Young children's creativity in science enquiry: a diffractive analysis of empirical and theoretical understandings

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Abstract

Little attention has been paid to the materiality of children's creative knowledge making practices in science enquiry. Conflicting discourses have instead shaped a narrow understanding of how children come to know in early childhood science education. This thesis draws on new materialist philosophy to offer a new approach to diffractive analysis by showing how critical points of difference are created when empirical data encounter theoretical perspectives diffractively. In doing so, conflicting discourses are challenged as limiting, and points of difference illuminated as crucial in affecting connections which can convincingly reconfigure dominant ways of seeing.

The thesis firstly presents empirical data which illustrates shared understandings of creativity in science enquiry held by early childhood practitioners, gathered using Video Stimulated Reflective Dialogues (Moyles *et al*., 2003) and analysed using a grounded theoretical approach. This data was found to be largely representative of existing perspectives on young children's creativity in science enquiry and the analysis restricted by theoretical, ontological and axiological norms within the interpretivist paradigm. The empirical data was subsequently 're-turned' in a diffraction together with i) existing research on early childhood science education, and ii) conceptualisations of creativity in the domain of art, to reveal critical points of difference which, in superposition, create the possibility for a new conceptualisation of young children's creativity in science enquiry. Consideration is given to the role and ethics of what is excluded in reading diffractively.

A diffractive reading found children's creativity in science enquiry to be enacted at once through talk and materials. Cutting together and apart child-material revealed children as decentred and coming to know through the materiality of materials. This opens possibilities to explore children's co-constitutive and affective ways of knowing in science enquiry. Attention is drawn to both video camera and footage as more-than-human matter and the need for further research into the significance of points of difference potentially emergent from the spaces in-between children's encounters with materials in science enquiry.

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Chapter One: Introduction

This study introduces a new approach to diffractive analysis which draws on shared understandings from empirical research data and existing literature to explore that which might 'not yet [be] known' (Davies, 2020, p.148) about materiality in young children's creative knowledge making practices in science enquiry.

The chapter begins with an introduction to the research focus to establish context and rationale. This is followed by an exploration of motivations and an overview of the central thread running through the thesis. A brief outline of aims and research questions is included, and reference is made to how the study was carried out. The introduction concludes with an overview of each of the thesis chapters.

Research focus

Little attention is paid to the materiality of young children's creative knowledge making practices in science enquiry. Rather, creativity in early childhood science education has been increasingly positioned as key in discourses of neoliberalism, due to the belief that it can promote the development of higher order thinking skills necessary for maintaining competitiveness in global markets (Havu-Nuutien *et al*., 2017; Mahon, 2016; Sims, 2017). In 'symbiotic relationship' with such discourses, the field of developmental psychology has become a decisive influence on early childhood science education, as manifest in contemporary policy frameworks which advocate 'push-down' curricula and the standardisation of knowledge (Giroux, 2015; Moss, 2019, p.13; Wood and Hedges, 2016). Emergent from the field of developmental psychology and informing pedagogy and practice are accepted truths within constructivist and sociocultural theory (Driver *et al*., 1994; Wood and Hedges, 2016). Consequently, children's creative knowledge making practices in science enquiry have largely been framed as enacted by the agentic being on individual or social planes, for cognitive development. This is not the case in all domains of study. For instance, within art creative processes have been defined as embodied and relational, with materials recognised as agentic in partnership with humans (see, for example, Barrett and Bolt, 2013; Penfold, 2019; Robertson and Roy, 2017).

This study draws on such conceptualisations of creativity together with i) empirical research data of shared understandings held by early childhood practitioners, and ii) existing research on early childhood science education, to explore the under researched area of materiality in young children's creative scientific enquiry. In doing so, a new approach to diffractive analysis is developed which convincingly challenges core assumptions about knowledge making practices within early childhood science education, thus reconfiguring dominant ways of seeing young children's creativity in science enquiry.

Motivations and context

I have long been interested in what it means to be creative. From the perspectives of both an educator and a maker, I have found its conceptualisations vibrant and nuanced as well as elusive and conflicting. As an early years teacher and, later, lecturer in early childhood studies, I have been fascinated by the ways in which young children enquire within the world. Their scientific explorations with materials have appeared, at times, like intimate dialogues, dances, and moments of connection synonymous with concepts such as *Ma,* which holds appreciation for unexpected interactions and meanings that are produced within the spaces between objects (Ferguson and Kuby, 2015).

Despite being a term used vaguely and interchangeably across many contexts (for example, domains of learning and knowledge; politics and the knowledge economy; culture and society) the interest in, and significance of, creativity is widely documented (see for instance, Banaji *et al*., 2010; Cremin and Chappell, 2019; Kupers *et al*., 2018). It is commonly recognised as a life force which enables meaningful engagement in the present (see for example, Chappell *et al.*, 2017; Craft, 2001b; Craft *et al.*, 2008), and a process which supports the human endeavour to move forward, charter new territories and produce new futures (see for instance, OECD, 2018; NACCCE, 1999; Nathan, 2019).

As an educator, I have learnt to appreciate creativity as an intellectual process rooted within the cognitive domain. I have valued it as a tool for thinking; coming to know it through paradigms of psychology. When ruminating ideas to create lectures

or seminars, I can ponder at length and immerse myself in my thoughts and ideas, identifying with a state of flow (Nakamura and Csikszentmihalyi, 2002). I find space to read and make meaning, to listen to others' perspectives and to consider different contexts (Chappell *et al.*, 2017; Craft, 2003). I recognise that my ideas sometimes need to incubate, to have time to germinate and grow, connect or change (Harrington, 1990). I acknowledge creativity's cyclical nature as my ideas transform to produce new, original material, grounded in what has been before (NACCCE, 1999). In a creative space I feel shifts in my knowledge boundaries and deepening in my understanding.

When working with early childhood undergraduate students, I encourage inquiry with models of creativity so that we might consider children's creative processes, and question whether and how creativity might be enacted in daily lived experiences. We explore creativity across areas of learning, examining assumptions that it could be democratic and lifewide (Craft, 2002). Focusing on young children's developing lines of (science) enquiry, we use established conceptualisations to make tentative interpretations as to how creativity might support children to make meaning; to develop intellectually in relationship with the world. The 'subject' of science proves a fruitful context for examining synergies with creativity, and for exploration of perspectives rationalising popular inquiry-based pedagogies within early childhood education (see for example, Cremin *et al.* 2015; Harlen, 2013). Inevitably, our explorations lead us to the established image of the child who possesses a curious and creative mind; an innate experimenter who forms intuitive theories based on their experiences.

The relationship between children's creative lines of science enquiry and knowledge making is widely documented within early childhood (science) education (see for instance, Cremin *et al.*, 2015; Hadzigeorgiou *et al.*, 2012; Rinaldi, 1998). Children are awed as alchemists who manipulate and transform materials, that they might come to know their possibilities and properties. As they investigate their material world through imagination and utterance, they seem to shift the ordinary into the extraordinary; sand and water can become mountains and rivers; a leaf, a boat; a magnet, a vacuum cleaner. It is accepted that, through their experiments with materials, children question, hypothesise, gather evidence, encounter, and

overcome problems. Through their subjective exploration, they are understood to make mental models of their perceptions of reality. Thus, by nature, they are scientists (Gopnik, 2010; Harlen, 2013; de Boo, 1999). Children's play is considered a rich opportunity for the development of scientific knowledge, skills and understanding (Marian and Jackson, 2016; Vartiainen and Kumpulainen, 2020), and with the support of teachers' skilful interventions, children are able to assimilate cultural and social norms, and reproduce the conventional, most accepted tools of science (Driver *et al.*, 1994). The works of psychologists Piaget and Vygotsky form the tenets of established understanding about children's development and learning in early childhood (science) education. Their theoretical legacies, epistemologically rooted in constructivism, dominate how we have come to understand young children's scientific enquiries. They inform and influence research, literature and the contemporary textbooks which educate teachers (see for example, Harlen, 2013; Johnston, 2014; Tunnicliffe, 2015). Significantly, their established truths signify human centric perspectives on knowledge making practices and support an outcome of (scientific) concept formation within the cognitive domain.

