematical concepts. This finding

echoed McNeil and Jarvin (2007) and Moyer's (2001) studies discussed in section 2.9 in which they describe teachers as using manipulatives as the catalyst for fun and engagement or as a means to add variety to the lesson. In this study, engagement was referred to as the degree of attention, curiosity, interest and passion the learners showed towards learning. However, engagement is a challenging construct to define as many factors can influence it. It was unclear from the participants' descriptions if they perceived engagement in terms of behavioural, emotional or cognitive engagement. In my experience 'engagement' should be taken as meaning active participation of the pupils in their learning. Equally, engagement can also be considered as potentially disruptive to the serious atmosphere assumed to be essential to learning (hooks, 1994).

The trainees acknowledged many of the benefits associated with the significance of learning and engagement when using manipulatives, as highlighted in the literature. However, section 5.3.1 highlights that these benefits are not always recognised as applying to all pupils.

Trainees Perceive Mathematical Manipulatives as Purposeful Aids for Building Confidence

The accounts revealed the recurrent theme where using manipulatives was described as having a purpose for pupils to develop self-confidence in mathematics. Section 5.2.2 described how the trainees perceived the benefits of manipulatives accrued from consistent use and manipulatives simplified the process of learning. While the trainees commented on the tactile benefits of manipulatives, their accounts described how they predominantly expected pupils to observe a demonstration and ‘play’ was forbidden. Pupils were permitted to handle manipulatives if they replicated the strategies modelled.

Although the participants confirmed and described manipulatives as purposeful for all, several participants also expressed concerns about making use of these objects too frequently. Sean and Sacha’s accounts in section 5.2.3 detail their concerns

about pupils perceiving manipulatives as baby toys. They also mentioned it was unfavourable for pupils to become too distracted from the real process of learning. This insight corroborates with McNeil and Jarvin (2007), Bouck and Flanagan (2010) studies cited in section 2.9 which highlighted teachers might dismiss playing with manipulatives as mere enjoyment at the expense of mathematical conceptualisation. Still, this characteristic of tinkering is a ritual of informal learning. My experiences have found it is challenging for trainees to notice the difference between play and learning. In educational settings, play is often mistaken as an activity solely for younger pupils, yet tactile techniques form the stages of the associative memory described in the literature.

Yet, research by Ball (1992) cited in section 2.4 problematises the assumptions teachers make regarding pupils' interpretations of manipulatives. This study claims it is a fallacy to assume pupils will automatically draw the conclusions the teachers desire. She also warns against placing too much faith in the power of the manipulative as a meaning-making tool as they are unable to carry meaning or insight. Ball (1992) contends the reason adults overstate the influence of concrete representations is that they see concepts they understand. Pupils may not have that same understanding and therefore, will 'see' differently. Steven commented '*I was looking to see whether she could translate the numbers into Dienes*.'

The participants also spoke about manipulatives using a range of metaphors (section 5.4.3). The term 'in my head' was used to describe the process of abstraction. Language such as 'get to grips' or 'hard' was also frequently used to describe the difficulties and frustrations involved in attempting to achieve the desired result. This finding correlated with my recent study (Charles-Cole, 2017) where pupils described an inverse relationship between the use of concrete manipulatives and the notion of intellectual understanding. Within this study the pupils asserted they were smarter if they no longer required the use of a manipulative.

As cited in section 2.5, Lakoff and Nunez (2001) contend human cognition is built up from the body; therefore, the metaphors used are not accidental. The body acts in response to perception which, in turn, creates changes in the environment that

are then perceived, and then motivates further action. Thus, in everyday speech, the metaphors used are not only linguistic but also describe engagement in the environment (Johnson and Lakoff, 1980). The trainees' descriptions also revealed the assigning of pseudonyms for the manipulatives used such as 'chimney' for Numicon. They assumed pupils would make the connection between the manipulative and the language they had ascribed.

Yet, studies (McNeil and Jarvin, (2007) demonstrate manipulatives can be creatively reconfigured beyond their basic purpose. While there are some overlaps across cultures, understanding of metaphors and pseudonyms are not always universal. For example, water has many affordances such as drinkability, aesthetic, social, political and religious meaning (Johnson and Lakoff, 1980). Since conceptual metaphors play a major role in the characterisation of mathematical ideas such metaphors have to be clear to the learner. What is clear from this study is the pupils have to understand the meaning ascribed, and the affordances of the manipulative before they can even begin even to tackle the mathematics. As cited in section 2.10, hooks (1994) argues it is not uncommon for pupils to have to adopt the same language as the teacher to be understood. This can result in confusion and learners feeling estranged from the language they know most intimately. She proposes learners should be presented with opportunities to use a range of languages to describe their learning, so they do not feel estranged from the language they are most familiar.

Surprisingly, this study revealed few descriptions of the participants engaging in mutual conversations with the pupils. Yet, Askew (2011), Leibeck (1984), hooks (1994) and Freire (1970/1996) cited in sections 2.6 and 2.10 suggest dialogue is indispensable. Leibeck (1984) Experience, Language, Pictures, Symbols (ELPS) approach, related to Bruner's phases, accentuates the importance of pupils' acquisition of language in mathematics. She stresses the significance of not only the pupils learning the correct mathematical vocabulary but also discusses the importance of the role of the teacher in engaging and extending the discussion (Leibeck, 1984).

The trainees perceived the visual and tactile aspects of manipulatives to be beneficial to pupils' understanding of mathematical concepts. The participants expected pupils to see and use manipulatives as intended. These findings are consistent with existing studies that examined teachers' practices and acknowledge the pitfalls of using manipulatives in this manner. These current studies, however, do not account for trainees' experiences that may differ from experienced teachers.

The study findings also revealed the trainees made use of metaphors and pseudonyms to describe manipulatives and learning. The participants took for granted the pupils would understand the language ascribed to the manipulative in the same way as intended. Yet, the meaning ascribed to manipulatives is not universal. They can have many affordances and they can be creatively reconfigured beyond their primary purpose. While existing literature such as McNeil and Jarvin (2007) demonstrate manipulatives can be utilised for different purposes, existing studies do not discuss the possibilities and limitations of the language ascribed to manipulatives. This finding is worthy of further investigation.

Trainees' Accounts Reveal Mathematical Manipulatives were Assigned to Pupils Requiring Further Support

Analysis of the transcripts revealed habitual practices (even though the trainees were novices) such as issuing manipulatives solely to the pupils classified as requiring further support (section 5.3.1). I considered habitual practices to be actions that are performed out of habit without critical thought. These actions were found to be without critical thinking or reflection as the trainees' perceived manipulatives to be valuable for all pupils. Yet, the accounts of use revealed they were only disseminated with the pupils classified as requiring further support. These pupils were often referred to by their grouping, frequently removed from the class, and taught by the teaching assistant.

An Ofsted (2012) publication cited in section 1.2, which examined teachers' practices with manipulatives also found there existed some inequalities in pupils' experiences of learning mathematics with manipulatives. This study also highlighted

manipulatives were often reserved as a teaching intervention to support the lowest-performing pupils. This downgrades their intrinsic value.

Trainees' Accounts Reveal A Silent Set of Rules and Some Fixed Approaches to Teaching

It was apparent from the findings that there existed a silent set of rules at play within schools as to how the manipulatives were selected, introduced and used. The rules suggested manipulatives should be used for lower attaining pupils, for modelling concepts. The trainees described in section 5.3.4 how mathematics lessons were under a lot more scrutiny than other subjects, so they felt they ought to follow an agreed method of delivery such as following policy and schemes of work during their practicum.

The trainees' accounts of practice also revealed their actions were very much guided by the feedback received during observations. The participants also described how they assumed they ought to adopt a systematic technique of following mastery approaches moving learning from physical to abstract understanding.

The transcripts revealed practices where the trainees guided pupils towards the desired objective. Subsequently, manipulatives were used to support the depositing of learning objectives or 'chunks of learning.' These descriptions appeared to inhibit the creative use of manipulatives. As a consequence, the majority of interactions with manipulatives were trainee orientated with a prevailing use of didactic approaches during both practicums. The findings revealed the participants always selected the manipulatives and directed the learners in how they expected the resources to be used. The above finding coincided with the existing studies (Moyer and Jones, 2004) cited within section 2.9 found manipulatives can be used by teachers to guide pupils towards the desired conclusion, for example, all learning must proceed from concrete to abstract. This study also found some teachers control what is seen and done by making rules about how to operate the manipulative or making use of tightly structured manipulatives (Moyer and Jones,

2004). Although studies such as Moyer and Jones (2004) acknowledge and problematise the myriad of difficulties qualified teachers experience with manipulatives, these studies do not consider the many challenges trainees experience too. The findings suggest trainees guide pupils towards the desired conclusion as they are fearful of losing control of the class during observations.

This novel finding also bears some commonalities to Freire (1970/1996) critical pedagogy theory cited in section 2.10. According to Freire (1970/1996), the banking system of education is based upon the assumption that education consists of consuming and memorising information. The regurgitation of this information represents gained knowledge that could be stored, deposited, and used at a later date (hooks, 1994). Within this model, pupils are considered to be manageable, adaptable beings who cannot produce their own knowledge and are just expected to categorise and catalogue. Education thus becomes the act of depositing in which the pupils are depositories, and the teacher is the depositor. Instead of collaboratively interacting, the teacher transmits the deposits which the student patiently receives memorises and stores. The more the teacher fills the students, the better teacher she is. The more receptive the learner is to be filled, the better the student is considered to be.

The trainees frequently described how using manipulatives enabled pupils to move from a physical understanding to an abstract. Freire (1970/1996) proposes pupils have the illusion of acting through the action of the teacher. The teacher chooses the programme content, and the student (who is not consulted) adapts to it. Freire (1970/1996) also implies within this model of education that there exists a constant repetition of actions ‘a narrative sickness’ that does not produce any new knowledge.

Deci and Ryan's (1987) research mentioned in section 2.9 reported that controlled choice can have an impact on students’ intrinsic motivations and concluded that motivation increased in lessons where pupils were provided with high autonomy. Brown and McNamara (2005) cited in section 2.7 offers a possible explanation for the didactic teaching approaches and suggests this is down to decades of recurrent

statutory revisions to the curriculum and stringent accountability measures that have been enforced on schools. This has resulted in an increased demand for control and performance, resulting in less room for risk-taking and mistakes (O'Neill, 2002). As a result, a deepening crisis of mistrust exists.

The trainees' accounts of using manipulatives indicated there existed a silent set of rules at play as to how the manipulatives are selected, introduced and utilised, reinforcing habitual practices such as assigning manipulatives solely to the pupils classified as requiring further support. Consequently, trainees guided pupils towards the desired conclusion when using manipulatives. While the current literature base examines experienced teachers practices with manipulatives and acknowledges the shortcomings of control orientated didactic teaching approaches, these studies do not consider the experiences of trainees. In addition, these studies do not refer to the institutional rules at play when using manipulatives.

Trainees' Accounts Detail the Challenges Involved in Identifying Manipulatives

Section 5.4.1 revealed the trainees experienced difficulties in identifying what materials counted as manipulatives. Diagrams such as place value mats and imagery (drawings) were frequently referred to as manipulatives illustrating this confusion. Overall this difficulty in defining manipulatives corroborates with studies discussed within the literature in sections 1.2 and 2.4.

Moyer and Jones (1998) study cited in section 1.2 highlights how manipulatives are often discarded when practitioners are unfamiliar with how best to make use of them and are fearful of losing the skill to control and assess knowledge when in use. It can be extremely difficult to train teachers in the use of manipulatives, specifically, as not only are there a multitude of manipulatives available, there are also many ways these resources can be used effectively.

In section 5.2.2 and 5.2.3 the participants described using a range of imagery to support learners in developing a repertoire of mental images as they held the perception this strategy would enhance the retention of mathematical concepts. This finding was consistent with the existing studies mentioned in section 2.7 where

practical aids are described as helpful and often necessary to the development of pupils' mental images of mathematical concepts and mental strategies (Moyer, 2001; Drews, Hansen and Earnshaw, 2007). However, Hodgen's (2017) review of practical and evidence-based recommendations for teaching mathematics found using multiple representations can exert a heavy cognitive load, which may hinder learning. This study cited in section 2.7 also asserts more research is needed to inform teachers' choices about which, and how many, representations to use.

Sophie and Sacha mentioned the use of 'virtual manipulatives', but it was unclear from their accounts if these descriptions could fulfil the criteria of a manipulative. Reys (1971) cited in section 2.4 cautions not all teaching aids are manipulatives. When defining manipulatives Hynes (1986) also mentioned in section 2.4 argues it is not sufficient for students to observe a demonstration of the use of an aid. He defines manipulatives as real objects that pupils can handle feel and move, which have a social application.

The findings revealed beyond primary school, none of the participants specifically recall using manipulatives except at university workshops. Interestingly enough, David described he could not make use of unfamiliar manipulatives such as Numicon until he felt comfortable, which required time and subsequently referred to textbooks and schemes of work to guide his knowledge. This outcome supports conclusions drawn by Lesh, Post and Behr (1987) cited in section 1.2 who identified how factors such as limited understanding and experience influence the integration of manipulatives into teaching practice. The trainees' descriptions revealed manipulatives such as Numicon, Dienes and counters were selected most frequently due to familiarity and class teacher or mentor recommendations. Illustrated within the story boxes (section 4.2) Samantha was the only participant who selected video footage of her working alongside the class teacher. The teacher appeared to be modelling (while Sarah observed) how to make use of double-sided counters to learn about negative integers.

The verbatim transcripts also revealed the manipulatives recommended by the University and textbooks catalysed the selection. This significant result may have contributed to the transfer of unquestionable truths regarding use, reinforcing a silent

set of rules. The participants shared concerns about their level of confidence in the teaching of mathematics lessons as they felt this type of teaching did not come naturally to them. Confidence and competence were, consequently, an ongoing process often taking considerable time and repeated attempts. The accounts revealed learning by trial and error was a risky undertaking, and the trainees very much relied on the safety of tried and tested methods such as drawing on their past experiences of learning.

Remarkably even though the trainees were novices, there was no evidence to suggest the trainees were able to contact or ask others for support when dealing with uncertainties relating to manipulatives and the subsequent delivery of mathematics lessons during placement. Howard, Perry and Tracey (1997) conducted a study in Australia that examined existing teachers' practices with manipulatives found there exists a lack of support for teachers which can have severe implications. This result was surprising as existing studies indicated in section 2.10 detail the relationship between the mentor and trainee and a supportive environment is paramount to successful professional development (Nolan, 2011).

Findings from this study also revealed the participants experienced both overt and covert feelings of fear when learning mathematics and using manipulatives. Trainees have to independently pass mathematics subject knowledge audit tests alongside assessed observations during placement to pass the PGCE mathematics module. The participants attributed the act of asking for support as an indication of failure or cheating. In section 5.2.1 Sacha is quoted *"There's no freedom (…). There's this fear if you do anything differently, there's a risk that you can fail."*

Furthermore, Linden's (2016) study cited in section 2.5 has found social rejection and physical pain can impact the body in similar ways. This research highlights social relationships have deep biological roots and demonstrated the regions of the brain that are activated in response to social rejection also elicits literal physical pain. Therefore, it is no coincidence emotions are called feelings. This study contends social rejection evolved as a threat to life signal. Individuals who experienced isolation are more likely to alter their behaviour to remain part of the community

(Linden, 2016). This novel finding would then account for the habitual practices found within this study. The fear and pain associated with social rejection and isolation influences the participants' perceptions towards risk-taking with their mathematics lessons. Thus, trainees tend to stick to tried and tested methods. Studies have found people who experience distressing situations can hold an implicit memory of traumatic events in their brains and bodies. That memory (somatic memory) is often expressed in the symptomatology of posttraumatic stress disorder-nightmares, flashbacks, startle responses, and dissociative behaviours (Rothschild, 2000). Put simply, the body of the distressed individual refuses to be ignored.

This study offers valuable insights into the relatively unexplored area of trainee's experiences of using manipulatives on placement. The trainees' accounts revealed uncertainties in identifying manipulatives. A factor noted in existing studies that limit the integration of manipulatives into teaching practice.