Constructivist theory within early childhood science education places little emphasis on the potential materiality offers to our understanding of children's knowledge making practices. Though some alternative narratives have challenged this, along with the dominant focus on the cognitive domain, they do not shift the positioning of children as 'agentic', and material as fixed, inert matter. Instead, emphasis is put onto how meaning can be made through categories other than the cognitive; that a 'higher order' understanding of concepts, norms and values might be developed. For instance, materials have been acknowledged as activators of learning through empathic, emotional and intense relationships that they potentially hold with children (Vecchi, 2010), and granted affordances (Gibson, 1979) which may support the use of visual perception to actively explore and make knowledge (Kernan, 2010). Ultimately, these perspectives maintain a position in which children's creative engagement with materials mirrors their pre-existing inner world. This is perhaps due to age old debates within early childhood (science) education which endeavour to reconcile or overcome perceived limitations between differing epistemologies underpinning Piaget and Vygotsky's theories. Such debates manifest in the 'lone scientist' actively making meaning through the environment, and socio-cultural

perspectives which recognise the construction of knowledge as mediated by both physical and psychological tools, including language (see for instance, Driver *et al.*, 1994).

When exhausted of thinking creatively, of generating and processing ideas, I retreat to making, to using my hands. I immerse myself in a sensorial space which grounds and stills the buzzing chatter of my mind. In a relationship with materials, I twist, turn and run yarn across my hands, weaving and knitting and transforming fleece into form and shape. I am creating and enquiring; I know and produce something new and original. Yet, I am required to relinquish control, to slow and listen to the material. I am not engaged in a solely intellectual experience and I do not try to exert my will or my thought over the yarn (a pointless endeavour which leads to unpicking). Rather, within this space the material and I emerge through relationship; it acts upon me as I upon it. This experience resonates with artists' reference to how, ‘after a certain point, the material that they engage with seems to take over and lead action to its completion’ (Glăveanu, 2014, p.64). Though, in my engagement with yarn, there is more than just myself and the material. There is something about the process of working with materials which takes me back to the concept of *Ma* and its reverence for the in-betweenness or ‘produced meanings that reside in seemingly empty spaces’ (Ferguson and Kuby, 2015, p.408). Similarly, to Lenz Taguchi’s (2011, p.38) relational materialist reading of a child as emerging and becoming in mutual relationship with a material, and play as taking place ‘in-between’ that relationship.

Conceptualisations of creativity from art and new materialist philosophy, in particular, offer perspectives on knowledge making practices which have inspired curiosity about processes of creativity in my own making and, in the context of early childhood education, questions about established understandings of young children’s creative scientific enquiry. These centre on the extent to which creative knowledge making practices reside within the cognitive domain and the role that materiality and spaces of ‘in-betweenness’ might play in meaning making.

New materialist, Karen Barad (2003, p.815; 2007), argues that relationships exist between matter within phenomena. Drawing on Bohr’s claim that phenomena, not

the individual object, are the primary ontological unit, she states ‘relata do not preexist relations’, and thus everything begins through relationships within phenomena (Barad, 2007, p. 141). For Barad (2007), this must include humans and materials (matter) as both of and emerging through relationships within phenomena. Therefore, our voice, our social enactments, theories, and materials are conditions both contributing to and creating phenomena, and also emerging from within phenomena. As Barad (2007) articulates, phenomena include unseen and omitted elements dependent on how boundaries are created through and within them. Thus, there are infinite ways of arriving at any meaning, and meaning making is a practice which is necessarily both entangled material and discursive by nature. That is, it is mutually inseparable as material-discursive.

Accordingly, within any phenomenon, there is an entanglement of relationships which act as a site of knowledge production. For example, the phenomenon of questioning my creative process as a maker makes visible the entanglement of myself, needles, yarn and spaces ‘in-between’. There are infinite other entanglements within this phenomenon which remain unseen. Thus, meaning that is made about my creative experience is recognised as one moment of ‘mattering’ as it is inevitably created by what is made visible; needles, myself, space and yarn. Knowledge making practices are therefore influenced and shaped by particular tools. The tools are co-constitutive of one another and agentic, both being and becoming in any given moment - a phenomenon defined as ‘intra-action’ by Barad (2007, p14). There is acknowledgement here that in any moment something different may be made to matter, dependent on which co-constitutive tools, known as apparatus, are made visible. Crucially, the act of making meaning necessarily excludes other meanings from being seen. An act, Barad (2007) states, in which we hold responsibility for meanings that are and are not made visible.

Barad (2007, p.140) claims that performative agential cuts make visible moments of meaning by cutting ‘together and apart’ the agentic qualities of phenomena. Such cutting together and apart make things matter by revealing indeterminate boundaries through and within a phenomenon. For instance, a cut may be performed simultaneously inside and outside the entangled phenomenon of creative experience using the material-discursive apparatus of ‘spaces in-between’, making this a

moment which defines what matters. As a material-discursive practice, the apparatus 'spaces in-between' is performative and consists of innumerate social, cultural, political, physical and other enactments. Thus, such an agential cut offers insight into creative experience as defined by the particular material-discursive practices which make up understanding of 'spaces in-between'. In another moment, an agential cut may be enacted with needles or yarn making something different matter about creativity. How we come to know then, is defined by agential cuts using relational material-discursive apparatus which are co-constituted within an entangled intra-acting phenomenon.

This is an ethico-onto-epistemic position which is articulated through Barad's (2007) theory of agential realism as the inseparability of ethics, ontology and epistemology in knowledge production. In such production, the subject and the world are in a constant, dynamic state simultaneously and differentially being and becoming. Agential realism has provided a pivotal frame from which to explore materiality in young children's creativity in science enquiry beyond the 'logocentric' or 'anthropocentric' (Lenz Taguchi, 2011, p.42) frames of constructivist theories.

Research Design

Baradian new materialist philosophy is woven throughout the study. Indeed, it has inspired an emergent position on young children's creativity in science enquiry within the literature review; underpinned the research design, informing the development of a new approach to diffractive analysis in educational research; and supported the creation of new knowledge.

Initially, the research design was informed by an interpretivist position as a means through which to explore early childhood practitioners' perspectives on creativity in science enquiry. Video Stimulated Reflective Dialogues (VSRD) (Moyles *et al.*, 2003) was identified as a research tool to use within communities of practitioners as it held potential to contribute to the development of knowledge. The use of VSRD in groups appeared particularly pertinent given its previous success in gaining insight into individual practitioners' understanding of pedagogy and practice. It also supported the possibility to explore dialogic spaces; whereby groups of practitioners' differing

perspectives might expand spaces between dialogues to create new insights about practice (Wegerif, 2014). However, although yielding some findings, this framework was found to limit insight into young children's creative knowledge practices within science enquiry as it privileges human centric perspectives on knowledge making practices. Additionally, as argued by Barad (2007, p.72), an interpretivist framework presented 'geometries of sameness' which mirror perceived existing realities rather than support the creation of new knowledge.

Diffractive methodology, as articulated by Barad (2007, p. 381), offered an alternative in that it claims to map interferences and effects of where relational, entangled and material-discursive differences appear. Barad's positioning of difference in diffractive methodology was particularly important as rather than something to be overcome for the benefit of internal, cognitive processes of meaning making, it is conceived as performative and agentic in knowledge creation. Thus, diffractive methodology was embraced as a process of reading differences and identifying emergent diffractive patterns from which *make* knowledge differently (Lenz Taguchi and Palmer, 2013, p. 616). In doing so, Baradian (2007, p.90) perspectives on ethical practices were explored, and responsibility was taken to consider 'which differences matter, how they matter and for whom'. Experimentation with diffractive methodology led to the development of a new approach to diffractive analysis in educational research. The approach places significance on *critical points of difference* by focusing on the points where data 'interfere' with each other and subsequently determines what differences are made to matter. Thus, revealing potential new knowledge.

Barad (2014) argues that diffraction makes possible 'returning' to data to read differences. As such, although not productive of abundant insights within the confines of an interpretivist framework, findings from the early meaning phase of the study are 're-turned' in a diffractive reading of i) empirical research data of shared understandings held by early childhood practitioners, ii) existing research on early childhood science education, and iii) conceptualisations of creativity. Subsequently, a new approach to diffractive analysis is used to challenge prevalent research outcomes and discourses in early childhood science education which reinforce dominant constructs of young children's creativity in science enquiry.

Aims

Given the introduction to the research focus, context and research design, this thesis aims to:

- illustrate existing discourses of creativity within and beyond the field of (early childhood) education to demonstrate elusive and wide-ranging conceptualisations;
- challenge conflicting and dominant discourses on creativity in science enquiry in early childhood education as limiting;
- illuminate the potential for alternative conceptualisations of young children's creativity in science enquiry, adopting diffractive methodology as a knowledge making practice; and
- present a new approach to diffractive analysis by showing critical points of difference as crucial in affecting connections which can convincingly reconfigure dominant ways of seeing.

The intended outcomes of the thesis are thus both a different conception of creativity in young children's scientific enquiry and the introduction of a new approach to knowledge creation within the field of early childhood science education using diffractive methodologies of new materialism.

Research Questions

The following working questions, which focus on ways to gather new insights on conceptualisations of creativity, the perspectives of early childhood practitioners' and diffractive analysis, have guided the study:

- R1: What representations of creativity exist within and beyond the field of (early childhood science) education?

- R2: What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

- R3: What insights are gained from a diffractive analysis of current understandings in literature and of empirical research on young children's creativity in science enquiry?

Chapter overviews

Chapter Two: Literature Review

The literature review is shaped by the three working research questions. Research question one through representations of young children's creativity that exist within the fields of education and art. Research question two in relation to early childhood practitioners' engagement in research, and research question three through new materialist philosophy.

The review begins with a discussion of new materialist philosophy. Key theoretical concepts are introduced in relation to the study and to early childhood science education. Particular attention is paid to diffractive methodology as pertinent to research question three. Concepts introduced in this section are drawn on throughout the review to question more common and established practices within early childhood science education. The review is developed with a broad discussion focused on understandings of young children's knowledge making practices within early childhood education, and early science education. Dominant theoretical perspectives are identified along with the epistemologies which underpin them. These are argued as limiting knowledge to representations of what is perceived to be already in existence. The next part of the review is framed by research question one. As such, epistemic roots of creativity in education are explored alongside conceptualisations of creativity within early childhood science education. The chapter then moves from an examination of dominant perspectives in the education literature to broader conceptualisations of creativity, within the domain of art. Creativity, as articulated in this domain, is claimed as potentially providing insight into the materiality of young children's creative knowledge making practices in science enquiry. The outcome of this is discussed in the conclusion to the thesis. The final section of the review includes literature on research with early childhood practitioners. This includes collaborative practices, the use of video technologies and

conceptualisations of practitioners' meaning making as related to research question two. This literature informed the initial research design and so is representative of early thinking which was framed through an interpretivist paradigm.

Chapter Three: Research Design

The research design chapter maps the emergence of the ethico-onto-epistemic framework which underpins the study. As such, research question three is closely considered. Research question two is also addressed in the chapter with respect to the initial interpretivist position which informed the early stages of research.

The chapter is split into two distinct parts. The first, early meaning making, begins with exploration of the interpretivist influence on the initial research design, data collection, ethics and the early stages of analysis. As related to research question two, this includes the dialogic approaches used to gain insight into shared understandings of young children's creativity in science enquiry within the context of video reflective dialogues in communities of practice. The limitations of an interpretivist framework are examined in light of influences including new materialist philosophy. The second part of the chapter, later knowledge creation, focuses on research question three and the Baradian perspectives which influenced later analysis of shared understandings, as enacted through a diffractive reading of theoretical and empirical data. The new materialist concepts introduced in the literature review are developed with particular focus on diffractive methodologies. Related concepts are introduced to illuminate the development of a new approach to diffractive analysis in educational research. Central to the new approach are critical points of difference which are presented as affecting connections which can reshape dominant ways of seeing. The chapter concludes with a pause to consider ethics as situated within an ethico-onto-epistemological framework.

Chapter Four: Findings

Echoing the research design, the findings chapter is presented in two parts and related to research questions two and three.

With reference to research question two, the first part of the chapter details early insights which emerged from the analysis of early childhood practitioners' shared

understandings of young children's creativity in science enquiry. Consideration is also given to the potential that Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003), within communities of early childhood practitioners, holds in contributing to perspectives on creativity in science enquiry. Attention is drawn to my positioning as researcher and participant in the study and it is suggested that dominant conceptualisations of young children's creativity and scientific enquiry are prevalent in practitioners' perspectives. Additionally, it is shown that practitioners' pedagogical dilemmas largely mirror established insights. Findings which indicate a departure from normative understandings on creativity and children's engagement with materials in science enquiry are presented, and the role of video footage in contributing to shared understandings is illustrated. The second part of the chapter argues that little new insight about creativity in science enquiry is gained from an interpretivist analysis of empirical research data. Rather, it is claimed that findings from a new approach to diffractive reading reveal new ways of seeing young children's creativity in science enquiry. This is illuminated through the process of identifying and exploring critical points of difference emergent from a diffractive reading of i) 're-turned' fragments of empirical research data from part one, ii) existing literature focused on early childhood science education, and iii) conceptualisations of creativity within the domain of art, as related to research question three. The subject of ethics is revisited at the end of this chapter, in response to the pondering on an ethico-onto-epistemic position which began in the research design chapter.

Chapter Five: Discussion

The discussion chapter is divided into two parts following the pattern of the previous two chapters. Research questions are addressed holistically throughout, and discussion is informed by an ethical position which foregrounds empathic questioning.

Part one reiterates the finding that little new understanding is gained from a thematic analysis of empirical data gathered within an interpretivist paradigm. However, value is placed on these findings as a starting point for later diffraction. As such findings are addressed in relation to literature and wider debates within the field of early

childhood education. Key points relating to talk, creativity, materials and the positioning of both video camera and footage are explored as points of interest. In the second part of the chapter, it is claimed that the findings from a new approach to diffractive analysis reconfigure ways of seeing young children's creativity in science enquiry. These are discussed as three new understandings; reading diffractively; knowledge making practices and coming to know through material encounters. Attention is paid to the significance of a transdisciplinary position, critical points of difference, superposition, and agentic cuts with reference to Barad's concept of dis-continuity. The limitations and learning from the study form the conclusion to the chapter.