The participants also shared concerns about confidence in the teaching of mathematics lessons with manipulatives. The existing literature states it is necessary to form an effective partnership between the mentor and trainees. Yet, the participants disclosed they were very much left alone to cope with challenges that occurred during placement. This is a novel finding that is worthy of further study as my experiences suggest trainees who are more confident in their teaching ability are more successful in promoting effective learning.

Emergent Findings: Trainees Disclose Their Childhood Perceptions of Manipulatives Influence Use

The findings revealed the participants drew upon their own fond and happy memories of learning with manipulatives as justification for use. This result is consistent with McNeil and Jarvin's (2007) study, which found the physical act of handling manipulatives can cue memories. It is widely accepted perceptions and beliefs are an important aspect of life, and they shape the experiences of individuals (Broadfoot, 1993; Lotto, 2017). Yet, analysis of the transcripts disclosed these fond

memories were predominantly associated with learning mathematics at home with family. The participants' recollections detail manipulatives were used as fun and engaging supports. Their accounts suggested family members used manipulatives as a learning support to bridge the gap between home and school learning. Nonetheless, Eagleman (2015) asserts recollection of the same experience will vary at different stages of a person's life. For example, the memory held of the same experience as a child will differ significantly to what an adult perceives as the same event. Studies such as these exemplify how although memories are sparked by a sensory stimulus such as manipulatives, these memories will change over time.

Sophie's transcripts revealed her childhood memories influenced her perception and subsequent use of manipulatives. Her preference for preferring to use what she considered as child friendly smooth or rounded manipulatives was very much influenced by her childhood memories of learning. Although Sophie may have perceived her decision was best for the pupils she taught, she unwittingly limited her knowledge and experience of a whole range of manipulatives. Subsequently, her perceptions can significantly alter and even restrict pupils' interactions with manipulatives too. This important result could be attributed to a lack of support. Howard, Perry and Tracey's (1997) study which examined the teaching practices of qualified teachers found continued support to be necessary. Should teachers lack support, they can develop accepted truisms that have little theoretical underpinning.

Few would argue the beliefs and perceptions held by educators play a critical role in determining how they teach (Perry, Tracey & Howard, 1999; Parjares, 1992; Askew, et al., 1997), yet the precise nature of how these enacted beliefs or perceptions play out in the classroom remain unclear. Studies that have examined the relationship between teachers' beliefs and their practices have indicated a correlation exists, albeit with varying results. This is an understandable result as perceptions, like experiences, are personal to the individual. Existing studies such as Perry Tracey and Howard, (1999) claim adopted beliefs can often seem to be an internal conflict as teachers can hold perceptions about their instructional aims in mathematics, the nature of teaching and the subject matter itself which are logically incompatible.

This study has also identified several misalliances between the trainee's perceptions and accounts of using manipulatives. For example, the participants considered manipulatives to be inclusive materials for all yet only distributed these objects to the pupils they perceived as failing. Yet, as mentioned within the review Askew et al. (1997) argues although beliefs and perceptions are important in shaping lessons, they are only part of the story, and different aspects of teacher's knowledge contribute in significant ways.

The participants explicitly described a desire to protect pupils from experiencing the same types of fear that they had when learning mathematics. However, perception filters are a set of preconditioned responses that determines how the individual reasons (Mutodi and Ngirande, 2014). Research dedicated to this field has demonstrated the mind homes in on specific details to which the individual has predisposed sensitivity. These experiences are most relevant and correspond to the beliefs already held (Mutodi and Ngirande, 2014). The perception filter operates in such a way that the person is unaware of its presence. The past experiences of the individual characterise the filter and therefore, different people perceive reality in different ways.

The findings revealed the trainees drew upon their own experiences and perceptions of learning with manipulatives to teach, and these insights were often cued by the handling of manipulatives. Significantly, this study also discovered several misalliances between the trainee's perceptions and accounts of using manipulatives. In section 6.2.6, I have drawn on new literature to illustrate this new and interesting finding. The results of this study cannot demonstrate a direct connection between the lack of support experienced by the trainees and their perceptions of use in the classroom. Yet the study findings are noteworthy as the perceptions held can have a significant impact on the manipulatives used to teach should trainees fail to recognise their value. This, in turn, can significantly alter pupils' experiences with manipulatives. This novel finding adds to the existing literature base as interesting insights have been found surrounding the mismatch between trainee's perceptions and accounts of using manipulatives.

Trainees' Accounts Reveal Manipulatives are Used as a 'Lifebuoy'

Analysis of the transcripts revealed the participants routinely issuing manipulatives as a 'lifebuoy' to the pupils they perceived to be struggling with mathematics. Routine practices are considered to be actions that are performed out of habit without critical thought.

I have used the metaphor 'lifebuoy' as it encapsulates what I have found out about how trainees use manipulatives. A lifebuoy is not used for rescuing but distributed as a temporary measure to keep individuals afloat until they are rescued later. In section 5.2.1 Steven was asked about the purpose of using manipulatives, he responded: "*I'd say certainly I think in terms of grasping the first [part of the lesson] I think they are essential."*

A lifebuoy is a buoyant safety device thrown to individuals perceived to be in a situation of dire straits. This implies the trainees identified some of the pupils they taught were in a situation of dire straits as a consequence of a deficit in learning. There existed a perceived recognition that these pupils were different due to the lack of learning which was considered problematic. Studies such as Moscardini (2009) cited in the literature concluded and challenged the notion of manipulatives use to perform rigid instructional sequences. He contended pupils should be permitted the opportunity to develop flexible responses.

Notably, analysis of the transcripts revealed manipulatives were not issued to enhance mathematical instruction, but solely to rescue those pupils identified as requiring further support. It appeared the trainees did not consider manipulatives as a tool the pupils could use to learn but instead as a resource thrown to them to allay fears and keep them above water. Manipulatives were used as a supportive aid as the transcripts confirmed they were not used to address learning needs.

As is illustrated above in section 5.2.3 Donna is quoted *"I would say if I asked a child a maths question without a real resource and they couldn't get the answer, I would*

then give them a manipulative to use and then they could get the answer. You would know obviously, that the resource has had an impact on their learning."

It appeared the trainees expected pupils to understand through the presence of the manipulative rather than engagement, although the trainees did discuss the importance of engagement. There appeared to be an expectation that pupils did not have to work with the manipulative; learning would become apparent through directions issued by the trainees.

This important finding is consistent with Howard, Perry and Tracey (1997) study that found using manipulatives in this manner is based on a transmission and absorption approach, where manipulatives are used so that mathematics to be developed can be given an embodiment which is real to the learner. This study details that teaching in this way is based on a theoretical perception mathematical learning is somehow captured or contained within the manipulatives. Therefore, all the learner has to do is discover 'the mathematics' and transfer the physical representation into a conceptual and symbolic representation. My experiences suggest if pupils are to construct meaning from manipulatives, then trainees have to be explicit about the mathematical concepts to be developed from the manipulative.

The findings revealed the trainees experienced difficulty in unpacking the different bodies of knowledge they were exposed to in mathematics. A recurrent theme was the desire to support learners move from visual representations to abstract via the use of manipulatives. The participants' notion of learning with manipulatives revolved around collections of loosely related abstract concepts where mathematics achievement was based on symbols and procedural fluency (Howard, Perry and Tracey, 1997). Clements' (1999) study contends the concrete operational stage is often misused as a rationalisation for the use of manipulatives. The concrete operational stage is rooted in the idea young pupils reason concretely before they are able to reason abstractly. Even though manipulatives are physical objects, understanding how they represent concepts requires a shared understanding of the purpose of the manipulative (Laski et al., 2015). The value attached to some manipulatives is not forever fixed in its meaning and can be understood on many

levels. Pupils, therefore, require time to notice the relationship between the concrete (physical) material and the abstract concept that they represent. Learners also need to be given time to gain familiarity with the manipulative so that rather than focus on the manipulative itself, they focus on mathematics that is being developed.

The subtleties of how pupils use manipulatives are still not clearly understood. Moyer and Jones (2004) propose a model for using manipulatives that incorporates the role of reflection and discussion alongside action to ascertain pupils are learning. Within this model, the mathematical needs of learners can be teased out by observing and talking with pupils providing valuable insights. Ball (1992) study highlights teaching with manipulatives requires not only an understanding of suitable pedagogical strategies and techniques but a significant reframing of instructional practices.

Analysis of the transcripts revealed the trainees did not talk very much about the importance of actively handling and manipulating objects to bring about new learning. There appeared to be a lack of understanding of the role of enactive representations even though mastery approaches were endorsed. The findings suggest participants may be perceiving manipulatives in different ways based on literature and yet in the classroom, they are relying on them as a lifebuoy or a supportive device due to a lack of understanding. The above finding is consistent with Griffiths and Gifford's (2016) findings that there is an emphasis on mastery approaches in school, there remains an absence of guidance available surrounding the use of manipulatives, particularly in terms of supporting learners when moving fluently between representations of mathematical ideas.

Ball and Bass (2000) contend the demands of teaching mathematics create the need for a specialised body of knowledge that connects content and pedagogy. Shulman (1986) describes pedagogic content knowledge as information specifically relating to the subject of teaching that is the bridge between the teacher's knowledge, and enabling the pupils to know. Shulman (1986) argues '*a teacher needs not only to understand that something is so, they must also understand why it is so.*' It, therefore, involves presenting and formulating mathematical concepts in

order to create suitable opportunities to learn as well as an appreciation of pupils' conceptions, difficulties and common errors. A major part of this specialist content knowledge is the ability to appraise learners' methods and determine whether the methods can be generalised to other problems.

The findings revealed the trainees and pupils appeared to be using manipulatives for different purposes and in different ways and the distinction between tools and supportive devices concerned choice and dependency. The transcripts revealed the trainees based their teaching on transmission absorption approaches whereby learners seek to grasp the mathematical meaning assigned that is inherent in the words and actions of the trainee (Cobb, 1994). Moscardini's (2009) study found pupils use manipulatives for sense-making, whereas in contrast, teachers tend to use these objects to demonstrate procedures for pupils to practice. Therefore, it is imperative manipulatives are perceived as more than physical supports as learners have to actively manipulate these materials to construct meaning and use them to develop their ideas further (Baroody, 1989).

Findings from the study demonstrated manipulatives were used to bridge the social gap created by the perceived lack of learning. The use of manipulatives as a lifebuoy suggests a lack of awareness surrounding the purpose of the manipulative. While studies such as Baroody (1989) asserted manipulatives are used on some occasions as crutches for pupils with specific needs, this study does not examine how trainee teachers' use manipulatives. Therefore, the use of manipulatives as a 'lifebuoy' is a new finding.

Trainees' Recommendations

This research revealed the trainees considered utilised learning theories or textbooks recommended by the University as paramount to a successful placement. Brown and McNamara (2005) found the specific procedures set out in instructional texts and U.K Government guidance often meet the demand and provide support where there may be a lack of confidence. However, these step by step guides may

reinforce the banking concept of education and make the art of teaching appear deceptively simple. It can be challenging for trainees to identify the theoretical steps when confronted with the reality of classroom practice. While it is widely acknowledged the relationship between the quality of mathematics teaching and the subject knowledge is important (Hyde and Edwards, 2014), it is equally important that trainees are provided mentors to support them.

The accounts describe the powerful recurrent theme where trainees thought a bank of strategies would prove useful in increasing their confidence and competence in the delivery of mathematics. A commonly held perception was obtaining a bank of strategies was a productive way forward to support pupils identified as requiring support. The trainees appeared to want to build a recipe of knowledge rather than to make a repertoire of skills (Brown and McNamara, 2001).

Thompson and Spenceley's (2019) research found trainees often consider theory as a set of ideals or general principles which can be used to explain a fact, event or opinion. Still, it can also be viewed as a set of rules which have the potential to guide the action. In this sense, theories thus become a form of the abstract that are often applied directly to either explain or guide teaching practices. Utilising existing theory to inform practices can potentially reinforce the status quo leaving little room for change and development of innovative practices (Thompson and Spenceley 2019). Yet, it is the play with the convention that originality arises, not in the rejection of it. A middle ground needs to be found whereby pupils are given time to explore the manipulatives and encouraged towards finding their own solutions as restrictions can result in pupils thinking there is just one correct procedure (Moscardini, 2009).

Analysis of the transcripts revealed all the trainees considered reflective time was paramount to a successful placement. Samantha also felt watching video clips of her teaching were a useful reflective tool. Gattegno (1969) proposed to teach others, one must become aware of one's own awareness. He held the opinion media (video recordings) provided an ideal opportunity to enhance perception and very much viewed it as one of the greatest educational tools, providing a framework for developing effective and efficient techniques. Video recordings create a space

to open up the discussion and develop metacognition that is awareness and understanding of how one's own thought processes influence their perception. Videos encourage a paradigm shift moving trainees to focus on the present and what's happening now, not their future goals. Freire (1970/1996) also testifies that when the oppressed are submerged, it can prove difficult for them to 'see' differently and suggests that the only way to counteract this is in the engagement of critical reflection.

The purpose of the video clip is to direct attention away from the participant and focus upon the learning, which was not is not easy for trainees to do when their actions are under scrutiny on placement. This finding correlates with the existing literature by Coles (2013). Rosaen et al. (2008) found a significant difference between what pre-service teachers noticed when reflecting on lessons from memory compared to when they viewed video footage and also noticed when using video recordings, observations and statements about teaching were more specific and focused. This finding is also supported by McDuffie et al. (2014) as well as Armador (2017) who found evidence that the use of video clips as a tool for analysis with pre-service teachers supported their capabilities to notice the pupils' competencies related mathematical thinking, the classroom environment and teacher-student communication during the lesson. The video clips enable the trainees to develop metacognitive skills.

However, while the trainees requested opportunities for reflection, the findings indicate the participants may benefit from reflexivity opportunities. Reflection is considered a systematic reviewing process for trainees and teachers, which permits the individuals to make links from one experience to the next questioning pedagogic practice (Feucht, Lunn Brownlee and Schraw, 2017). Whereas reflexive learning involves the individual examining their own feelings, reactions and emotional motives and how these influence the person's thinking in a situation. Feucht, Lunn Brownlee and Schraw (2017) argue reflection on its own does not necessarily guarantee informed practice; therefore, it may be beneficial to support reflection for action with reflexivity. It is well documented that theories of reflexivity not only permit

the act of self-reference but can uncover possible causal relationships for human social structures at play (Robins et al., 2003).

Although the trainees did not request any further support from their mentors, it was probable the trainees may benefit from establishing closer relationships. Engaged pedagogy establishes a mutual relationship between teacher and trainee that nurtures the growth of both parties creating an atmosphere of trust and commitment that is always present when genuine learning happens (hooks, 2010)

This study found trainees made use of learning theories and textbooks recommended by the University to develop their subject knowledge in how to use manipulatives. The trainees requested a bank of strategies to further enhance their knowledge of how to make use of manipulatives. This finding was consistent with the existing literature base, which found trainees often perceive theory as a set of ideals or general principles to guide their actions.

The study findings revealed all the trainees perceived additional time to be reflective during placement and the use of video clips as a reflective tool were paramount to a successful placement. This finding was consistent with existing studies. Although the trainees did not request any further support, analysis of the transcripts revealed the trainees could benefit from establishing closer support with mentors. This is a finding worthy of further investigation.

6.3 **Significance and Originality**

This research enhances previous work in this area. The insights presented in this thesis contribute to understanding how and why trainees use mathematical manipulatives as they develop their professional learning during placement. The findings indicate the trainees acknowledged the many benefits associated with using manipulatives. Yet, there existed a silent set of institutional rules at play as to how the manipulatives are selected, introduced and utilised. These rules reinforced habitual practices such as assigning manipulatives solely to the pupils classified as

requiring further support. The sensory experiences of the manipulative were therefore used by the trainee as a 'lifebuoy' to bridge the social gap caused by grouping by ability.

The participants also revealed uncertainties in identifying manipulatives, yet they were very much left alone to cope with the challenges that occurred during placement. Mismatches existed between perceptions and accounts of use, and although manipulatives have countless affordances, it was taken for granted the manipulatives and the associated language assigned would be universally understood. These are novel findings that are worthy of further study.