Chapter Six: Conclusion

Both the research questions and study aims are revisited in the concluding chapter. The outcomes of research question one are considered in relation to the literature review and the later diffractive reading of shared understandings of young children's creativity in science enquiry. Research questions two and three centre on findings from both the early insights and later diffractive reading which provoked further questions. As such, the scope for further research and implications for practice are considered. Recommendations for pedagogy and practice within early childhood and science education conclude the chapter.

Chapter Two: Literature Review

Introduction

Chapter one argued the importance of the study, introduced key motivations and mapped the central threads of the thesis. The review of literature explores these threads in three parts. The first examines Karen Barad's philosophy of new materialism. The second focuses on current influences on knowledge making practices within early childhood and science education. Finally, the third part explores research with early childhood practitioners.

The first part of the literature review focuses on the study's central theoretical framework; Baradian new materialism. Its emergence within research in the field of early childhood studies is outlined and followed by a discussion of new materialist thinking in relation to research in early science education. Also included is a summary of key new materialist concepts, as related to research question three and the research design of this study.

To contextualise the research, the epistemological perspectives which inform understanding about children's knowledge acquisition and meaning making within early childhood education are explored in the second part of the review. Their influence on early childhood education policy, pedagogy and practice is subsequently considered. This is followed by a detailed overview of epistemic positions which shape contemporary pedagogy and practice in early childhood science education. Finally, guided by research question one, the epistemic roots of creativity are examined alongside conceptualisations of creativity within early childhood science education and the domain of art. This section concludes with a summary arguing that dominant perspectives which inform understanding of creativity and of science in early childhood education are limiting, representational perceptions of existing knowledge which neglect the place of materiality. In contrast, conceptualisations of creativity in art are discussed as a means through which to explore the materiality of creative knowledge making practices in science enquiry.

As the research was initially underpinned by an exploration of the voices and shared understandings that early childhood practitioners held of young children's creativity in science enquiry, the final part of the chapter focuses on research question two and reviews literature on early childhood practitioners' knowledge making practices and professional learning.

In particular and as related to this study: collaborative practices; the use of video technologies; and conceptualisations of meaning-making are considered.

New Materialism

The introduction to the thesis claimed that little attention is paid to the materiality of young children's creativity in science enquiry and that, as such, the philosophical works of the theoretical physicist and feminist scholar Karen Barad provide a meaningful framework through which to explore this issue. Barad's (2007) positioning of knowledge making practices beyond the 'logocentric' or 'anthropocentric' (Lenz Taguchi, 2011, p.42), and assertion of the ontological inseparability of matter from meaning making were presented as significant perspectives informing and shaping the study. Diffractive methodology (Barad, 2007) was also introduced as central to the later development of the research design and a new approach to diffractive analysis.

This first part of the literature review moves from here to examine research in early childhood (education) which is influenced by new materialism. Included are the few studies which focus on young children's science. This is followed by a deeper exploration of the Baradian philosophy which underpins the study. In particular, the theory of *agential realism* and an *ethico-onto-epistemological* position are discussed alongside the concepts *phenomena and intra-activity*; *material-discursive practices; apparatus and agential cuts; and diffraction*. As the literature review progresses, the new materialist concepts introduced are drawn on to question dominant theoretical influences and established practices within early childhood science and creativity in education.

New materialism and early childhood (science) education

Karen Barad's philosophical position is situated within the broader interdisciplinary paradigm of new materialisms, at times described as posthuman and post-qualitative (MacLure, 2015; Ulmer, 2017). As well as Barad, leading theorists include Rosi Braidotti, Elizabeth Grosz, and Jane Bennett. Central to their works is a turn away from traditional and human dualist positions which underpin cultural theory (Alaimo and Hekman, 2008; Coole and Frost, 2010). As such, they turn to matter to question the linguistic and constructivist/constructionist turns. However, whilst there is a 'return' to materialism, cultural theory is not entirely dismissed. Rather, it is built upon and co-constituted with new materialist ideas. Building on 'what is and what has been' is important to this study and particularly pertinent to later diffractive readings of empirical and theoretical understandings of young children's creativity in science enquiry.

New materialism's emergence within studies of early childhood education has been relatively recent. Notably, Hillevi Lenz Taguchi (2010; 2012; 2013; 2014), Karin Murris (2015; 2016; 2018) and Bronwyn Davies (2014; 2018) have pioneered research in the field. Following this, new materialist philosophies have received increasing attention (see for instance, Fairchild, 2020; Giorza and Haynes, 2018; Hackett, Pahl and Pool, 2017; Osgood, 2019; Otterstad, 2018; Penfold, 2019; Procter and Hackett, 2017; Reddington and Price, 2018; Somerville and Green, 2015; Tesar and Arndt, 2016). So much so that in 2015, Jane Osgood and Red Ruby Scarlet/Mirian Giugni suggested that research in early childhood education had 'turned' to posthumanism. Indeed, it seems that new materialism has influenced this field more so than other phases of educational research. Though, as Osgood and Guigni (2015, p.347) discuss, there has been less focus on the methodologies used to 'harness and employ posthumanist approaches'. Rather, research which draws on new materialism predominantly foregrounds the role of materials in children's daily lived experiences; a theme defined as 'lifefulness' by Somerville (2019) in her recent literature review of posthuman theory and practice in early years learning. Lenz Taguchi's (2011) research which draws on earlier work with Karin Hultman, exemplifies the theme. Inviting the reader to consider an image of a child pouring sand from multiple theoretical perspectives including new materialism, she argues

for learning events as occurring simultaneously between hands and material things. In doing so, she de-centres the child and defines the child-sand relationship emergent 'becoming organism as an effect of multiple encounters and inter-relations' (*ibid*, p.38). This is a non-hierarchical relationship between human and more-than-human matter that is illuminated by a number of scholars. For instance, Giugni (2011) describes children as becoming with clay, internet and practices of faith. Rautio (2013), drawing on Bennett's (2010) Vibrant Matter, discusses the materiality of children's everyday life environments through autotelic play with stones. Somerville and Powell (2018, p.8) explore the 'living element' mud as an enabler of children's processes of representation such as language and story making whilst 'hanging out' in an early learning centre. And Giorza and Haynes (2018, p.90) take Bennett's (2010) 'thing power' and the 'in-between space of play and thing' to describe knowing as a range of social and material relations. Such (re)positioning of the child-material relationship to one in which matter is not passive or inactive is significant to this study which seeks to challenge dominant discourses on children's creative knowledge making practices in early childhood science enquiry as limited to anthropocentric perspectives.