Searches of the literature indicated that there is a paucity of qualitative research dedicated to examining trainee teachers' perceptions of manipulatives generally. To my knowledge, no record exists of qualitative studies of this type that have been conducted investigating trainee teachers' perceptions of mathematical manipulatives. The existing research base tends to focus on qualified teachers' experiences with manipulatives; therefore, it is hoped that this current study would make an original contribution to the existing knowledge base.

6.4 **Contribution to Professional Practice**

It is anticipated this study will encourage mentors such as myself to support trainee teachers to move beyond routine practices and make use of the practicum to develop and employ the more experiential aspects of classroom learning. As my study progressed, my teaching evolved. My sessions include opportunities for everyone to collaborate, handle, and discuss the range of manipulatives available.

It is foreseen this study will enable trainees to experiment with creating high-quality curricula and teaching materials. As trainee' teachers teach pupils, it is anticipated revisions will take place in professional learning that will help foster child-centred teaching and learning. There are potential benefits in terms of academic attainment and personal, communal wellbeing to pupils, young people and their trainee

teachers, regionally nationally or internationally should this research promote wider participation and shared decision-making.

A summary of the key findings will be presented to the University to which I am linked, where the research will contribute to the knowledge, and pedagogical practice (teaching and learning) of the mathematics modules of study. Some changes have already been implemented at the institutional based on the preliminary findings such as further training provided during placement. I proposed strengthening trainees' understanding through appropriate professional development relating to using manipulatives needs to take place specifically within the overall context of pupils' learning.

This study can offer the starting point for sustained change and impact concerning course validation documents, programme material, as well as recruitment. At present students are recruited on traditional ITE routes and school-based routes. There is a need to understand the challenges both camps face when embarking on teacher training.

The idiographic nature of IPA permits the voices of individual participants to be heard. Research such as this provides students with a voice which is a vital component of student satisfaction and influences not only how much they enjoy their learning but how well they perform.

The benefits outside of academia could occur through social enterprise, professional practice and policy design and assist in the production of creative, enthusiastic, innovative, qualified mathematics teachers that are willing to engage in liberatory practice, with a real sense of integrity taking professionalism to a deeper level.

6.5 **Methodological Considerations**

I found the idiographic focus of Interpretative Phenomenological Analysis (IPA) to be a strength as it enabled in-depth exploration of each participants' experiences.

Each transcript was analysed thoroughly and in detail, as I considered this strategy would improve the rigour of the study.

As IPA is a recently developed methodology within the field of education, there existed some challenges. I found it challenging to present the results in response to the two separate research questions as the trainees' experiences did not fit nicely into the expected structure. There existed some overlaps in the responses given that could be used to respond to either research question. Also, some of the responses did not meet either research question, such as the interesting results of the mismatch between trainees' perceptions and accounts of use. This nimble approach focuses on the commonality of the lived experience on its own terms' rather than attempting to reduce it to 'predefined or overtly abstract categories' (Smith, Flowers and Larkin, 2009).

Also, this approach is relatively new, and readers may question the structure of including additional literature within the discussion. I experienced some difficulty in navigating the boundary of providing enough structure for readers to follow and meet the expected conventions while remaining true to the IPA process and capturing authentic accounts. For the reasons highlighted above, it may be helpful for future novice researchers to make use of just one research question.

Although the sample size was small and could be perceived as a limitation, the small size proved to be advantageous as it permitted a thorough analysis. Each interview was analysed carefully as I considered this strategy would improve the rigour of the study. Interpretation of data at the descriptive, linguistic and conceptual levels ensured all the voices of the participants were heard, therefore meeting the idiographic commitment of this approach (Smith, Flowers and Larkin, 2009).

A further improvement would be to invest more time into the recruitment of a purposive sample. I found that it was not sufficient to rely on the participants' assurances that they could comprehend the research topic. They must also demonstrate their understanding of it. Perhaps issuing a short questionnaire or

responding to a case study scenario before recruitment could improve the study further.

Hermeneutics proved to be a valuable tool for analysing texts and documents. In this instance, a 'triple hermeneutic' took place as I was making sense of the participants' past recollections of experiences, while they were making sense of the phenomenon. When the reader is added to this process, the reader is making sense of the researcher who is making sense of a participant, who is making sense of the phenomenon (Behal, 2018). There are multi-layers of interpretation on the part of both the participant, researcher and reader.

While it is easier to identify convergences, divergences and contradiction when the sample is small, a criticism of this approach was the sample size. Nonetheless, IPA only requires a small number of participants, especially for researchers (a corpus of 6) with limited experience and a limited word count (Smith, Flowers and Larkin, 2009). Smith Flowers and Larkin (2009) contend it is more problematic when the sample is too large than too small.

Enabling participants to select their own video recording also proved to be a strength as well as a limitation of the study. I had no control over what the students brought, and the video clips varied in length, focus and age groups. Some of the participants arrived without a recording. While this strategy proved advantageous as I was able to establish trust enabling the trainees to feel much more relaxed in discussing their experiences, it was also limiting for me. As a new researcher, it proved extremely difficult for me to gather all the information I wanted during the interview as I had a limited time frame to focus and respond to the contents. It also proved challenging to recall the footage observed from memory and accompanying notes.

Although considerable research exists supporting the use of this medium to develop mathematics teachers learning, little is known about the precise skills required in terms of the role of the facilitator (Clay and Kirtley, 2005). There are significant design issues, particularly concerning facilitation and how to establish norms of what to notice. Blomberg et al. (2013) reported: "*The use of video is mostly described in*

quite general terms; when in fact, it is the details of how video is integrated into instruction that seem to determine its effectiveness" (2013: 94).

Also, I found two people can watch the same video clip and draw different conclusions. Videos are a subjective simplification of reality. Sean interpreted on many occasions, a lack of engagement and deemed the child to be playing, whereas, in contrast, I considered the child to be exploring various solutions to the task at hand. As a new researcher, I struggled on occasion to direct the participants' attention away from themselves and focus upon the learning.

While I am new to qualitative analysis and IPA, I attended conferences, advanced workshop sessions with experienced staff, worked closely with my supervisors and engaged in a wide breadth of reading surrounding this methodology to ensure the quality of this study. These steps were in addition to the taught sessions I received as part of my doctoral training.

In future studies of this nature, it may be helpful to conduct a pilot study. It is accepted that the interview schedule would have some effect on the themes interpreted in the analysis, as it was the basis for the structure of the interview. When analysing the transcripts, I noticed that there were minor unplanned interruptions that interrupted the flow and some opportunities where I should have paused or ask further follow-up questions. Listening carefully to the participants is an important skill as what is not said is just as important as what is said. A pilot study would have provided some valuable insights, enabling me to develop the interview schedule further and test the research instruments.

Nonetheless, every effort was made to avoid the use of leading questions, and the interview schedule was used flexibly. Some revisions were made to the schedule of questions following each interview. The answers aided in the formulation of new questions. At the end of the interview, all participants were offered the right to ask questions, and they were provided the chance to further clarify the responses given. I believe IPA was the correct methodology for this research. Still, I am also aware that the challenge of keeping within the word count has to some extent, limited what I have been able to describe in terms of analysis of the participants' experiences.

6.6 **Suggestions for Future Research**

The study findings revealed the trainees were very much left alone to cope with challenges that occurred during placement. The U.K. Government has recently implemented the Early Career Framework (DfE, 2019) funding package to support early career teachers. My long-term aim is to develop professional development cluster groups within the region. The workshops will contribute to the drafting and publication of quality school-based action research relating to the ongoing developments of inquiry-based mathematics in schools. Studies such as this permit researchers to remain within the detail of the experience while at the same time, uncover something new (Coles, 2019). Teachers can immediately adapt according to the findings reinforcing a strong link between theory and practice. As research and scholarly activity remains an essential feature of university faculties, activities, and the results of the research will be published in educational journals, websites and conferences.

Interpretative Phenomenological Analysis is a recently developed investigative methodology that originates in the field of phenomenological psychology. However, it is now increasingly utilised within a range of fields that examine human and cognitive sciences. The use of story boxes as a way of reporting research results could potentially inspire future researchers to consider a similar format and make greater use of video recordings as a reflective tool. Staff within the mathematics team who are in the process of completing Masters/Doctorate can use the findings to contribute and enhance the quality of their research. Studies that are written in an accessible style, such as this may encourage audiences who are not used to reading research papers such as trainee teachers to access and engage research about people similar to themselves and become better consumers, targeting a broader audience.

In future it may be possible to engage in the process of inquiry with the trainees whereby teaching and research are brought closer together. The trainees could build

upon this study by researching their own practice, and consent to pupils recording their learning experiences with manipulatives from their perspective to compare with the trainees' own accounts. This could also involve trainees team teaching on placement. I consider it is important to appraise learning from all perspectives and include more child-centred approaches.

As an active member of external professional bodies relating to mathematics, this study will enable me to continue to refine my teaching skills, publish publications, confidently contribute to policy, national debates and create further opportunities for cross-faculty development.

I have drawn on the research of a wide variety of scholars to make sense of the trainees' experiences, particularly the literature of hooks (2003). While hooks (2003) literature is predominantly situated in the field of critical pedagogy, many of her findings can be applied to assist in engaging learners in mathematics. I have found in my journey of exploring primary mathematics, the subject cannot be meaningfully considered in isolation.

6.7 **Study Reflection**

I consciously chose this study as it created a space to help me make sense of a professional problem and formulate a solution to a complex issue.

Years of heavy teaching loads had removed some of the passion. Education for me had become future-orientated, so much so that I lost focus on the reason I entered the profession. Ashwin (2017) argues that even at institutions which pride themselves as focused on teaching implement heavy teaching loads and high administrative requirements that can reduce teaching to a procedural activity rather than a student-centred creative interaction.

Engaging in this study and working closely with supportive supervisors has provided a space for reflexivity and supported me to find my voice. I am beginning to develop

the courage to question more and step outside my comfort zone. I have amalgamated my professional and academic knowledge into my writing while remaining mindful any knowledge found should be purposeful in serving others.

This research has enabled me not only to share information but to share in the intellectual and spiritual growth of my trainees. I now have a greater understanding of the importance of nurturing reciprocal relationships when building confidence and competence on placement. Now that I have a greater understanding of the challenges trainees face on placement, I endeavour to ensure trainees are provided more opportunities to express choice and provided increased contact and support, particularly during placement. This will include more enterprise events for mentors and trainees where everyone will have opportunities to share ideas, collaboratively develop lesson plans, handle and experiment with a range of manipulatives, building a community of practice and creating a safe space for discussion. I also aim to ensure there are opportunities for trainees to develop their knowledge and experiences about how to use manipulatives collaboratively, particularly during the practicum. I have found that the richer and broader the inputs, the more the brain has to play with. Creativity, for me, is not about generating something out of nothing but involves creatively taking risks and reconfiguring what is known.

One of the benefits of using IPA methodology is the researcher is analysing others while at the same time analysing themselves. This sensitivity to context, commitment to validity and rigour enabled me to make sure the descriptions and accounts were reflective of the participants' perceptions, thus answer the research questions. Through an examination of the experiences of others, I was able to examine and reflect on my practice's biases, assumptions and habitual unconscious practices, particularly surrounding the teaching of mathematics with manipulatives. As a consequence of this study, I endeavour to make sure trainees are provided with more support and further opportunities to handle discuss and experiment with their use of manipulatives not just when attending sessions but when they are on placement too.

A recent outbreak of COVID-19 (an infectious respiratory pandemic) has caused a worldwide lockdown. Social interactions are now heavily restricted. Everyone has been advised to stay at home to prevent the spread of the virus. Lectures are now available in digital environments. Yet not all trainees/students will have access to excellent broadband computers or laptops at home. These measures will have a significant impact on learning experiences and the use of physical manipulatives for some time, while all public faculties remain close.

Nonetheless, I intend to use video footage more frequently as a reflective tool to create the space for a shared understanding and enhance students' reflections. I hope my findings highlight the importance of building reciprocal social relationships and providing opportunities for trainees and learners alike to physically handle and manoeuvre manipulatives while learning mathematics. It is anticipated in the future; revisions will take place that will help preserve teaching and learning that is fun and child-centred.

Chapter 7: Conclusion

This study aimed to gain an informed understanding of PGCE trainee teachers' perceptions and accounts of using manipulatives as they developed their professional learning during placement. Few studies in this area have focused on trainee teachers. Understanding trainees' perceptions about manipulatives offers insights into how our next generation of teachers might use and apply manipulatives in the classroom.

Following a phenomenological tradition, this study sought to give meaning and significance to the trainees' commentary. Qualitative methods, including interviews were used with participants to gain personal insights and accounts of using and applying manipulatives. Interviews were recorded, transcribed and analysed using Interpretative Phenomenological Analysis (IPA). This approach focuses on the commonality of the lived experience within a particular group 'exploring experience in its own terms.' Therefore, the emphasis is on seeking to explore the patterns of unanticipated and unexpected relationships between phenomena opening other avenues of exploration.

Analysis resulted in the identification of four important areas of focus: the first being the 'purposes' of using manipulatives as described by the trainees, the second being the accounts of 'practices' of using manipulatives, the third being the related 'emotions' and 'feelings' experienced, and the final being how the use of manipulatives 'impacted' trainees' learning. Overall, findings indicated a silent set of institutional rules at play as to how manipulatives are selected, introduced and utilised, reinforcing habitual practices such as assigning manipulatives solely to the children classified as requiring further support. Routine practices are considered to be actions that are performed out of habit without critical thought. Study data revealed the sensory experiences of the manipulative were used as a 'lifebuoy' to bridge the social gap caused by grouping by ability.

Significantly, this study also revealed that although trainees are novices, they appeared to be expected to cope and navigate difficulties with teaching in isolation. In response, trainees drew on support for manipulative use from sources such as learning theories, textbooks and their own experiences. Mismatches existed between perceptions and accounts of use, and although manipulatives have countless affordances, it was taken for granted the manipulatives and the associated language assigned would be universally understood. Trainee teachers' accounts revealed an emphasis on transmission and absorption modes of teaching, thus teaching and learning with manipulatives becomes an act of depositing. Without a community of collaboration, trainees are isolated; therefore, cultural norms will be reinforced. Trainees should feel empowered to explore the different manipulatives available during the practicum as they develop their professional learning.

This study found the use of video recordings as a reflective tool can help challenge the traditional view of mathematics teaching. Engaged pedagogy and inquiry practices can untangle some of the complexities that occur during placement. Engaged pedagogy is not about solely providing trainees with experience of using manipulatives, or a bank of strategies and directing them how to use them, but about the removal of systemic barriers. When used effectively, manipulatives involve creating a mutual relationship between teacher and learner that nurtures the growth of both parties, creating an atmosphere of trust and co-operation.

Studies that are written in an accessible style, such as this may encourage audiences who are not used to reading research papers such as trainee teachers to access and engage research about people similar to themselves and become better consumers, targeting a broader audience. This study, to the best of my knowledge is first to use a phenomenological approach to provide deeper insights into the experiences of trainee teachers' use of mathematical manipulatives. The findings reinforce the notion that trainee teachers' perceptions are mediated by many influences, so innumerable and complex. This study has highlighted the need for both formal and informal support for trainees on placement that support the building of confidence when integrating manipulatives into their teaching. A balance has to

be found between providing enough support to nurture trainees into becoming autonomous professionals and setting policies that prescribe practices.

REFERENCES

Adichie, C.N. (2009). *The danger of a single story*. Available [Online] at: https://www.ted.com/talks/chimamanda_ngozi_adichie_the_danger_of_a_single_story. [Last accessed 11 December 2019].

Akkerman, S. and Bakker, A. (2011). 'Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. Review of Educational Research, 81, 132-169.'. *Review of Educational Research*, 81, pp.132–169.

Amador, J., Estapa, A., De Araujo, Z., Weston, T. and Kosko, K. (2017). 'Eliciting and analysing pre-service teachers' mathematical noticing'. *Mathematics Teacher Educator*, 5, pp.158–177.

Antropov, A. (2014). 'Secondary school mathematics teacher candidates' research pedagogical and content knowledge (Order No. 3667251).'. University of Toronto (Canada). Available [Online] at: https://search.proquest.com/docview/1636535845?accountid=14511.

Armador, J. (2017). 'Preservice teachers' video simulations and subsequent noticing: a practice-based method to prepare mathematics teachers'. *Research in Mathematics Education*, 19 (3), pp.217–235.

Ascher, M. (1998). *Ethnomathematics: A Multicultural View of Mathematical Ideas*. California: Chapman & Hall. Available [Online] at: https://www.crcpress.com/Ethnomathematics-A-Multicultural-View-of-Mathematical-Ideas/Ascher/p/book/9780412989414. [Last accessed 24 June 2019].

Ashwin, P. (2017). *Reflective Teaching in Higher Education*. London, UK: Bloomsbury Academic.

Askew, M. (2011). *Transforming primary mathematics*. New York: Taylor & Francis.

Askew, M., Brown, M., Rhodes, V., D Wiliam and Johnson, D. (1997). *Effective Teachers of Numeracy: Report of a study carried out for the Teacher Training Agency*. London, UK: King's College, University of London.

Askew, M., King's College London. School of Education and Teacher Training Agency (1997). *Effective teachers of numeracy. Final report (Feb 1997): report of a study carried out for the Teacher Training Agency 1995-96 by the School of Education, King's College London / Mike Askew (project contact) ... [et al.]*. London: King's College, London, School of Education.

Ball, D.L. (1990). 'Prospective Elementary and Secondary Teachers' Understanding of Division'. *Journal for Research in Mathematics Education*, 21 (2), pp.132–144. Available [Online] at: https://www.jstor.org/stable/749140. [Last accessed 1 June 2019].

Ball, D.L. (1992). 'Magical Hopes: Manipulatives and the Reform of Math Education'. *American Educator: The Professional Journal of the American Federation of Teachers*, 16 (2), pp.14-18,46-47. Available [Online] at: http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,shib&db=eric&AN=EJ449539&site=ehost-live&scope=site.

Ball, D.L. and Bass, H. (2000). *Bridging Practices:Intertwining content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.) Multiple perspectives on mathematics teaching and learning (p.83-104)*. Westport, CT: Westport, CT : Ablex Pub.

Barber, M. and Mourshed, M. (2007). *How the World's Best-Performing School Systems Come Out on Top*. London: McKinsey & Company.

Barker, C. (2002). *Research Methods in Clinical Psychology: An Introduction for Students and Practitioners*. 2nd edition. New York: Wiley.

Baroody, A. (1989). 'Manipulatives Don't Come with Guarantees.'. *The Arithmetic Teacher*, 37 (2), p.4.

Behal, D.A. (2018). *Negative Capability: A Phenomenological Study of Lived Experience at the Edge of Certitude and Incertitude*. Independently published.

Bell, J. (1999). *Doing Your Research Project: A Guide for First-time Researchers in Social Science, Education and Health*. 3rd ed. Philadelphia: Open University Press.

Bernstein, A.L. (1963). 'Use of Manipulative Devices in Teaching Mathematics'. *The Arithmetic Teacher*, 10 (5), pp.280–283.

Blomberg, G., Renkl, A., Sherin, M.G., Borko, H. and Seidel, T. (2013). 'Five research-based heuristics for using video in pre-service teacher education'. *Journal for Educational Research Online*, 5 (1), pp.90–114. Available [Online] at: https://www.scholars.northwestern.edu/en/publications/five-research-based-heuristics-for-using-video-in-pre-service-tea. [Last accessed 4 February 2019].

Bloom, A. (1991). *Introduction' to Rousseau, J-J. (1762) Émile,*. London: Penguin.

Bloom, B.S. (1968). 'Learning for Mastery. Instruction and Curriculum. Regional Education Laboratory for the Carolinas and Virginia, Topical Papers and Reprints, Number 1. Evaluation comment, 1, n2.' [Internet]. Available [Online] at: https://files.eric.ed.gov/fulltext/ED053419.pdf.

Bouck, E.C. and Flanagan, S.M. (2010). 'Virtual Manipulatives: What They Are and How Teachers Can Use Them'. *Intervention in School and Clinic*, 45 (3), pp.186–191.

Boulton-Lewis, G.M. (1998). 'Children's strategy use and interpretations of mathematical representations'. *Journal of Mathematical Behavio*, 17 (2), pp.219–237.

Brinkmann, S. and Kvale, S. (2015). *Interviews, Learning the Craft of Qualitative Research Interviewing*. London: Sage Publications.

British Educational Research Association (2018). 'Ethical Guidelines for Educational Research, fourth edition (2018)' [Internet]. Available [Online] at: https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018-online. [Last accessed 9 August 2020].

Broadfoot, P. and O., M. (1993). 'The Meaning of Professionalism'. In *Perceptions of teaching : primary school teachers in England and France,*. London: Cassell, pp.77–87.

Brooks, R., Riele, K. and Maguire, M. (2014). *Ethics and education research*. United Kingdom: SAGE Publications.

Brophy, J. (2007). 'Discussion. In J. Brophy (Ed.), Using video in teacher education'. In Bingley, UK: JAI Press, pp.287–304.

Brown, M. (2014). 'The Cockcroft report: time past, time present and time future. Mathematics Teaching, 243, 5-9.'.

Brown, T. and McNamara, O. (2001). 'British research into initial and continuing professional development for teachers. In M. Askew and M. Brown (eds.), Teaching and learning:primary numeracy, practice and effectiveness'. *British Educational Research Association*, pp.55–56.

Brown, T. and McNamara, O. (2005). *New Teacher Identity and Regulative Government - 2005 The Discursive Formation of Primary Mathematics Teacher Education Authors:* United States of America: Springer.

Bruner, J.S. (1966). *Toward a Theory of Instruction*. Cambridge: Mass.: Belkapp Press.

Bruner, J.S. (1978). *The role of dialogue in language acquisition. In A. Sinclair, R., J. Jarvelle, and W. J.M. Levelt (eds.) The Child's Concept of Language.* New York: Springer-Verlag.

Bruner, J. and Haste, H. (2010). *Making Sense. The Child's construction of the world*. London: Taylor & Francis.

Bryman, A. (2012). *Social research methods*. 4th ed. New York: Oxford University Press.

Bullock, S. and Russell, T. (2010). 'Does teacher education expect too much from field experience? In T. Faulkenberg, & H. Smits (Eds.),'. *Field experiences in the context of reform of Canadian teacher education programs*, 2, pp.91–100.

Burghes, D., Szalontai, T., Koyama, M., Myllyntausta, S., Beston, Y.(2012). *Enhancing Primary Mathematics Teaching and Learning Research Report*. Berkshire: CfBT. Available [Online] at: www.cimt.plymouth.ac.uk/papers/epmtl.pd.

Cagliari, P., Castagnetti, M., Giudici, C., Rinaldi, C., Vecchi, V. and Moss, P. eds. (2016). *Loris Malaguzzi and the Schools of Reggio Emilia, A selection of his writings and speeches, 1945 -1993*. Oxon: Routledge.

Carbonneau, K.J., Marley, S. and Selig, J.P. (2013). 'A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives'. *Journal of Educational Psychology*, 105 (2), pp.380–400. Available [Online] at: https://asu.pure.elsevier.com/en/publications/a-meta-analysis-of-the-efficacy-of-teaching-mathematics-with-conc. [Last accessed 24 June 2019].

Charles-Cole, S. (2017). 'A Study of Children's Views of Mathematical Manipulatives in the Transition from Primary to Secondary, unpublished manuscript, University College London'. London, UK: UCL.

Charmaz, K. (2014). *Constructing grounded theory*. 2nd ed. United Kingdom: Sage Publications.

Chillot, R. (2013). 'Surface Impact.The physical sensations of objects we touch influence our more abstract feelings.' [Internet]. Available [Online] at: https://www.psychologytoday.com/articles/201303/surface-impact.

Clay, J. and Kirtley, K. (2005). 'The Transition of a Secondary Mathematics Teacher: From a Reform Listener to a Believer'.

Clements, D.H. (1999). ''Concrete' Manipulatives, Concrete Ideas'. *Contemporary Issues in Early Childhood*, 1 (1), pp.45–60.

Clements, D.H. and McMillen, S. (1996). 'Rethinking Concrete Manipulatives. Teaching Children Mathematics'. *National Council of Teachers of Mathematics*, 2 (5), pp.270–279. Available [Online] at: http://investigations.terc.edu/library/bookpapers/rethinking_concrete.cfm.

Cobb, P. (1994). 'Where Is the Mind? Constructivist and Sociocultural Perspectives on Mathematical Development'. *Educational Researcher*, 23 (7), pp.13–20.

Coles, A. (2013). 'Using video for professional development: the role of the discussion facilitator'. *Journal of Mathematics Teacher Education*, 16 (3), pp.165–184. Available [Online] at: http://link.springer.com/10.1007/s10857-012-9225-0. [Last accessed 24 June 2018].

Coles, A. (2014). 'Mathematics teachers learning with video: the role, for the didactician, of a heightened listening'. *ZDM*, 46 (2), pp.267–278. Available [Online] at: https://doi.org/10.1007/s11858-013-0541-3. [Last accessed 4 February 2019].

Coles, A. (2017). 'A Relational View of Mathematical Concepts. In E. deFreitas, N. Sinclair, & A. Coles (Eds.), What is a Mathematical Concept? (pp. 205-222). Cambridge University Press.' [Internet]. Available [Online] at: https://doi.org/10.1017/9781316471128.013.

Coles, A. (2019). 'Facilitating the use of video with teachers of mathematics: learning from staying with the detail'. *International Journal of STEM Education*, 6 (1), pp.1–13.

Cresswell, J.W. (1998). *Qualitative inquiryand research design: choosing among five traditions*. California: Thousand Oaks, Sage Publications.

Cuisenaire, G. and Gattegno, C. (1961). *Numbers in Colour. A New Method of Teaching Arithmetic in Primary Schools*. London: Heinemann.

Davidson, P.S. (1968). 'An Annotated Bibliography of Suggested Manipulative Devices'. *The Arithmetic Teacher*, 15 (6), pp.509–524.

Dayan, U., Perveen, S. and Khan, M.I. (2018). *Transition from Pre-Service Training to Classroom: Experiences and Challenges of Novice Teachers in Pakistan*.

Deci, E.L. and Ryan, R., M. (1987). 'The support of autonomy and the control of behavior'. *Journal of Personality and Social Psychology*, 53 (6), pp.1024–1037.

Department for Education. (2013). *The National Curriculum in England*. Available [Online] at: https://www.gov.uk/government/collections/national-curriculum.

Department for Education. (2019). 'Supporting Early Career Teachers GOV.UK' [Internet]. Available [Online] at: https://www.gov.uk/government/publications/supporting-early-career-teachers. [Last accessed 17 June 2020].

Department of Education and Science and the Welsh Office. (1989). *Mathematics in the National Curriculum*. London: Her Majesty's Stationery Office. Available [Online] at: http://www.school-maths.info/downloads/Maths_National_Curriculum_1989.pdf.

Dewey, J. (1916). *Democracy and Education*. New York: Barnes and Noble Books.

Dewey, J. (1933). *Dewey, J. (1933). How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process. Boston, MA:* Boston, MA: D.C. Heath & Co Publishers.

Dienes, Z. (1967). *Building Up Mathematics*. London: Hutchinson Educational.

Dowker, A. (2009). *Department for Children, Schools and Families. What Works for Children with Mathematical Difficulties? The Effectiveness of Intervention Schemes [The National Strategies Primary]*. Great Britain.: Available [Online] at: https://www.catchup.org/resources/735/what_works_for_children_with_mathematical_difficulties.pdf.

Drews, D., Hansen, A. and Earnshaw, A. (2007). *Using Resources to Support Mathematical Thinking: Primary and Early Years (Achieving QTS: Practical Handbooks)*. Exeter: Learning Matters.

Drury, H. (2014). *Mastering Mathematics, Teaching to Transform Achievement*. Oxford: Oxford University Press.

Duvarci, S. and Nader, K. (2004). 'Characterization of Fear Memory Reconsolidation'. *Journal of Neuroscience*, 24 (42), pp.9269–9275. Available [Online] at: http://www.jneurosci.org/content/24/42/9269. [Last accessed 5 February 2019].

Dweck, C.S. (1999). *Self-theories: their role in motivation, personality, and development*. Philadelphia, Pa.: Psychology P.

Eagleman, D. (2015). *The Brain: The Story of You*. New York: Pantheon Books.

Elliott, R., Fischer, C.T. and Rennie, D.L. (1999). 'Evolving guidelines for publication of qualitative research studies in psychology and related fields'. *British Journal of Clinical Psychology*, 38 (3), pp.215–229. Available [Online] at: http://doi.crossref.org/10.1348/014466599162782. [Last accessed 11 February 2019].

van Es, E.A. (2010). 'A Framework for Facilitating Productive Discussions in Video Clubs'. *Educational Technology*, 50 (1), p.8.

van Es, E.A. and Sherin, M.G. (2008). 'Mathematics teachers' "learning to notice" in the context of a video club'. *Teaching and Teacher Education*, 24 (2), pp.244–276.

van Es, E., Tunney, J., Goldsmith, L. and Seago, N. (2014). 'A Framework for the Facilitation of Teachers' Analysis of Video'. *Journal of Teacher Education*, 65, pp.340–356.

Fennema, E. (1973). 'Manipulatives in the classroom'. *The Arithmetic Teacher*, 20 (5), pp.350–352.

Feucht, F.C., Lunn Brownlee, J. and Schraw, G. (2017). 'Moving Beyond Reflection: Reflexivity and Epistemic Cognition in Teaching and Teacher Education'. *Educational Psychologist: Changing Epistemic Cognition in Teaching and Teacher Education: A Focus on Reflection and Reflexivity*, 52 (4), pp.234–241.

Fichtman Dana, N. and Yendol-Hoppey, D. (2002). 'The Reflective Educator's Guide to Classroom Research'. In United States of America: SAGE Publications. Available [Online] at: https://www.amazon.co.uk/Reflective-Educators-Guide-Classroom-Research/dp/1544352182/ref=sr_1_2?keywords=the+reflective+educators+guide+to+classroom+research&qid=1573483699&sr=8-2. [Last accessed 11 November 2019].

Flutter, J. and Alexander, R.J. (2009). *Towards a New Primary Curriculum: a report from the Cambridge Primary Review. Part 1: Past and Present.* Cambridge: University of Cambridge Faculty of Education. Available [Online] at: https://cprtrust.org.uk/wp-content/uploads/2014/06/Curriculum-report-2.pdf.

Freire, P. (1996). *Pedagogy of the Oppressed*. London: Penguin.

Froebel, F. and Hailmann, W.N. (2015). *The Education of Man*. Place of publication not identified: Vero Verlag.

Furman, C.E. (2017). 'Making Sense with Manipulatives: Developing Mathematical Experiences for Early Childhood Teachers'. *Education and Culture*, 33 (2), pp.67–86.

Gattegno, C. (1969). *Towards a Visual Culture: Educating Through Television*. Second Printing edition. United States of America: OUTERBRIDGE & DIENSTFREY-1969.

Germain-McCarthy, Y. (2017). *Mathematics and Multi-Ethnic Students*. 2nd ed. New York: Routledge.

Gibbs, G. (1998). *Learning by Doing: a guide to teaching and learning methods* -. Oxford: Oxford Brooks University. Available [Online] at: https://shop.brookes.ac.uk/product-catalogue/oxford-centre-for-staff-learning-development/books-publications/ebooks/learning-by-doing-a-guide-to-teaching-and-learning-methods-by-graham-gibbs-ebook. [Last accessed 17 February 2018].

Gifford, S. and Thouless, H. (2016). 'Using Pattern to Inspire Rich Mathematical Discourse in Mixed Attainment Groups' [Internet]. Available [Online] at: https://discovery.ucl.ac.uk/id/eprint/10053628/1/Gifford&%20Thouless_MT254-16-08.pdf.