Of importance to the study's research design and relating to research question three

- What insights are gained from a diffractive analysis of current understandings in literature and of empirical research of young children's creativity in science enquiry?

is the consideration given by scholars to the entangled role of researcher when enacting new materialist approaches to inquiry. For example, Davies (2018, p.122), draws on Barad (2007) and Asberg *et al.* (2015, p.150) to read affect as 'the world unfolding from within'. In doing so, she describes herself as co-implicated in the lines of force that flow between child and rock. Frigerio *et al.* (2018, p.392) rethink the production of an autistic child by 'cutting together and apart' the label 'autistic'. Thereby, they offer the child's relationship with the world as conditioned by the materiality of the environment and their own entanglement in processes of meaning making. Of particular interest are academics' accounts of their entanglement in experiments with new materialist diffractive methodologies in studies of early

childhood education (see for instance; Davies, 2014; Hultman and Lenz Taguchi, 2010; Lenz Taguchi and Palmer, 2013; Osgood and Giugni, 2015; Otterstad, 2018), and beyond (see for example, Bozalek and Zembylas, 2017; Chappell *et al.*, 2019; Hoel and van der Tuin, 2012; Mazzei, 2014; Taylor and Gannon, 2018). Their insightful discussion on the application of a diffractive approach in research has influenced the development of a new approach to diffractive analysis in this study. For instance, Lenz Taguchi (2012) argues that in diffractive analysis we need to move ontologically, from identifying bodies as separate entities with distinct parts to think in terms of phenomena. To do so, she adopts a 'minor' role as embodied material researcher, positioning herself 'within' interview data and acknowledging that she is not the sole subject of knowledge production. Similarly, Davies (2014, p.739), investigating young children's experiences of anger, suggests that diffraction is 'best understood as flows of intra-action, rather than separate entities inter (intra) acting with each other'. Reading diffractively with the material of theory, Mazzei (2014) considers the entanglement of bodies, texts, relationships, data and language, and uses diffraction to produce questions for exploration. Also drawing on theory as matter, Taylor and Gannon (2018) discuss 'two passes' through data in order to find difference in their diffractive writing experiments. Considering the entangled relationality of transdisciplinary creative pedagogy, Chappell *et al.* (2019), describe methodological cuts as creative of new knowledge *and* new research questions in their diffractive process. Such examples embody approaches to diffraction which are discussed further through the key Baradian perspectives introduced below, and later in the research design chapter.

Despite the interest in new materialism within early childhood education research, studies focusing on early science education have received surprisingly little attention. In my trawl of literature, I found two chapters which focus on new materialism within the context of early childhood science education in Milne and Scantlebury (2019) (see, Areljung, 2019; Haus and Siry, 2019). Other than this, there were a relatively small number of articles (Gunther-Hanssen *et al.*, 2020; Haus, 2018; Taylor and Pacini-Ketchabaw, 2015). Areljung (2019), Haus and Siry (2019), Haus (2018), and Taylor and Pacini-Ketchabaw's (2015) studies direct attention away from established approaches within early science education, towards an object-child relationship in

scientific encounters. Whereas Gunther-Hanssen *et al.* (2020) focus on gendered processes in early science drawing on Barad's theory of Agential Realism.

Two of these papers have particularly influenced the development of this study. Areljung (2019), reworks her previous research underpinned by socio-cultural theory to illustrate child-object explorations as agentic, emergent and as being in relational intra-action. For instance, in a child-mattress encounter, both object and subject are described as making themselves intelligible to one another through rolling. Through such intra-actions, Areljung (2019) claims, comes new knowledge. This knowledge is articulated through the existing science concept of force. In my entangled reading of the paper, I question how the outcome of intra-actions between child and material come to be defined through concept formation of established scientific knowledge and wonder about the determining apparatus of researchers. The positioning of established knowledge as the outcome of intra-action also appears inherent in Haus and Siry (2019, p.146) who claim experience of the concepts sound and condensation as the new understanding which emerges from within intra-acting children and bottles of liquid. Here the authors argue the importance of open-ended explorations between materials and objects in early science, yet children's new learning appears defined as pre-existing knowledge. I question what other unknown or less visible 'scientific knowledges' may emerge through such intra-actions and consider whether the already known to us is imposed onto children through an adult apparatus of interpretation, potentially limiting the scope or opportunity for new knowledges to come to matter. Such limitations appear in Areljung's (2019) recommendation that practitioners consider the time of year that they might know ground to be hard, icy and slippery because an intra-action with objects could lead to an experience of friction. In such practice, knowledge making and learning seems predetermined and without space for children to meaningfully explore and discover their *differential* becomings. In this study, I take a different perspective and rather than articulating children's knowledge outcomes, I focus on gaining deeper insight into the tools, the apparatus, which determine particular outcomes. Thereby, I argue children's creative knowledge making practices in science enquiry as emergent through critical points of difference, where apparatus collide and differentially cut, within diffractive encounters.

Acknowledging that this review cannot cover the complexity and depth of Baradian theory which has influenced this perspective, what follows here is an overview of key theory and concepts which are drawn on throughout the study and developed in the research design chapter.

Agential Realism is an ethico-onto-epistemological position

Central to Barad's new materialist philosophy is her theory of agential realism. Barad (2007, p. 225) positions agential realism as an ontological, epistemological and ethical framework which challenges the Cartesian divides as manifest, for instance, in human/nonhuman, mind/body, object/subject, matter/discourse. As such, Barad (2007) argues entities as inseparable, and knowing and being as emergent through entangled relationships: relata therefore does not proceed relating (2003, p. 815). Agential realism is thus performative by nature; the subject and the world are in a constant, dynamic state simultaneously being and becoming. Thiel (2018, p.234) explains this through Barad's rejection of Newtonian physics in which independent objects move through space and forward in time. For Barad (2007), space, time and matter do not independently exist. Instead, they emerge together in the shape of 'spacetimemattering'. There is thus no prior separation between the world and humans. Indeed, Barad (2003) contests a human-centred concept of agency and instead argues that it concurrently exists and emerges through relationships within phenomena. Therefore, agency does not belong to the individual or separately to the world (Rautio, 2013). Such a conceptualisation of agency is helpfully articulated by Bennett (2010) through the analogy of an encounter.

Of importance to this study, is Barad's (2003; 2007) claim that, from an agential realist perspective, knowledge making practices are emergent and open phenomena without a beginning or end. There is, thus, no privileged position from which knowledge can be produced. Additionally, Barad (2007) argues that the physical laws underpinning the reality we experience are, themselves, an ethical matter. Ethics then is about being responsible to the ways in which we make the world. As such, it includes consideration for the effects that our knowledge-making processes have on the world (Barad, 2007, p. 381). This position has deeply influenced my thinking about ethics within this study, as articulated in the research design chapter.

Phenomena are entangled intra-acting relationships

Within an ethico-onto-epistemic framework, single, separate perspectives which mirror or reflect a reality, as perceived by humans, do not exist. Rather, relational phenomena are the foundational unit (Barad, 2007). Barad (2003; 2007) explains relationships within phenomena through the concept of intra-action. Significantly, intra-action is not the same as interaction which presumes that individuals exist prior to exchanges (Kleinmann, 2012). Instead, intra-actions are ontologically inseparable and agential components. They are entangled, with no isolated binary co-productions within. That is, intra-actions are matter which emerge as part of entangled relating, ever vital, shifting and performative. They entail the complex co-productions of 'human and nonhuman matter, time, spaces, and their signification' (Sanzo, 2018, p.1).

Of particular relevance to the study's focus on early childhood practitioners' development of shared understandings of young children's creativity in science enquiry is Lenz Taguchi's (2012, p.268) explanation of intra-activity. This includes the ways in which 'discourse and matter are understood to be mutually constituted in the production of knowing'. For Barad (2003; 2007) this is conceptualised as material-discursive.