Golafshani, N. (2013). 'Teachers' Beliefs and Teaching Mathematics with Manipulatives'. *Canadian Journal of Education; Toronto*, 36 (3), pp.137–159. Available [Online] at: http://search.proquest.com/docview/1540743115/abstract/5C4AA56737DD4757PQ/1. [Last accessed 29 May 2019].

Gonzalez Thompson, A. (1984). 'The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice'. *Educational Studies in Mathematics*, 15 (2), pp.105–127.

Great Britain (1998). 'Data Protection Act 1998' [Internet]. Available [Online] at: https://www.legislation.gov.uk/ukpga/1998/29/contents. [Last accessed 12 February 2018].

Great Britain (2014). 'Children and Families Act 2014, Elizabeth 11, Chapter 6' [Internet]. Available [Online] at: http://www.legislation.gov.uk/ukpga/2014/6/pdfs/ukpga_20140006_en.pdf. [Last accessed 20 April 2015].

Green, T.E. (1971). *The Activities of Teaching*. New York: McGraw-Hill.

Greig, A., Taylor, J. and MacKay, T. (2012). *Doing research with children: a practical guide*. London: Sage Publications Ltd.

Griffiths, R., Back, J. and Gifford, S. (2017). 'Using Manipulatives in the Foundations of Arithmetic Main Report | Nuffield Foundation' [Internet]. Available [Online] at: https://www.nuffieldfoundation.org/using-manipulatives-foundations-arithmetic. [Last accessed 27 July 2019].

Griffiths, R. and Gifford, S. (2016). *Making Numbers: Using manipulatives to teach arithmetic*. Oxford: Oxford University Press.

Grosser, R. (2002). 'Cubit: Egyptian Measures' [Internet]. Available [Online] at: http://freepages.rootsweb.com/~rgrosser/history/amarna/neywetaten/measures.htm. [Last accessed 16 June 2020].

Hamilton, E.W. (1966). 'Manipulative Devices'. *The Arithmetic Teacher*, 13 (6), pp.461–467.

Harre, R. (1979). *Social Being: A Theory for Social Psychology: Written by Rom Harre, 1979 Edition,*. Oxford: Wiley-Blackwell.

Harshman, H.W., Wells, D.W. and Payne, J.N. (1962). 'Manipulative materials and arithmetic achievement in grade 1'. *The Arithmetic Teacher*, 9 (4), pp.188–192.

Hiebert, J. and Lefevre, P. (1986). 'Conceptual and procedural knowledge in mathematics: An introductory analysis'. In *Conceptual and procedural knowledge: The case of mathematics*. Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc, pp.1–27.

Hiebert, J., Stigler, J., Jacobs, J., Givvin, K., Garnier, H., Smith, M., Hollingsworth, H., Manaster, A., Wearne, D. and Gallimore, R. (2005). *Mathematics Teaching in the United States Today (and Tomorrow): Results From the TIMSS 1999 Video Study*.

Hilton, C. (2017). 'The mathematical development of children with Apert syndrome, PhD Thesis, University College London'. London, UK: UCL.

Hodgen, J. (2017). 'Practical and evidence-based recommendations for teaching mathematics' [Internet]. Available [Online] at: http://www.ucl.ac.uk/ioe/news-events/news-pub/nov-2017/recommendations-teaching-mathematics. [Last accessed 22 January 2018].

hooks, B. (1994). *Teaching to Transgress: Education as the Practice of Freedom*. New York, London: Routledge.

hooks, B. (2003). *Teaching Community: A Pedagogy of Hope*. 1 edition. New York: Routledge.

hooks, B. (2010). *Teaching Critical Thinking: Practical Wisdom*. Routledge. New York.: Available [Online] at: https://www.amazon.co.uk/Teaching-Critical-Thinking-Practical-Wisdom-ebook/dp/B000SH3ZYS. [Last accessed 2 May 2020].

Horton, L. (1981). 'Mastery Learning: Its prospects and problems'. *Educational Digest*, 47 (4), pp.29–32.

Howard, P., Perry, B. and Tracey, D. (1997). 'Mathematics and manipulatives: Comparing primary and secondary mathematics teachers' views'. *Paper presented at the Australian Association for Research in Education (AARE) Annual Conference*, p.9.

Hyde, R. and Edwards, J.A. (2014). *Mentoring Mathematics Teachers: Supporting and inspiring-pre-service newly qualified teachers*. Oxon: Routledge.

Hynes, M.C. (1986). 'Selection Criteria'. *Arithmetic Teacher*, 33 (6), pp.11–13.

Jackson, T. (2012). *Mathematics: An illustrated History of Numbers*. Cambridge: Worth Press.

Johnson, M. and Lakoff, G. (1980). *Metaphors We Live By*. New edition edition. Chicago: University of Chicago Press.

Jones, A. (2010). 'Secondary School Mathematics Teachers' Views Of Manipulatives And Their Use In The Classroom'. University of Ottawa.

Joseph, G.G. (2011). *The Crest of the Peacock: Non-European Roots of Mathematics*. 3rd Edition. New Jersey: Princeton Press.

Kablan, Z. (2016). 'The effect of manipulatives on mathematics achievement across different learning styles'. *Educational Psychology*, 36 (2), pp.277–296.

Kanjirathinkal, M.J. (1990). *A sociological critique of theories of cognitive development : the limitations of Piaget and Kohlberg / by Mathew J. Kanjirathinkal.* Lewiston, N.Y.: Lewiston, N.Y.

Kwhali, J. (2017). 'The accidental academic'. In D. Gabriel and S. A. Tate (Eds.), *Inside the Ivory Tower*. London: UCL Institute of Education, pp.5–24.

Lakoff, G. and Nunez, R. (2001). *Where Mathematics Come From: How The Embodied Mind Brings Mathematics Into Being*. Reprint edition. New York, NY: Basic Books.

Laski, E.V., Jor'dan, J.R., Daoust, C. and Murray, A. (2015). 'What Makes Mathematics Manipulatives Effective? Lessons From Cognitive Science and Montessori Education'. Available [Online] at: https://kuscholarworks.ku.edu/handle/1808/20642. [Last accessed 18 February 2019].

Leibeck, P. (1984). *How Children Learn Mathematics*. London: Penguin.

Lesh, R., Post, T. and Behr., M. (1987). 'Lesh, R., Post, T., & Behr, M. (1987). Representations and Translations among Representations in Mathematics Learning and Problem Solving.'. *In C. Janvier (ed.) Problems or representations in the teaching and learning of mathematics*, (21), pp.33–40.

Lesseig, K., Elliott, R., Kazemi, E., Kelley-Petersen, M., Campbell, M., Mumme, J. and Carroll, C. (2017). 'Leader noticing of facilitation in videocases of mathematics professional development'. *Journal of Mathematics Teacher Education*, 20 (6), pp.591–619.

Lester, F.K., Garofalo, J. and Kroll, D.L. (1989). 'Self-Confidence, Interest, Beliefs, and Metacognition: Key Influences on Problem-Solving Behavior'. In D. B. McLeod and V. M. Adams (Eds.), *Affect and Mathematical Problem Solving: A New Perspective*. New York, NY: Springer, pp.75–88. Available [Online] at: https://doi.org/10.1007/978-1-4612-3614-6_6. [Last accessed 1 May 2020].

Lewis, C., Perry, R., Friedkin, S. and Roth, J. (2012). 'Improving teaching does improve teachers:Evidence from lesson study.'. *Journal of Teacher Education*, 63, pp.368–375.

Linden, D.J. (2016). *Touch: The science of the sense that makes us human*. United Kingdom: Viking.

Lortie, D. (1975). *Schoolteacher: A Sociological Study. L*. London: University of Chicago press.

Lotto, B. (2017). *Deviate: The Science of Seeing Differently*. W&N.

Mahoney, K. (2002). 'Latin Dictionary and Grammar Resources - Latdict' [Internet]. Available [Online] at: http://latin-dictionary.net/. [Last accessed 17 December 2018].

Mandrou, R. (1977). *Introduction to Modern France, 1500-1640: An Essay in Historical Psychology*. Harper & Row. Available [Online] at: https://books.google.co.uk/books?id=VfVWAAAAYAAJ.

van Manen, M. (2016). *Phenomenology of Practice: Meaning-Giving Methods in Phenomenological Research and Writing*. Oxon: Routledge.

Marshall, L. and Swan, P. (2005). 'Developing Mathematical Thinking With the Assistance of Manipulatives' [Internet]. Available [Online] at: https://pdfs.semanticscholar.org/0fe3/7c15d26165e3d629603519cb1882576fc68a.pdf?_ga=2.266717388.398447593.1592265130-277375741.1592265130.

Marshall, L. and Swan, P. (2010). 'Exploring the Use of Mathematics Manipulative Materials: Is It What We Think It Is?'. *Australian Primary Mathematics Classroom*, 15 (2), pp.13–19.

Mason, J. (2002). *Researching your own practice : the discipline of noticing*. London: Routledge Falmer.

Matusov, E. and Hayes, R. (2000). 'Sociocultural critique of Piaget and Vygotsky'. *New Ideas in Psychology*, 18, pp.215–239.

McDuffie, A.R., Foote, M.Q., Bolson, C., Turner, E.E., Aguirre, J.M., Bartell, T.G., Drake, C. and Land, T. (2014). 'Using video analysis to support prospective K-8 teachers' noticing of students' multiple mathematical knowledge bases'.

Journal of Mathematics Teacher Education, 17 (3), pp.245–270. Available [Online] at: https://arizona.pure.elsevier.com/en/publications/using-video-analysis-to-support-prospective-k-8-teachers-noticing. [Last accessed 18 February 2019].

McIntosh, J. (2015). 'Final report of the Commission on Assessment without Levels' [Internet]. Available [Online] at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483058/Commission_on_Assessment_Without_Levels_-_report.pdf. [Last accessed 22 January 2018].

Mcleod, J. (2013). *Doing Research in Counselling and Psychotherapy*. Third Edition edition. London: Sage Publications Ltd.

McNeil, N. and Jarvin, L. (2007). 'When theories don't add up: Disentangling he manipulatives debate'. *Theory into Practice*, 46 (4), pp.309–316. Available [Online] at: http://www.tandfonline.com/doi/abs/10.1080/00405840701593899. [Last accessed 31 March 2015].

Medhananda (2006). *The Royal Cubit: Psychometrics of Ancient Egypt*. Puducherry: Sri Mira Trust.

Montessori, M. (1989). *The Montessori method*. New York; London: Schocken.

Morrow, V. and Martin, R. (1996). 'The Ethics of Social Research with Children: An Overview'. *Children and Society*, 10, pp.90–105.

Moscardini, L. (2009). 'Tools or crutches? Apparatus as a sense-making aid in mathematics teaching with children with moderate learning difficulties'. *Support for Learning*, 24 (1), pp.35–41.

Moyer, P.S. (2001). 'Are we having fun yet? How teachers use manipulatives to teach mathematics.'. *Educational Studies in Mathematics*, 47 (2), pp.175–197.

Moyer, P., Bolyard J. and Spikell, M. (2002). 'What Are Virtual Manipulatives?'. *Teaching Children Mathematics, Learning and Teaching Mathematics with Technology*, 8 (6), pp.372–377. Available [Online] at: http://www.jstor.org/stable/41197834 Accessed: 23-03-2015 11:53 UTC.

Moyer, P.S. and Jones, M.G. (1998). 'Tools for Cognition: Student Free Access To Manipulative Materials in Control-versus Autonomy-Oriented Middle Grades Teachers' Classrooms' [Internet]. Available [Online] at: http://eric.ed.gov/?id=ED420524. [Last accessed 31 March 2015].

Moyer, P. and Jones, M. (2004). 'Controlling Choice: Teachers, Students, and Manipulatives in Mathematics Classrooms'. *School Science and Mathematics*, 104 (1), pp.16–31. Available [Online] at: http://doi.wiley.com/10.1111/j.1949-8594.2004.tb17978.x http://onlinelibrary.wiley.com/doi/10.1111/j.1949-8594.2004.tb17978.x/abstract.

Mutodi, P. and Ngirande, H. (2014). 'The Influence of Students` Perceptions on Mathematics Performance. A Case of a Selected High School in South Africa'.

Mediterranean Journal of Social Sciences, 5 (3), p.431. Available [Online] at: http://www.mcser.org/journal/index.php/mjss/article/view/2161. [Last accessed 18 February 2019].

National Association of Mathematics Advisers (2015). 'Five Myths of Mastery in Mathematics' [Internet]. Available [Online] at: http://www.nama.org.uk/Downloads/Five%20Myths%20about%20Mathematics%20Mastery.pdf. [Last accessed 26 January 2018].

Nespor, J. (1987). 'The role of beliefs in the practice of teaching'. *Journal of curriculum studies*, 19 (4), pp.317–328. Available [Online] at: http://www.tandfonline.com/doi/pdf/10.1080/0022027870190403. [Last accessed 31 March 2015].

Newell, R. (2019). *Mastery Mathematics for Primary Teachers*. London: SAGE Publications.

Nipper, K. and Sztajn, P. (2008). 'Expanding the instructional triangle:conceptualizing mathematics teacher development'. *Journal fof Mathematics Teacher Education*, 11, pp.333–341.

Nolan, K. (2011). 'Dispositions in the field: viewing mathematics teacher education through the lens of Bourdieu's social field theory'. *Educational Studies in Mathematics*, 80 (1–2), pp.201–215.

Ofsted (2012). 'Mathematics: made to measure - Publications - GOV.UK' [Internet]. Available [Online] at: https://www.gov.uk/government/publications/mathematics-made-to-measure files/277/mathematics-made-to-measure.html.

O'Neill, O. (2002). *A Question of Trust: The BBC Reith Lectures 2002*. United Kingdom: Cambridge University Press.

Opie, C. and Sikes, P. (2004). *Doing educational research: a guide to first-time researchers*. 1st ed. Thousand Oaks, Calif: SAGE Publications Ltd.

Papert, S.A. (1993). *Mindstorms: Children, computers, and powerful ideas*. 2nd ed. New York: Perseus Books.

Parjares, F. (1992). 'Teachers' Beliefs and Educational Research: Cleaning Up A Messy Construct'. *Review of Educational Research*, 62, p.3.

Perry, B., Tracey, D. and Howard, P. (1999). 'Head mathematics teachers' beliefs about the learning and teaching of mathematics'. *Mathematics Education Research Journal*, 11 (1), pp.39–53. Available [Online] at: https://doi.org/10.1007/BF03217349.

Piaget, J. (1936). *Origins of Intelligence in the Child*. London: Routledge & Kegan Paul.

Piaget, J. (1952). *The Origins of Intelligence in Children*. New York: International Universities Press.

Post, T. (1981). 'The Role of Manipulative Materials in the Learning of Mathematical Concepts' [Internet]. Available [Online] at: http://www.cehd.umn.edu/ci/rationalnumberproject/81_4.html. [Last accessed 17 February 2018].

Rao, N., Ng, S.S.N. and Pearson, E. (2010). 'Preschool Pedagogy: A Fusion of Traditional Chinese Beliefs and Contemporary Notions of Appropriate Practice'. In C. K. K. Chan and N. Rao (Eds.), *Revisiting The Chinese Learner: Changing Contexts, Changing Education*. CERC Studies in Comparative Education. Dordrecht: Springer Netherlands, pp.255–279. Available [Online] at: https://doi.org/10.1007/978-90-481-3840-1_9. [Last accessed 22 July 2019].

Raphael, D. and Wahlstrom (1989). 'The influence of instructional aids on mathematics achievement'. *Journal for Research in Mathematics Education*, 20 (2), pp.173–190.

Reid, K., Flowers, P. and Larkin, M. (2005). 'Exploring lived Experience'. *The Psychologist*, 18 (1). Available [Online] at: https://thepsychologist.bps.org.uk/volume-18/edition-1/exploring-lived-experience.

Reys, R.E. (1971). 'Considerations for teachers using manipulative materials'. *The Arithmetic Teacher*, 18 (8), pp.551–558.

Robins, A., Ashbaker, B., Enriquez, J. and Morgan, J. (2003). 'Learning to reflect: Professional practice for professionals and paraprofessionals'. *International Journal of Learning*, 10, pp.25555–2565.

Robson, C. (2011). *Real World Research: A Resource for Users of Social Research Methods in Applied Settings*. United Kingdom: Wiley-Blackwell (an imprint of John Wiley & Sons Ltd).

Rosaen, C.L., Lundeberg, M., Cooper, M., Fritzen, A. and Terpstra, M. (2008). 'Noticing noticing: How does investigation of video records change how teachers reflect on their experiences?'. *Journal of Teacher Education*, 59, pp.347–360. Available [Online] at: https://www.rebeccawestburns.com/my-blog-3/notes/rosaen-et-al-noticing-noticing-how-does-an-investigation-of-video-records-change-how-teachers-reflect-on-their-experiences. [Last accessed 18 February 2019].

Rothschild, B. (2000). *The Body Remembers: The Psychophysiology of Trauma and Trauma Treatment*. 1 edition. New York: W. W. Norton & Company.

Sarama, J. and Clements, D.H. (2016). 'Physical and Virtual Manipulatives: What Is "Concrete"?'. In P. S. Moyer-Packenham (Ed.), *International Perspectives on Teaching and Learning Mathematics with Virtual Manipulatives*. Mathematics Education in the Digital Era. Cham: Springer International Publishing, pp.71–93. Available [Online] at: https://doi.org/10.1007/978-3-319-32718-1_4. [Last accessed 27 July 2019].

du Sautoy, M. (2012). 'BBC Four - The Story of Maths, The Genius of the East, Eastern maths and the invention of zero and negative numbers'. *BBC Four*. Available [Online] at: https://www.bbc.co.uk/programmes/p00wj2v3. [Last accessed 28 July 2019].

Schön, D.A. (1983). *The Reflective Practitioner: How Professionals Think in Action.* London: Temple Smith.

Sellars, M. (2017). *Reflective Practice for Teachers*. London: Sage.

Shulman, L.S. (1986). 'Those who Understand: Knowledge Growth in Teaching'. *Educational Researcher*, 15 (2), pp.4–14.

Silber, K. (1965). *Pestalozzi: The man and his work*. London: Routledge and Kegan Paul.

Skemp, R. (1977). 'Relational Understanding and Instrumental Understanding, Mathematics Teaching,'. *Mathematics Teaching*, 77, pp.20–6.

Skemp, R. (1987). *The psychology of learning mathematics*. Expanded American ed. Hillsdale, N.J.; Hove: Lawrence Erlbaum.

Smith, J.A., Flowers, P. and Larkin, M. (2009). *Interpretative Phenomenological Analysis: Theory, Method and Research*. London: SAGE.

Sousa, D.A. (2015). *How the Brain Learns Mathematics*. United States: SAGE Publications.

Sowder, L. (1976). 'Criteria for concrete models'. *The Arithmetic Teacher*, 23 (6), pp.468–470.

Sowell, E.J. (1989). 'Effects of Manipulative Materials in Mathematics Instruction'. *Journal for Research in Mathematics Education*, 20 (5), pp.498–505. Available [Online] at: http://www.jstor.org/stable/749423.

Spross, P. (1964). 'Considerations in the Selection of Learning Aids'. *The Arithmetic Teacher*, 11 (5), pp.350–353.

Struik, D.J.J. (1987). *A Concise History of Mathematics*. 4th ed. New York: Dover Publications.

Sutton Trust (2014). 'What makes great teaching?' [Internet]. Available [Online] at: https://www.suttontrust.com/research-paper/great-teaching/. [Last accessed 5 February 2018].

Suydam, M.N. (1986). 'Manipulative Materials and Achievement'. *The Arithmetic Teacher*, 33 (6), pp.10–32.

Swan, P. and Marshall, L. (2010). 'Revisiting Mathematics Manipulative Materials'. *Australian Primary Mathematics Classroom*, 15 (2), pp.13–19. Available [Online] at: https://eric.ed.gov/?id=EJ891801. [Last accessed 22 June 2019].

Swetz, F. (2019). 'Mathematical Treasure: Ishango Bone | Mathematical Association of America' [Internet]. Available [Online] at: https://www.maa.org/press/periodicals/convergence/mathematical-treasure-ishango-bone. [Last accessed 18 January 2019].

Takaya, K. (2013). *Jerome Bruner, Developing a Sense of the Possible*. Netherlands: Springer.

Taylor, S.J. and Bogdan, R. (1984). *Introduction to Qualitative Research Methods: A Guidebook and Resource*. Wiley.

The Organisation for Economic Co-operation and Development (OECD) (2019). 'The Organisation for Economic Co-operation and Development (OECD)' [Internet]. Available [Online] at: https://www.oecd.org/. [Last accessed 23 October 2019].

Thompson, C. and Spenceley, L. (2019). *Learning Theories for Everyday Teaching*. 1 edition. London: Learning Matters.

Threlfall, J. (1996). 'The Role of Practical Apparatus in the Teaching and Learning of Arithmetic'. *Educational Review*, 48 (1), pp.3–12.

Tran, C., Smith, B. and Buschkuehl, M. (2017). 'Support of mathematical thinking through embodied cognition: Nondigital and digital approaches'. *Cognitive Research: Principles and Implications*, 2 (1), p.16. Available [Online] at: https://doi.org/10.1186/s41235-017-0053-8.

UNCRC (2010). 'United Nations Convention on the Rights of the Child (UNCRC): how legislation underpins implementation in England' [Internet]. Available [Online] at: https://www.gov.uk/government/publications/united-nations-convention-on-the-rights-of-the-child-uncrc-how-legislation-underpins-implementation-in-england. [Last accessed 14 June 2020].

Uttal, D.H., Scudder, K.V. and DeLoache, J.S. (1997). 'Manipulatives as symbols: A new perspective on the use of concrete objects to teach mathematics'. *Journal of Applied Developmental Psychology*, 18 (1), pp.37–54. Available [Online] at: http://linkinghub.elsevier.com/retrieve/pii/S0193397397900137. [Last accessed 29 January 2019].

Van Zoest, L.R. and Bohl, J.V. (2002). 'The Role of Reform Curricular Materials in an Internship: The case of Alice and Gregory'. *Journal fof Mathematics Teacher Education*, 5 (3), pp.265–288.

Vygotsky, L.S., Cole, M. and John-Steiner, V. (1978). *Mind in society: the development of higher psychological processes*. 1st ed. Cambridge, Mass. [u.a.]: Harvard University Press.

Waddock, S. (2015). *Intellectual Shamans: Management Academics*. Cambridge, UK: Cambridge University Press.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning and Identity*. Cambridge: Cambridge University Press.

Wharton, P.& K., L. (2015). *Reggio Emilia Encounters, Children and adults in collaboration*. Oxon: Routledge.

Wheelahan, L. (2007). 'How competency-based training locks the working class out of powerful knowledge: a modified Bernsteinian analysis'. *British Journal of Sociology of Education*, 28 (5), pp.637–651. Available [Online] at: https://doi.org/10.1080/01425690701505540. [Last accessed 20 February 2019].

Willig, C. (2001). *Introducing Qualitative Research in Psychology: Adventures in Theory and Method*. Buckingham: Open University Press.

Wilson, M. (2002). 'Six views of embodied cognition'. *Psychonomic Bulletin & Review*, 9 (4), pp.625–636. Available [Online] at: https://doi.org/10.3758/BF03196322.

Yackel, E. and Rasmussen, C. (2003). 'Beliefs and Norms in the Mathematics Classroom. In G. C. Leder, E. Penkonen & G. Törner (eds) Beliefs: a hidden variable in mathematics education?'. In Dordrect, Netherlands: Kluwer Academic Publishers, pp.313–330.

Yardley, L. (2000). 'Dilemmas in qualitative health research'. *Psychology & Health*, 15 (2), pp.215–228.

Zaslavsky, C. (1999). *Africa Counts: Number and Pattern in African Cultures (9781556523502): Claudia : Books*. United States of America: Lawrence Hill Book. Available [Online] at: https://www.amazon.com/Africa-Counts-Pattern-African-Cultures/dp/1556523505. [Last accessed 24 June 2019].

APPENDICES

Appendix 1: Doctoral Student Ethics Application Form

Anyone conducting research under the auspices of the Institute (staff, students or visitors) where the research involves human participants or the use of data collected from human participants, is required to gain ethical approval before starting. This includes preliminary and pilot studies. Please answer all relevant questions in simple terms that can be understood by a lay person and note that your form may be returned if incomplete.

***Registering your study with the UCL Data Protection Officer as part of the UCL Research Ethics Review Process**

If you are proposing to collect personal data i.e. data from which a living individual can be identified **you must be registered with the UCL Data Protection Office before you submit your ethics application for review**.

If the Data Protection Office advises you to make changes to the way in which you propose to collect and store the data this should be reflected in your ethics application form.

For further information see Steps 1 and 2 of our Procedures page at:

Section 1 Project details		
a.	Project title	**PGCE Primary Trainee Teachers' Perceptions of Mathematical Manipulatives and Accounts of Use during Placement**

b.	Student name and ID number (e.g. ABC12345678)		Syreeta Charles-Cole
c.	*UCL Data Protection Registration Number		Date issued
c.	Supervisor/Personal Tutor		Dr Melissa Rodd/ Dr Cathy Smith
d.	Department		Faculty of Education
e.	Course category (Tick one)	PhD ☐	EdD ☒
		DEdPsy ☐	
f.	**If applicable,** state who the funder is and if funding has been confirmed.		
g.	Intended research start date		March 2018
h.	Intended research end date		July 2019
i.	Country fieldwork will be conducted in *If research to be conducted abroad please check www.fco.gov.uk and submit a completed travel risk assessment form (see guidelines). If the FCO advice is against travel this will be **required** before ethical approval can be granted: http://ioe-net.inst.ioe.ac.uk/about/profservices/international/Pages/default.aspx*		

j.	Has this project been considered by another (external) Research Ethics Committee?	
	Yes ☐	External Committee Name:
	No ☒ ⇨ *go to Section 2*	Date of Approval:

yes:

- Submit a copy of the approval letter with this application.
- Proceed to Section 10 Attachments.

Note: Ensure that you check the guidelines carefully as research with some participants will require ethical approval from a different ethics committee such as the National Research Ethics Service (NRES) or Social Care Research Ethics Committee (SCREC). In addition, if your research is based in another institution then you may be required to apply to their research ethics committee.

Section 2 Research methods summary (tick all that apply)

- ☒ Interviews
- ☐ Focus groups
- ☒ Questionnaires
- ☐ Action research
- ☐ Observation
- ☐ Literature review
- ☐ Controlled trial/other intervention study
- ☐ Use of personal records
- ☐ Systematic review ⇨ ***if only method used go to Section 5.***
- ☐ Secondary data analysis ⇨ ***if secondary analysis used go to Section 6.***
- ☐ Advisory/consultation/collaborative groups
- ☒ Other, give details: Visual methods

Please provide an overview of the project, focusing on your methodology. This should include some or all of the following: purpose of the research, aims, main research questions, research design, participants, sampling, data collection (including justifications for methods chosen and description of topics/questions to be asked), reporting and dissemination. Please focus on your methodology; the theory, policy, or literary background of your work can be provided in an attached document (i.e. a full research proposal or case for support document). *Minimum 150 words required.*

PGCE Primary Trainee Teachers' Perceptions of Mathematical Manipulatives and Accounts of Use during Placement

The aim of this study is to discover PGCE trainee teachers' perceptions towards the use of mathematical manipulatives (resources teachers use to aid and engage students in their learning) and discover how they account for their use as they develop their professional learning during placement.

While there is a large body of complimentary literature endorsing the use of manipulatives some evidence exists some evidence exists within literature that concrete manipulatives, are not used as effectively or as extensively as they could be. Too few primary teachers used practical resources well to aid the teaching of mathematics. Understanding trainee teachers' perceptions and use of manipulatives, could enhance previous work in this area and facilitate meaningful discussion surrounding initial teacher training programmes, particularly within the postgraduate sector.

Study Aims

This study has five major objectives:

- To record and report PGCE trainee teachers' perceptions towards mathematical manipulatives, and how they account for their use of manipulatives during placement.
- Why do they take that approach, if, with or without manipulatives?
- What are the barriers and incentives to using manipulatives?
- If a disconnect exists between the training and current use, why?
- What do trainees think would be a way to increase this connectivity?

Formulation of Research Questions:

1. What are PGCE trainee teachers' perceptions of mathematical manipulatives?
2. How do PGCE trainees account for their use of manipulatives during placement?

Phenomenology is an approach to qualitative research that describes the meaning of lived experience of phenomena for several individuals, which in this case is the experiences of trainee teachers. The purpose is to describe the commonalities of the experience. The epistemological position regarding the study can be formulated as data is contained within the prospective of trainees that make use of manipulatives.

Participants and Sampling

Purposive criterion sampling is proposed to identify trainees who have experience with the phenomena of using mathematical manipulatives.

At present, there are two PGCE models available: a full-time university-based course and schools direct model. The university-based model takes place on campus in south of England, while the schools direct programme is delivered in the north of England. A key question is whether trainee teacher's views of manipulatives differ in the south in comparison to those in the north.

A non-obligatory, anonymous online sweep survey (Appendix 1) will be disseminated to identify primary participants. The survey includes a five-point Likert scale, with a few questions included requiring the respondent to produce a more reflective response. Following this, a convenience sample will be drawn in order to avoid bias surrounding selection and participation.

Prior to the interview, participants will be offered the opportunity to video record a lesson where they consider manipulatives were utilised well. This strategy could create a context for the participants to reflect upon their experiences introspectively, provide a focal point for responses and describe them in more detail.

The sample will be invited to participate in an audio-recorded semi-structured interview (in conjunction with scribed notes, privately. The interview includes 10 questions with probes and follow-up questions in order to encourage participants to elaborate or clarify responses. It is anticipated that more specific questions will be added as the interview progresses in response to themes that emerge.

There is no standard for a minimum number of participants in qualitative research because the purpose is not to generalise, however previous experts within the field have identified a sample size of 12 as adequate.

Section 3 Research Participants (tick all that apply)

☐ Early years/pre-school ☐ Ages 5-11 ☐ Ages 12-16 ☐ Young people aged	☒ Adults *please specify below* ☐ Unknown – specify below ☐ No

17-18	participants 21-65

NB: Ensure that you check the guidelines carefully as research with some participants will require ethical approval from a different ethics committee such as the National Research Ethics Service (NRES) or Social Care Research Ethics Committee (SCREC).

Section 5 Systematic reviews of research (only complete if applicable)

a.	Will you be collecting any new data from participants?	Yes ☒ *	No ☐
b.	Will you be analysing any secondary data?	Yes ☐ *	No ☒

* *Give further details in* ***Section 8 Ethical Issues***

If your methods do not involve engagement with participants (e.g. systematic review, literature review) ***and*** *if you have answered* ***No*** *to both questions, please go to* ***Section 8 Attachments.***

Section 4 Security-sensitive material (only complete if applicable)

Security sensitive research includes: commissioned by the military; commissioned under an EU security call; involves the acquisition of security clearances; concerns terrorist or extreme groups.

a.	Will your project consider or encounter security-sensitive material?	Yes ☐ *	No ☒
b.	Will you be visiting websites associated with extreme or terrorist organisations?	Yes ☐ *	No ☒
c.	Will you be storing or transmitting any materials that could be interpreted as promoting or endorsing terrorist acts?	Yes ☐ *	No ☒

* *Give further details in* ***Section 8 Ethical Issues***

Section 6 Secondary data analysis (only complete if applicable)

a.	Name of dataset/s	N/A

b.	Owner of dataset/s		
c.	Are the data in the public domain?	Yes ☐	No ☐
			If no, *do you have the owner's permission/license?* Yes ☐ No* ☐
d.	Are the data anonymised?	Yes ☐	No ☐
		Do you plan to anonymise the data? Yes ☐ No* ☐	
		Do you plan to use individual level data? Yes* ☐ No ☐	
		Will you be linking data to individuals? Yes* ☐ No ☐	

e.	Are the data sensitive (DPA 1998 definition)?	Yes* ☐	No ☐
f.	Will you be conducting analysis within the remit it was originally collected for?	Yes ☐	No* ☐
g.	**If no,** was consent gained from participants for subsequent/future analysis?	Yes ☐	No* ☐
h.	**If no,** was data collected prior to ethics approval process?	Yes ☐	No* ☐

* *Give further details in* ***Section 8 Ethical Issues***

If secondary analysis is only method used ***and*** *no answers with asterisks are ticked, go to* ***Section 9 Attachments.***

Section 7 Data Storage and Security

Please ensure that you include all hard and electronic data when completing this section.

a.	**Data subjects -** Who will the data be collected from? Trainee teachers
b.	**What data will be collected?** Please provide details of the type of personal data to be collected Encrypted Cloud storage and laptop (password encrypted).
c.	**Disclosure** – Who will the results of your project be disclosed to? Participants and the institutions involved.
d.	**Data storage** – Please provide details on how and where the data will be stored i.e. UCL network, encrypted USB stick*, encrypted laptop* etc. All survey-generated data will record as an Excel spread sheet. Interview data will be stored on NVivo via the UCL network and encrypted laptop. All data will be stored until my doctorate is completed (over 5 years).