Matter is material-discursive

From a new materialist position a dichotomy between material and discursive is not possible. Barad (2007) argues that material-discursive, is positioned beyond, for instance, Foucault's conceptualisation of discursive whereby material is argued to remain passive, and, in another instance, Butler's definition of material as derived from the agency of language and culture. Barad (2003, p.810) instead relates material more directly to matter - bodily, historically and culturally - thus material-discursive practices are the 'social, cultural, psychic, economic, natural, physical, biological, geopolitical, geological, which are important to particular processes of materialisation'. Therefore, within the phenomena of this study, shared understandings of creativity in science enquiry are recognised as entangled material-discursive practices of video camera and footage [material], institution [cultural],

bodies [material], policies [political] children's and practitioners' enactments [physical].

Considered also within the phenomena are *ideas* which Barad claims as not separate from material counterparts (Barad, 2007, p.55). That is, theories are physical arrangements that participate in material ways. Theorising is so recognised as a material practice, not an activity solely within the mind, and theories subsequently matter. This position is also argued for 'knowing' which Barad describes as 'a material practice of engagement as part of the world in its differential becoming' (2007, p.89). Crucially, here, difference is of note. It is only through 'difference', Barad (2007) argues, that we can come to 'know'.

Apparatus and agential cuts determine what is known

Material-discursive entanglements within phenomena are described as including apparatus which intra-act together, contribute to and provoke change. Such apparatus is conceptualised as specific material configurations of the world which act as boundary drawing practices to produce infinite material realities (Barad, 2007, p. 148; Hollin *et al.*, 2017). Drawing on Niels Bohr, Barad (2007) claims that apparatus, within a phenomenon, can make 'agential cuts' as they consist of agencies which both become and emerge through intra-action (Thiel, 2020). Thus, they determine what is and what is not made to matter (Barad, 2007). For instance, changing the apparatus in an experiment could enact a different 'agential cut' and hence a different meaning. Thus, agential cuts are not fixed, boundaries or perspectives within an intra-active phenomenon (Barad, 2003, 2007). Significantly, the apparatus and agential cuts determine meaning, not not an individual. A number of visible and invisible material-discursive entanglements are acknowledged in this study, along with particular agential cuts and thus particular meanings. What is not made visible is recognised as significant, ethically bound and also contributing to phenomena. This perspective is discussed and developed in the research design chapter.

Diffraction positions difference as agentic space

From a physics perspective, diffraction is wave behaviour. Waves bend out and distort when they hit an obstruction. Barad (2007, p.74) describes these as disturbances which are marked by patterns of difference. A Baradian

conceptualisation of difference is described by Rautio (2013) and Hultman and Lenz Taguchi (2010) as the condition of rather than a product of our existence as human beings. They explain that both diffraction and difference highlight the focus of attention within new materialism to the in-between as a space that ceaselessly proliferates material-discursive reality (Barad 2007, p.140). From a research perspective, Lenz Taguchi (2012), usefully describes diffraction as a methodology which looks for differences within as if dropping two pebbles into water and observing how the surface ripples collide. Diffractive methodology, therefore, unlike reflection and reflexive stances which engage 'geometries of sameness', is performative and agentic (Barad, 2007, p. 72). As a knowledge making practice, it can be understood as 'an enactment of flows of differences, where *differences get made* in the process of reading data into each other, and identifying what diffractive patterns emerge in these readings' (Lenz Taguchi and Palmer, 2013, p.616). It is concerned specifically with the relational differences which are inevitably created within material-discursive, intra-acting entanglements (Barad, 2007, p. 88). Particular consideration is paid to how differences get made, what gets excluded and how these exclusions matter (Barad, 2007, p.30). Reading diffractively is thus, as with agential cutting, an ethical act. An important point for this study is Barad's (2007) explanation that the details of one discipline can be read attentively and with care through another in order to help illuminate differences as they emerge. This, Barad claims, supports the potential for new creative insights.

The key Baradian perspectives introduced here underpin the theoretical framework for this study. They are drawn on throughout the literature review to establish a position on current discourses within the context of early childhood education, early childhood science education, and creativity in (early childhood) education. Following this, they are returned to in the research design chapter to support the development of a rationale for a new approach to diffractive analysis.

Early Childhood Education

Dominant discourse: developmental psychology

Pedagogical traditions, including Froebelian, Rousseauian and Deweyian, which have influenced ecological and epistemological framing in early childhood education (see Chung and Walsh, 2000; Fleer and March, 2009) have broadened in scope over the past two decades. Indeed, informing recent discourse is critical theory such as Marxist dialectic; postmodernist perspectives including Foucault and Deleuze and Guattari; new materialism; sociological analysis especially drawing on Berstein, and socio-political goals including, social justice, rights and power (Osgood and Guigni, 2015; Singer and Wong, 2018). Nonetheless, the discipline of developmental psychology has maintained a long-standing hold on early childhood education and care (ECEC), informing policy, curriculum, pedagogy and practice (Moss, 2019; O'Dell *et al.*, 2018). Wood and Hedges (2016) proclaim it as the dominant discourse explaining the discipline as a means for providing scientific credibility and evidence for what had previously been observed intuitively within ECEC. In their exploration of the emergence of developmental psychology within early childhood education, they note it as a reaction to previous approaches deemed 'laissez-faire' due to their advocacy of free play, observation of natural development, and little adult intervention. Such 'laissez-faire' approaches sit under the nebulous term 'child-centred' practice. There is little consensus on the meaning of 'child-centred', though Chung and Walsh (2000) provide a useful overview of three key influences from a US context: Froebel's romantic perspective of the child at the centre of their world; a developmentalist position which posits that children are at the centre of schooling; and a progressive, democratic stance whereby children should direct their own activities. Georgeson *et al.* (2015) argue that all three influences are evident across contemporary early childhood education and that, additionally, (socio) cultural contexts shape understanding of child-centredness. In their research across three European countries, the authors identified common principles in a child-centred approach. These included valuing children for who they are in the here and now; a focus on the child as a being and as being part of a community; freedom; learning through play and developing activities in response to the interests of the child. Adding critical perspectives to such conceptualisations, Campbell-Barr (2017),

drawing on Walkerdine (1984), states that ‘child-centred’ has become a paradox due to its grounding in liberal pedagogy and theories of child development. Whilst Stephen (2010, p. 18) contends that, given the variety of interpretations of ‘child-centred’, it is difficult to agree ‘that it is pivotal to the success of children’s learning’. Such views are echoed by Langford (2010) who deems it an ideological discourse within early childhood education.

Developmental psychology is defined as a focus on what and how development occurs, how children learn, and how their experiences and activities lead to more developed or mature forms of cognition, behaviour, and competence (Wood and Hedges, 2016). As the discipline has translated to early childhood policy, curriculum, pedagogy and practice, broad developmental norms and prescribed models have presented learning as cognitive maturation in fixed ages and stages. These prescribed models are widely criticised as ‘regimes of truth’ (see for instance, Mac Naughton, 2005) which sit in ‘messy’ tension with current child-centred practices (Cherrington, 2016). Fredricks, Blumenfeld and Paris (2004) and Fleer and March (2009) concur stating that, despite commitment to child-centredness, much of early childhood education now follows a narrow and traditional psychological pathway where young children are atomised and consequently characterised through fragmented groups of behaviours, feelings and learning. They argue that this is mirrored in most Western early childhood programmes where curricula and pedagogy have traditionally been organised in relation to outcomes in social-emotional development, cognitive/language development, and physical development.