	*Advanced Encryption Standard 256 bit encryption which has been made a security standard within the NHS	
e.	**Data Safe Haven (Identifiable Data Handling Solution)** – Will the personal identifiable data collected and processed as part of this research be stored in the UCL Data Safe Haven (mainly used by SLMS divisions, institutes and departments)?	Yes ☐ No ☒
f.	How long will the data and records be kept for and in what format? As above. Will personal data be processed or be sent outside the European Economic Area? (If yes, please confirm that there are adequate levels of protections in compliance with the DPA 1998 and state what these arrangements are: Will data be archived for use by other researchers? (If yes, please provide details.) N/A	

Section 8 Ethical issues

Please state clearly the ethical issues which may arise in the course of this research and how will they be addressed.

All issues that may apply should be addressed. Some examples are given below, further information can be found in the guidelines. *Minimum 150 words required.*

- Methods
- Sampling
- Recruitment
- Gatekeepers
- Informed consent
- Potentially vulnerable participants
- Safeguarding/child protection
- Sensitive topics
- International research
- Risks to participants and/or researchers
- Confidentiality/Anonymity
- Disclosures/limits to confidentiality
- Data storage and security both during and after the research (including transfer, sharing, encryption, protection)
- Reporting
- Dissemination and use of findings

1). Risks to participants

- Confidentiality and anonymity
- Conforming testimony: Unequal power relationships and how to counter the perceived unequal relationship between an adult researcher and student participant.
- Addressing vulnerability. The Pupils Act (2004) enforces a range of regulation relating to the rights of pupils and young people.

2. Reputational risk

- To institution
- To researcher

3. Data storage and security

- Online survey material/ transcripts/scribed notes from interview.

4. Participation Selection

- Understanding and Informed Consent.

These are the steps I plan to take in order to address the issues highlighted above:

1). Risk to participants

- The dual role of researcher and senior lecturer can cause an inherent power imbalance as well as tensions in areas such as psychological harm, privacy, anonymity and confidentially. In order to overcome the challenges identified the following precautions will be taken. An anonymised online survey will be distributed to willing participants in order to minimise the risk associated with obedience compliance.

  The follow up interviews will be conducted with a convenience sample to avoid bias surrounding selection and participation. I do not expect the research to raise sensitive material, however as a precaution the information sheet states that the researcher might not be able to guarantee complete anonymity should the participant disclose a safeguarding issue that impacts on the safety and well-being of the participants. All participants are afforded the right to refrain from responding to any questions without penalisation such they feel the questions posed are of a sensitive nature (eg ability set). I endeavour to comply with safeguarding procedures in line with current best practice. The identity of participants will not be disclosed, and all issues related to confidentiality will be in line with the BERA guidance and Data Protection Act (1998).

  Article 3 of the United Conventions of the Rights of Pupils (ENCRC) requires that all actions concerning pupils should be made in the best interests of the child, and their needs given primary consideration. The Pupils Act (2012) enforces that pupils should be consulted about matters that affect them. If required, an information sheet and consent form will be issued to pupils parents/carers in line with the schools' policy. Participants who provide consent will have the right to withdraw at any given time and I will comply with any requests following withdrawal including the deletion of data if requested. Whilst I remain mindful that the withdrawal from qualitative research can bias the results, I will maintain ethical integrity.

2. Reputational Risk

- The researcher will ensure the proposed study is compliant with the ethical guidelines available at the institution where employed. This is in order to avoid a breach of privacy, legal consequences, anonymity and confidentially, as well as potential ethical harm to the reputation of the organisation.
- Although unlikely, there is a small potential risk that conducting this research could cause physical and/or reputational risk to the researcher. All interviews will take on site within the secure confinement of the campus. The supervisors I have assigned will monitor and mitigate the study.

3. Data storage and security

- I will follow the British Education Research Association (BERA) written guidance of good practice when storing data. The online survey results will be cloud encrypted

with private access (restricted to my supervisor and I). All data from the survey and interviews will be anonymised with the allocation of codes and password encryptions. Participants will be debriefed following the collection of the data to ensure the participants have not been adversely affected. It will also provide the participants with the opportunity to reflect upon their contributions, ask questions, as well as be thanked for their contribution.

4. Participation Selection

- Interviews will be conducted with a convenience sample (based on who is available at the time) in order to avoid bias surrounding selection and participation. All participants who have provided consent will be included irrespective of gender, race or perceived ability.

  An information sheet and consent form will be provided to all participants.

Section 9 Attachments Please attach the following items to this form, or explain if not attached			
a.	Information sheets, consent forms and other materials to be used to inform potential participants about the research *(List attachments below)*	Yes ☒	No ☐
	If applicable/appropriate:		
b.	Approval letter from external Research Ethics Committee		Yes ☐
c.	The proposal ('case for support') for the project		Yes ☒
d.	Full risk assessment		Yes ☐

Section 10 Declaration

I confirm that to the best of my knowledge the information in this form is correct and that this is a full description of the ethical issues that may arise in the course of this project.

I have discussed the ethical issues relating to my research with my supervisor.

☒ ☐

I have attended the appropriate ethics training provided by my course.

☒ ☐

I confirm that to the best of my knowledge:

The above information is correct and that this is a full description of the ethics issues that may arise in the course of this project.

Name	[redacted]
Date	18/02/2018

Please submit your completed ethics forms to your supervisor for review.

Notes and references

Professional code of ethics
You should read and understand relevant ethics guidelines, for example:
British Psychological Society (2009) *Code of Ethics and Conduct*, and (2014) *Code of Human Research Ethics*
or
British Educational Research Association (2011) *Ethical Guidelines*
or
British Sociological Association (2002) *Statement of Ethical Practice*
Please see the respective websites for these or later versions; direct links to the latest versions are available on the Institute of Education http://www.ioe.ac.uk/ethics/.

Disclosure and Barring Service checks
If you are planning to carry out research in regulated Education environments such as Schools, or if your research will bring you into contact with pupils and young people (under the age of 18), you will need to have a Disclosure and Barring Service (DBS) CHECK, before you start. The DBS was previously known as the Criminal Records Bureau (CRB)). If you do not already hold a current DBS check, and have not registered with the DBS update service, you will need to obtain one through at IOE. Further information can be found at
http://www.ioe.ac.uk/studentInformation/documents/DBS_Guidance_1415.pdf

Ensure that you apply for the DBS check in plenty of time as will take around 4 weeks, though can take longer depending on the circumstances.

Further references
The www.ethicsguidebook.ac.uk website is very useful for assisting you to think through the ethical issues arising from your project.

Robson, Colin (2011). *Real world research: a resource for social scientists and practitioner researchers* (3rd edition). Oxford: Blackwell.
This text has a helpful section on ethical considerations.

Alderson, P. and Morrow, V. (2011) *The Ethics of Research with Pupils and Young People: A Practical Handbook.* London: Sage.
This text has useful suggestions if you are conducting research with pupils and young people.

Wiles, R. (2013) What are Qualitative Research Ethics? Bloomsbury.
A useful and short text covering areas including informed consent, approaches to research ethics including examples of ethical dilemmas.

Departmental use

If a project raises particularly challenging ethics issues, or a more detailed review would be appropriate, the supervisor **must** refer the application to the Research Ethics and Governance Coordinator (via ioe.researchethics@ucl.ac.uk so that it can be submitted to the Research Ethics Committee for consideration. A departmental research ethics coordinator or representative can advise you, either to support your review process, or help decide whether an application should be referred to the REC.
Also see 'when to pass a student ethics review up to the Research Ethics Committee': http://www.ioe.ac.uk/about/policiesProcedures/42253.html

Student name		
Student department		
Course		
Project title		
Reviewer 1		
Supervisor/first reviewer name		
Do you foresee any ethical difficulties with this research?		
Supervisor/first reviewer signature		
Date		
Reviewer 2		
Second reviewer name		
Do you foresee any ethical difficulties with this research?		
Supervisor/second reviewer signature		
Date		
Decision on behalf of reviews		
Decision	Approved	☐
	Approved subject to the following additional measures	☐
	Not approved for the reasons given below	☐
	Referred to REC for review	☐
Points to be noted by other reviewers and in report to REC		
Comments from reviewers for the applicant		

Once approved by both reviewers students should submit the ethics application form to the Centre for Doctoral Education team IOE.CDE@ucl.ac.uk.

Thank you for the application for Data Protection Registration.

I am pleased to confirm that this project is covered by the UCL Data Protection Registration, reference No Z6364106/2018/04/113 social research.

It is rarely necessary to store electronic personal data on portable devices such as laptops, USB flash drives, portable hard drives, CDs, DVDs, or any computer not owned by UCL. Similarly, manual personal data should not be regularly removed from UCL premises. In the case of electronic data, to minimise the risk of loss or disclosure, a secure remote connection to UCL should be used wherever possible.

Downloading personal data on to portable devices or taking manual personal data off-site must be authorised in writing by the Data Owner, who must explain and justify the operational need in relation to the volume and sensitivity of the data. The data must be strongly encrypted. Users should only store the data necessary for their immediate needs and should remove the data as soon as possible. To avoid loss of encrypted data, or in case of failure of the encryption software, an unencrypted copy of the data must be held in a secure environment. The Information Security Group guidance on encryption should be followed:

Manual personal data and portable electronic devices should be stored in locked units, and they should not be left on desks overnight or in view of third parties.

In order to comply with the fifth data protection principle personal data should be securely destroyed when no longer required, with consideration for the format of the data. The Information Security Group guidance should be followed.

Personal data must not be disclosed unlawfully to any third party. Transfers of personal data to third parties must be authorised in writing by the data owner and protected by adequate contractual provisions or data processor agreements, agree with UCL's notification and must use safe transport mechanisms.

There are cases where anonymised data needs to be treated as confidential, so please ensure that you comply with any further restrictions contained within contracts or agreements relating to the data.

If not already done so, please provide copies of any information sheets and consent forms that you are using.

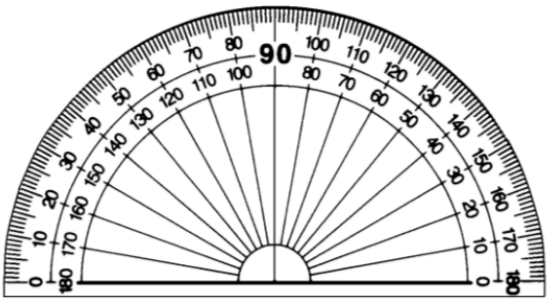
When all essential documents are ready to archive, contact the UCL Records Office by email records.office@ucl.ac.uk to arrange ongoing secure storage of your research records unless you have made specific alternative arrangements with your department, or funder.

Appendix 2: Online Survey

Mathematics Equipment Survey

Can you help us by filling in the survey below? There are a number of statements which provide five multiple choice options – please circle one option for each statement. There is an opportunity for you to write any comments or feedback at the end of this questionnaire. Thank you for taking the time to complete this questionnaire.

Protractor



1. **I have regularly used a protractor**
   Mark only one oval.
   - Strongly agree
   - Agree
   - Neither agree or disagree
   - Disagree
   - Strongly disagree

2. **All children should regularly use a protractor**
   Mark only one oval.
   - Strongly agree
   - Agree
   - Neither agree or disagree
   - Disagree
   - Strongly disagree

Compasses

3. **I have regularly used compasses**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

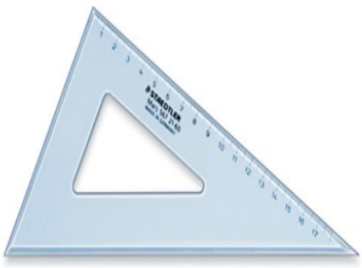
4. **All children should regularly use compasses**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

5. *Mark only one oval.*

- ◯ Option 1

Set Square



6. **I have regularly used a set square**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

7. **All children should regularly use a set square**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

Calculator

8. **I have regularly used a calculator**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

9. **All children should regularly use a calculator**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Unifix

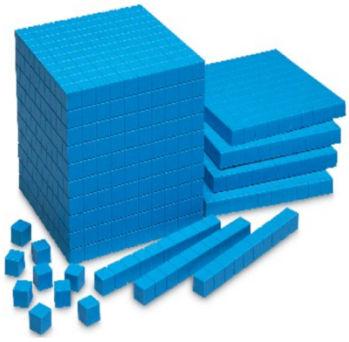
10. **I have regularly used unifix**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

11. **All children should regularly use unifix**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Base Ten Blocks



12. **I have regularly used base ten blocks**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

13. **All children should regularly use base ten blocks**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Dice

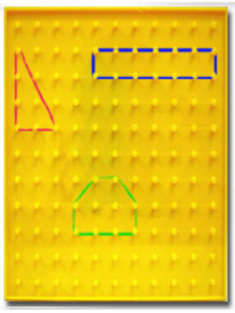
14. **I have regularly used dice**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

15. **All children should regularly use dice**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Geoboard



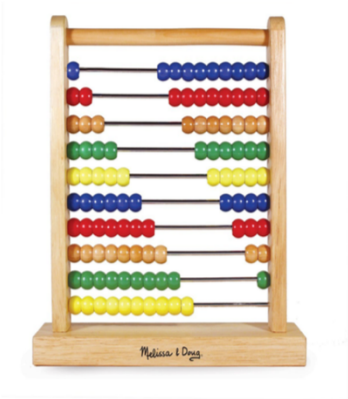
16. **I have regularly used geoboards**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

17. **All children should regularly use geoboards**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Abacus



18. **I have regularly use an Abacus**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

19. **All children should regularly use an Abacus**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Tangrams

20. **I have regularly used tangrams**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

21. **All children should regularly use tangrams**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

3d Nets

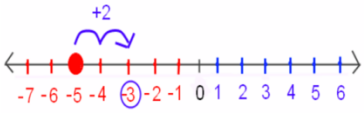
22. **I have regularly used 3d Nets**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

23. **All children should regularly use 3d Nets**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Numberline



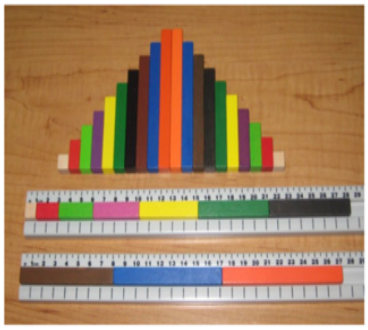
24. **I have regularly used numberlines**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

25. **All children should regularly used numberlines**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

Cuisenaire Rods



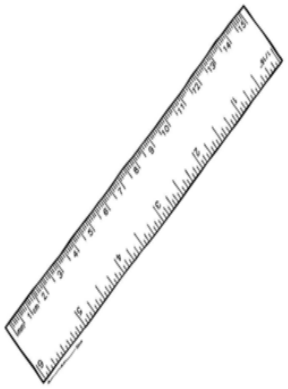
26. **I have regularly used cuisenaire rods**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

27. **All children should regularly cuisenaire rods**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

Ruler



28. **I have regularly used rulers**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

29. **All children should regularly use rulers**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

Online Mathematical Games

30. **I have regularly used online mathematical games**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

31. **All children should regularly use online mathematical games**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

32. **I have received adequate training in the use of mathematical resources**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

33. **I like using mathematical equipment with my class during lessons.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

34. **Using practical equipment makes maths lessons more fun.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

35. **Using online mathematical equipment makes maths lessons more fun.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

36. **I like to choose for my class which mathematical equipment to use.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

37. **My class usually find practical mathematical activities more interesting and exciting.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

38. **I encourage my students to use whichever equipment they like.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

39. **Mathematical equipment/resources are value learning tools.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

40. **The mathematical equipment support children to learn more advanced mathematics.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

41. **Children regularly feel challenged to try new methods when presented with new resources/equipment.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

42. **I regularly feel challenged to take risks when on teaching practice to use new resources/equipment.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

43. **The use of mathematical equipment helps children understand new concepts more easily.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

44. **Children achieve better results when using mathematical equipment.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

45. **Children always know how to use the equipment I provide.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

46. **I always know how to use the equipment I provide for children to support their learning.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

47. **I have access to a wide range of mathematical resources.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

48. **There are no set rules on how to use mathematical resources.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

49. **I permit children to use a range of both practical and online mathematical resources to complete their homework.**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

50. **I always use the mathematics equipment I have included upon my plan**
Mark only one oval.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

51. **I use a range of both practical and online mathematical resources when teaching.**
Mark only one oval.

- ◯ Strongly agree
- ◯ Agree
- ◯ Neither agree or disagree
- ◯ Disagree
- ◯ Strongly disagree

52. **If you could plan your own perfect mathematics lesson which equipment would you use? Why?**

53. **Which resources do you least like using with your class? Why?**

54. **Write a description of how you have used manipulatives.**

55. **Interview Target**

56. **Undergraduate Degree and Awarding University**

57. **Age**

58. **Gender**
Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other: _____

59. **Placement Year Group**
Mark only one oval.

- ◯ Reception
- ◯ Year 1
- ◯ Year 2
- ◯ Year 3
- ◯ Year 4
- ◯ Year 5
- ◯ Year 6
- ◯ Prefer not to say

60. **When did you last study mathematics?**

61. **Where did you receive your primary education?**
Mark only one oval.

- ◯ England
- ◯ Ireland
- ◯ Scotland
- ◯ Wales
- ◯ Other: _____

62. **Email address if you would like to participate further in the study.**

63. **Optional comments/Feedback**

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Google Forms

Appendix 3: Semi-structured Interview

Introduction

- Greet and thank participant, make personal introduction.
- Explain session will be recorded and transcribed and inform of rights to withdraw at any stage.
- All reports and excerpts are confidential, and anonymity of participants adhered.
- Review, sign and date consent form.
- Inform participants that a range of manipulatives will be available should they wish to refer to them.

Outline of the interview guidelines

- Start with general questions, then become more focused.
- Inform participant that the researcher may request that they elaborate or comment.
- Participants are not obliged to answer questions and ask questions at any point.

Situate participant - General background information (ice-breaker) to get participant comfortable to talk about their own education and teaching experience.

- Can you tell me about how you came to learn mathematics?
- What are your goals in relation to teaching mathematics?
- Why have you decided to embark upon a profession in teaching?
- How confident do you feel about teaching mathematics?
- How would you describe feelings towards mathematics teaching?

Research Questions

What are PGCE trainee teachers' perceptions of mathematical manipulatives?

How do PGCE trainees account for their use of manipulatives during placement?

1) Do you feel all pupils benefit from making use of manipulatives? Why?
2) Can you tell me about a lesson where manipulatives were used successfully?
3) Tell me about your childhood experiences of using manipulatives. How did they make you feel? Which manipulatives do you use?
4) Can you give me an example of manipulatives you are unsure of how to use?
5) What is it you are looking for when using manipulatives as proof of learning taking place (e.g. replication of how you learned – replication of modelled practice)?
6) Do you always manage to incorporate the use of manipulatives as indicated on your lesson plan?
7) When observed, which manipulatives are you motivated to use?
8) Do you feel there is a connection between manipulative use and pupils's ability?
9) Do you feel you can experiment with the use of mathematical manipulatives in the classroom? Can you provide an example to support this?
10) What instructional training/professional development do you believe students need in order to implement the use of manipulatives well in the classroom?

Final comments.

- Are there any questions that you would like to ask?
- Thank trainee for participating.

Video clip after introduction

Each PGCE student will record a short section of video (3/4 minutes -why) of continuous clip. The task for the student is to simply **describe** what is going on. The video recording will be played twice. First to identify anything **positive** they notice. Second time to identify sections where they would like to stop and discuss in greater depth areas they deem important. Rewatch watch bits of the video to see if they notice anything new. The emphasis will be on what was done and said.

Can you tell me what is going on in the video?
What is it you notice?
Can you tell me about how you came to select/use these manipulatives?
Why did you…
Why have you…

Descriptive – Please can you tell me what you do?
Narrative – Can you tell me about how you came to…?
Structural – So what are all the stages involved in…?
Contrast – What are the main differences between a good mathematics less and a bad?
Evaluative - How do you feel...?
Circular- What do you think your CBM thinks about how you?
Comparative – How do you think your lessons would be if you were placed …?
Prompts – Can you tell me a bit more about that?
Probes – What do you mean by… ?

Probe deeper
Why?
How?
Can you tell me more about that?
Tell me what you were thinking?
How do you feel?
Which theorist resonate with you?
What are your values?
Do you see career progression in terms mathematics?
What in your view is the purpose of the lecturers?
What are the most important aspects of the subject?
How do you develop your subject knowledge in maths?
What are the most important aspects of the subject?

Appendix 4: Information Sheet for Participants

We would like to invite you to participate in this research study by researchers at UCL. Before you decide whether you want to take part, it is important to read the following information and discuss it with the investigators if you have any questions.

Title of Project: **PGCE Primary Trainee Teachers' Perceptions of Mathematical Manipulatives and Accounts of Use During Placement**

This study has been approved by the Clinical, Educational and Health Psychology Research Department's Ethics Chair. Project ID No.:

Student Investigator: Syreeta Charles-Cole
Supervisors: Dr. Melissa Rodd, Dr. Cathy Smith

What is the purpose of this study?

The aim of this study is to discover PGCE trainee teachers' perceptions towards the use of mathematical manipulatives and discover how they account for their use as they develop their professional learning during placement. Manipulatives are resources teachers use to aid and engage pupils in their learning. In primary school, concrete manipulatives such as Dienes blocks are commonly used.

While there is a large body of literature relating to utility of professional learning, there exists a need to better understand the postgraduate trainees' perceptions regarding the use of manipulatives. Understanding trainee teachers' perceptions could help craft more effective and tailored mathematics curricula.

What will I be asked to do?

You will first be asked to participate in a brief online survey (stage 1). You will then be asked to complete some questions on the computer, which asks you about your experiences of using a range of different manipulatives. This stage of the study will take approximately 15 minutes.

If you agree to participate in the interview, you will be asked to record one short video (hands only) whilst on placement prior to participate in a recorded interview. Informed consent is required in line with the policy at your school. Recordings will be identified only by a code and will not be used or made available for purposes other than the research project. These tapes will be destroyed at the end of the study.

The interview will be conducted on campus and will involve a set of questions regarding your current and past use of mathematical manipulatives (stage 2). This interview will take approximately 30 minutes. The interview will take place in a private room where you can talk without being disturbed.

Participation in this study is voluntary and you will be asked to give your consent before the initial interview. Your consent will indicate that you have been informed of the study and all the information provided on this sheet and have had the chance to ask the investigator any questions you may have about the study. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. If you decide to take part you are still free to withdraw at any time during the process and without giving a reason.

Who can take part in this study?

To be eligible to take part in this study, you must be enrolled as a PGCE primary trainee teacher.

What are the benefits of participating in this study?

Understanding prospective teachers' perceptions could help educators craft more effective and tailored mathematics curricula.

What are the risks of participating in this study?

There are no disadvantages associated with taking part in the study. Participation can enhance your professional practice.

Who will have access to my information and how will my information be kept confidential?

All data will be kept confidential and only the student researcher and supervisors will have access to the data collected in this study. Any personally identifiable information (e.g., your name, e-mail address) will be kept separately from all other data collected in this study. Data entered online will be stored in password protected or encrypted files on UCL computers. All data will be handled according to the Data Protection Act 1998 and will be kept confidential.

What will happen with the results of this study?

Once the study has been completed the results will be published in a report. Confidentiality and anonymity will be maintained, and it will not be possible to identify you from any publications. If you would like to receive a summary of the results once the study has finished, you may indicate so on the Consent Form.

Please discuss the information above with others if you wish or ask us if there is anything that is not clear or if you would like more information.

If you have any questions about this study, please contact:

Syreeta Charles-Cole
(s.cole.14@ucl.ac.uk)

Appendix 5: Consent form for Participant

PGCE Primary Trainee Teachers' Perceptions of Mathematical Manipulatives and Accounts of Use During Placement

Degree of Doctor in Education (EdD)

Start date: March 2018
End date: October 2019

Please complete this form after you have read the Participant Information sheet explaining the research.

Please tick to confirm your understanding of the study and that you are happy take part.

1. I **agree** to take part in the above study. ☐
2. I confirm that I have read and understand the participant information sheet provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
3. I understand that participation in the research is voluntary and that I am free to withdraw at any time, without giving a reason. I can notify the researcher involved and withdraw immediately. ☐
4. I understand that any personal information collected during the study will be anonymised and remain confidential. ☐
5. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998. ☐
6. I understand that my participation will be taped/video recorded and I consent to the use of this material as part of the project. ☐
7. It is ok to use stills from the video recording (without faces) within the thesis. ☐

Name of Participant: Date: Signature:

Name of Researcher: Date: Signature:

Appendix 6: Consent form for Gate Keeper

PGCE Primary Trainee Teachers' Perceptions of Mathematical Manipulatives and Accounts of Use During Placement

Degree of Doctor in Education (EdD)

Start date: March 2018
End date: October 2019

Please complete this form after you have read the Participant Information sheet explaining the research.

Please tick to confirm your understanding of the study and that you are happy for your school to take part and your facilities to be used to host parts of the project.

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that participation of our organisation and students in the research is voluntary and that they are free to withdraw at any time, without giving a reason and that this will not affect legal rights. ☐

3. I understand that any personal information collected during the study will be anonymised and remain confidential. ☐

4. I agree for our organisation and students to take part in the above study. ☐

5. I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998. ☐

6. I understand that participation of our organisation and students will be taped/video recorded and I consent to the use of this material as part of the project. ☐

7. It is ok to use stills from the video recording (without faces) within the thesis. ☐

Name of Gatekeeper:	Date:	Signature:
Name of Researcher:	Date:	Signature:
Name of Person taking consent: (if different from researcher)	Date:	Signature:

Appendix 7: Audit Trail – List of Themes for David

Abstract
Alternative name for manipulative
Association of manipulative with younger pupils
Chunks of learning
Child's interest
Pupils's lack of choice
Collaboration
Concrete
Confidence from structure
Disconnect between action and perception
Confusion as to what counts as a manipulative
Description of manipulative
Description of practice with manipulative
Desire for pupils to avoid their experiences
Desire for learning to be interesting
Desire opportunities for reflection
Desire to make learning exciting
Develop subject knowledge
Difficulties learning without manipulative
Difficult meaning challenging
Dread
Experiences at university
Experiences of manipulatives as a child at school
Experiences of manipulatives at home
Experiences as a pupil informs the trainees model for teaching
Exploration
Inclusive
Interesting and enjoyable
Independent learning
Institution rules
Learning as tidy
Learning as work
Learning objective
Learning styles
Look
Love of mathematics
Manipulative as meaning maker
Manipulatives not confident using
Manipulatives when observed
Mastery
Memorable manipulative
Metaphor for learning
Metaphor for manipulative

Need to be acknowledged as doing the right thing
Negative feeling when learning mathematics
Non-verbal communication
Past experiences of learning with manipulative
Pattern
Planned outcome
Play
Pleasant feeling
Positive learning experience at home
Practice makes perfects
Practice creates subject's knowledge
Preference for learning with manipulative
Preference for using manipulative for problem solving at home
Prepare in advance
Progress to pictorial
Protect pupils from their experiences
References to grouping
References to sight
References to tactile senses
Remedial use of manipulative
Repetition
Replication of how they learnt mathematics
Rewarding experience - teacher standards
See what they see
Scheme of work
Selection process
Subject specific language
Systematic pattern
Tactile makes learning accessible
Teacher models student replicates
Teacher understanding prior to use
Teaching as a vocation
Textbook
Theoretical meaning abstract
Touch
Trainee wants a list of manipulatives detailing usage
Transgress boundaries
Use of manipulative at home
Use questioning with manipulative
Use textbook to understand
Words associated with struggle

Appendix 8: Subordinate and Superordinate Theme Table for David

Themes	Time	Key words
Purposes of using manipulatives		
Association of manipulative with younger pupils	23:11 17:47	That's how they start to learn in nursery and reception, you don't tend to use them further up the school try and give it a go, see if it works
Exploration	24:37	for each child to work in pairs
Collaboration	21:10	because it's all so logical,
Confidence from structure	00:15	systematically, looking for patterns everyone has input
Inclusive	06:30	Make it as interesting as possible
Interesting and enjoyable	02:28	Learn through play
Play	23.11	teach them basically concrete first so
Tactile makes learning accessible	04:41	pupils get to physically manipulative
Practices of using manipulatives		
Pupils's lack of choice	07:56 18.36 27:41	you get the pupils, pull them along point the pupils that you could ask a question, pupils have to do
Chunks of learning	03:42 05.15	works through systematically, any parts not confident with, build a lesson [objectives]
Description of practice with manipulative	12:49	after that they had to make the smallest number using all of the counters
Institution rules	03:42	we follow like a strict kind of programme, The White Rose
Learning as tidy	04.19	brush up on it
Lack of confidence	00:15	but actually, school myself, the experience I had wasn't particularly good
Planned outcome	27:41	I always do it myself first, lesson plan
References to grouping	05:15	Lower ability, higher ability
Remedial use of manipulative	08:34	For lower ability pupils
Repetition - rote	27:41	I basically just practiced. I always do it myself first before actually going into classrooms.
Status Quo	00:15 08:34	This was kind of done in maths, not that kind of maths lesson
Teacher models student replicates	12:49	They have to make the highest (meaning largest) with at least one place value counter in each column
Feelings		
Words associated with struggle	00:15	difficult to learn

Difficulties learning without manipulative	00:15	you didn't have the things in front of you and you kind of learnt by yourself
Dread	01.36	I didn't look forward to maths
Desire for learning to be interesting	02:28	Making it as interesting/enjoyable as possible, but obviously learning at the same time
Manipulatives not confident using	16:51	It is such a new resource; I'm trying to get to grips with it myself before you deliver it
Need to be acknowledged as doing the right thing	24:17	I hope I have answered properly
Negative feeling when learning mathematics	00:15	wasn't a particularly good experience
Love of mathematics	00:15	I love that type of work
Confusion as to what counts as a manipulative	05:15	A mat, like a place value mat.
	06:30	I would combine mainly the pictorial and the concrete teaching elements together on the interactive whiteboard
Desire for pupils to avoid their experiences	02:28	it would be not to have the pupils go through what I went through
Teacher Learning Theory		
Concrete	09:42	concrete resources that pupils can dip into
Abstract	06:30	they move onto the more abstract things
Desire opportunities for reflection	26:19	Not just kind of be talked at. I think we should, you know,
Experiences at university	26:19	when training to be a teacher was fantastic
Experiences of manipulatives as a child at school	00:15	There was very little of use of apparatus or any kind of
	14:45	I can actually remember the square blocks sticking together
Use textbook to understand	04:19	This is a place where I can kind of look and be able to teach myself