Of particular interest to this study is Fleer and March’s (2009) observation that this constitutes a developmental view of knowledge acquisition. This is a well versed point, argued as shaping teaching and learning in early childhood education with Cartesian logic which separates the mind and the body from one another (see for instance, Mac Naughton, 2005; Moss, 2018; Murris, 2016; Spyrou, Rosen and Cook, 2018). It is also of note that developmental psychology is informed by positivist ontology and epistemology which outline norms for typical development within the common categories: biological processes; the mechanisms for learning; social and emotional adaptation; and explanations for individual differences (Wood and

Hedges, 2016; Singer and Wong, 2018). Such norms are underpinned by data which has been gathered using a range of methods rooted in positivist methodological orientations such as observation, experimental interventions, and randomised control trials (Farquhar and White, 2014). Thus, developmental research has produced a variety of rating scales, measures, stages, categories, and norms through which early learning and development have come to be understood. As a 'good fit' with discourses of human capital (Moss, 2013; Penn, 2010), the rationalised and objective position on knowledge acquisition, alongside a model of learning in developmentally appropriate 'ages and stages', has become enmeshed and dominant in global trends towards investment in ECEC systems. For instance, as ECEC has become the site for government-funded universal provision in order to address inequities in educational achievement later in life, the focus in policy has shifted towards more instrumental questions, such as how might knowledge be arranged logically as curriculum content and how might coherence be achieved through pedagogical approach and assessment practices (Moss, 2019).

A particular objection to the influence of developmental psychology, when informed by policy which favours logical scales, measures and testability, is that it perpetuates a deficit position of children and their development (see for instance, Farquhar and White, 2014; Kasprisin, 2015). Although more recent developmental psychologists such as Whitebread and Coltman (2015) address the issue by positioning the child as competent and capable, Vandenbroeck *et al.* (2017) argue that insight from fields such as neuroscience is used today to perpetuate continued use of modernist traditions within the field of developmental psychology; this includes frameworks such as the 'ages and stages' model. He draws attention to 'early intervention' discourse manifest in early childhood policy, curriculum and practice in England (see for instance, The Allen Report, 2011) whereby it is claimed that a focus on children between birth and three years, through a number of non-defined intervention programmes, will help narrow any later underachievement or developmental 'gaps' and help to reduce 'costly' social problems. The more recent Bold Beginnings report by the English Office for Standards in Education, Children's Services and Skills (Ofsted) (Ofsted, 2017), also takes a traditional stance, drawing on the term 'school readiness' to propose better alignment between the Early Years Foundation Stage (EYFS) (DfE, 2017) and The Primary National Curriculum (DfE, 2013), that children

might be adequately prepared for schooling and the future (TACTYC, 2017). The outcome of this combination of policy which seeks to produce human capital in line with global discourses and a curriculum dominated by developmental psychology is an increasingly homogenised perspective on young children's knowledge making practices. Rather than seeking modernist universal 'truths', this study recognises the possibility of plurality and interconnection in knowledge making practices, including spaces 'outside' of the human mind. In doing so, it seeks insight into the contribution materiality may make in understanding young children's knowledge creation within their scientific enquiries - a focus potentially obscured by the influential discourses of globalism and governing practices of developmental psychology within early childhood education.

Wood and Hedges (2016) state that the dominant focus on developmental psychology has led to a continued struggle over curriculum in early childhood education which is now manifest in national and international research and debate (see for example, File *et al*., 2012; Lenz Taguchi, 2014; Moss, 2019). Of particular interest to this study is their claim that this is because of the similarities in what child-centred and more recent approaches within the field of developmental psychology believe. These approaches have been informed by constructivist and socio-cultural theories which are underpinned by a focus on discovery and inquiry as well as play-based curricula which responds to children's interests. However, within a child-centred curriculum, the role of the practitioner is positioned as non-directive and reactive (Siraj-Blatchford, 2009) whereas both constructivist and socio-cultural epistemologies position practitioners as active, intentional teachers who support children to develop mental models based on their perceptions of reality (Raskin, 2002). Significant to this study is Cherrington's (2016) argument that this creates discordance and confusion for early childhood practitioners. That is, the broad paradigm of developmental psychology essentially sits in opposition to more liberal child-centred ideals yet theories within the field both align and misalign with child-centred practices. Such discordance is manifest in age-long issues within early childhood education. These are discussed further in the next section which examines epistemological perspectives underpinning theories of constructivism.

Dominant epistemological perspectives: Constructivism(s)

Fleer and March (2009) state that despite wide contestations of the developmental categorisation of early childhood within sociological, ecological and cultural-historical literature (see for example, Fleer, Hedegaard and Tudge, 2009; Moss and Petrie, 2002; Pence and Benner, 2015; Turmel, 2008) and in early childhood education (see for example, Ailwood, 2003; Blaise, 2009; Bradbury and Roberts-Holmes, 2017; Edwards *et al.*, 2009; Moss, 2019), dominant philosophical perspectives on young children's meaning making remain rooted within the field of developmental psychology.

Drawing attention to differing perspectives within this field, Navarro (2013) states that, before the influence of Jean Piaget and Lev Vygotsky, little research was undertaken in terms of *how* young children develop cognitively. The assumption of knowledge as an acquisition, created by the positivist paradigm, saw cognitive progress solely measured by how well a person's knowledge corresponded to an objective reality (Raskin, 2002). Science, Sexton (1997, p.7) posits, was the tool through which knowledge could be accessed, thus it was considered a valid mirror of reality. This translated to the context of education as learning through direct instruction and transmission of existing knowledge from an existing reality (Moroz, 2015).

Constructivism, argued as both modernist and postmodernist (see for instance, Prawat, 1996; Wegerif, 2008) due to the respective positioning of knowledge as the property of individuals or as co-constructed in the environment, emerged as interest within the domain of psychology moved to how knowledge is acquired (Navarro, 2013). As a result, personal and social realities, and human participation in the construction of knowledge became a central focus for study (Raskin, 2002). Navarro (2013) explains that, unlike positivist epistemology which advocates empirical truth, modernist constructivism argues that knowledge exists within the human mind, not necessarily matching a 'real' external reality. Thus, the viability as opposed to the validity of knowledge claims were given value (Navarro, 2013). Learning was consequently perceived as a continual development of mental models based on perceptions of the 'real' world. Epistemologically, modern constructivism is therefore

rooted in subjective experience and interpretation. Such repositioning of discourses from knowledge acquisition to engagement in meaning and knowledge 'making' (Domenici, 2008; Raskin, 2002; 2008) foregrounded 'the child' as active and agentic, and intellect as a process developed within the individual (Mahoney, 2007; Singer and Wong, 2018).

According to modernist constructivists, knowledge is built from structures of previous knowledge and experiences (Meyer, 2009). Piaget translated this claim through the concept of schema, which he used to explain how children create knowledge (Thomas and Jones, 2020). Schemas acted like filing cabinets; as new experiences within the environment occur, existing mental models are expanded and new knowledge structures are created. Piaget believed that through cognitive conflict, that is when something does not fit with an existing mental model, (e.g. a 'light' object such as a pin sinks in water when previous experience about light objects (feathers for example) has illustrated that they float), further first-hand exploration would disturb initial points of view and lead to the creation of new mental models of perceived reality (e.g. not all 'light objects float). Intellectual progress was thus understood in terms of conflict in perspectives experienced within the mind. Differing perspectives were catalysts for adaptation and the formation of new knowledge, which was gradually assimilated by using or transforming the environment to expand existing knowledge structures, or accommodated which required the reshaping of existing structures (Applefield *et al.*, 2000; Mercer and Littleton, 2007).

Piaget advocated for children to learn through direct hands-on experience with materials, recognising them as a primary means through which conflicts in perspective could emerge and thus intelligence be derived (Mercer and Littleton, 2007). A child's sensorial interactions with the environment thus contributed to the development and expansion of schema. As they moved through differing pre-defined stages of development, materials were useful for children to gain increasingly complex understanding of their worlds. For instance, in a sensorimotor stage (birth to two years) a child may find objects that have been displaced within an environment and through touch, taste or hearing attribute them with simple properties. Whereas during the 'last' stage of development, formal operations stage (adolescence to adulthood), materials were deemed unimportant as a child would begin to

demonstrate abstract thought patterns including reasoning skills such as generalising and evaluating logical arguments (Anderson, 1990). Throughout predefined ages and stages of development, children were perceived to move from hands-on and minds-on to minds-on as the accomplished stage of cognitive development.

It is of note that, in terms of cognitive development, concept development is given credence. Knowledge may not reflect an external and 'true' reality in the environment, as with positivism, but it does appear to reproduce established scientific truths, through assimilation and accommodation. Knowledge is therefore not 'new' discovery by individual experience, but layers of 'old' knowledge structures (or accepted truths) built through sensorial exploration with materials. This is evidenced in the role of the (early childhood) teacher who, according to Piaget, was to provide a rich and stimulating environment so that a child's internal mental models might become increasingly sophisticated and less dependent on direct experience (Muller *et al.*, 2018). Through questioning, a teacher was believed to be able to elicit children's developing thought and cognition and provide further enriching environments (Ollerenshaw and Richie, 1997). Thus, humans controlled the environment and shaped it and its materials to the required end of concept development. Within Piagetian, endogenous constructivism, the environment thus appears as a pre-existing, flat and static dimension. Materials may have stimulated the senses, but they were passive objects.

Piaget's epistemology, known as genetic due to focus on the development of knowledge in humans, holds a tacit position within early childhood education pedagogy and practice. Drawing on Bailey and Wolery (1992), Fleer and March (2009, p.26) suggest that early childhood education still places high value on child-engagement through 'appropriate interactions with materials and people'. This pertains to Piaget's contention that peers as well as materials could act as a rich source of cognitive conflict for children. By offering multiple other perspectives, peers could support the development of sophisticated concrete operational and formal operational thinking. Materials were thus viewed as necessary in earlier stages of children's cognitive development, but they were rudimentary in supporting intellectual progress once children were able to apply reasoning skills. The telos of pedagogies

that involve materials was believed to be that of concept formation. Drawing on new materialist philosophy, this study challenges this view of materials as inert and passive aids. Materials are instead considered relational, entangled and performative in acts of knowledge making (Barad, 2007). Indeed, as Bennett (2010, p.vii) proclaims, directing attention away from human experiences of things to the 'vitality of matter', material formations such as Omega 3 fatty acids or chemical streams from landfills affect and transform us.

There is little critique of Piaget's positioning of materials in research on early childhood education. However, his other constructivist theories have long been contested. The field of early childhood regularly revisits and accuses the 'ages and stages' model of cognitive development of being a linear and rigid, biological perspective, which pays little attention to societal or cultural contexts (see, for example, Babakr *et al.*, 2019). Additionally, the representation of children as 'lone scientists' exploring and making meaning through interaction with the world, and teachers as the facilitators of active, autonomous discovery within rich environments, are heavily contested. Such criticisms stem from tensions created between constructivist and child-centred ideals, and between constructivist and social constructivist (socio-cultural) perspectives (see for example, Cherrington, 2016; Fleer and Pramling, 2015, Langford, 2010).

Following the emergence of Vygotsky's social constructivist theory (also known as socio-cultural, socio-historical or cultural-historical theory (Wells and Claxton, 2002)) into education, thinking about cognitive development shifted to consider the mind as mediated by cultural, historical and institutional processes (Mercer and Littleton, 2007). That is, rather than an individual establishing a relationship with the world to make meaning; psychological and technical tools first acted as mediators of knowledge construction, before any internal intellectual capacity was developed.

From a psychological perspective, culture was recognised as a product of social life and human social activity, with learning and subsequently knowledge construction partially occurring between humans (Vygotsky, 1981). Semiotics were also understood as psychological tools and included language, signs, symbols, numbers etc, as products of sociocultural mediation. Culture was thus human social activity

understood in terms of signs (Lantolf, 2004). Vygotsky (1981) claimed that intellect was predominantly shaped through the semiotics of language. Through interacting dialogically, on an intermental plane, children could both construct shared meaning and appropriate tools such as language as part of their mental capacity (Mercer and Littleton, 2007). Therefore, mental functioning within an individual could only be understood through examining the cultural and social processes from which they were derived (Wertsch and Tulviste,1992). The development of intellectual capacity was believed to follow participation on an intermental plane. This occurred through reflection, reasoning and argument on an intramental plane. Knowledge construction so took place in two related dimensions. Firstly, 'outside of the skin' (Wertsch and Tulviste, 1992) primarily through language, and then as a mental thought process within the cognitive domain.

Vygotsky (1978) claimed that on an intermental plane, adults or peers as More Knowledgeable Others (MKO) could support knowledge construction within a Zone of Proximal Development (ZPD). This zone is defined as the distance between a child's

> *"actual developmental level as determined by independent problem solving" and the higher level of "potential development as determined through problem solving under adult guidance or in collaboration with more capable peers"*
>
> (Vygotsky, 1978, p. 86).

Within this space, humans as More Knowledgeable Others act as another psychological tool, mediating meaning making and consequently supporting the development of intellect through dialogue. Teachers in (early childhood) education institutions are thus positioned to hold key roles in both measuring children's potential development (informed by use of formative and summative assessment) and mediating their cognitive progress. Rather than using elicitation, as in Piagetian constructivism, to gain insight into current structures of knowledge, or materials to promote a rich environment for concept development, the teacher, child and peers use dialogue to co-construct knowledge. Defined as dialectical constructivism, knowledge is made through a highly interactive process which involves sharing, comparing and debating between learners (Applefield *et al.*, 2000).

It is of significance to this study that although knowledge construction is not solely viewed as residing within the mind, it is believed necessary that an individual make sense of and overcome differences between others' perspectives, and between the inter and intramental plane through logical, internal reasoning. This is an important issue as difference from this sociocultural perspective is to be overcome or synthesised internally in order for knowledge to be gained (Wegerif, 2008). This stance is argued as modernist thinking by Wegerif (2008) as ultimately knowledge is still perceived to be acquired within the cognitive domain. The shift from a perspective viewing cognition and knowledge making as properties within the individual to a perception of knowledge construction as mediated on an intermental plane, 'outside of the skin', is also significant. However, although Vygotsky claimed that the mind emerges following joint external activity, his positioning of knowledge making remains human centric. Meaning making is a process enacted between people. This study argues knowing as a distributed practice which includes material arrangements (Barad, 2007, p. 379). Situated within a new materialist and thus posthuman framework, its ethico-onto-epistemic position recognises the potential for new knowledge to emerge from difference (Barad, 2007). It is thus something to be embraced, not overcome; as within a Vygotskian dialectal position. By privileging language as the primary means through which knowledge is constructed, the role of materials appears more diminished than within Piaget's genetic constructivism.

According to Wertsch and Tulviste (1992), Vygotsky's theorising on cultural mediators included materials, in the form of technical tools. Technical tools mediated the physical environment (Shepardson and Britsch, 2015). For instance, science equipment such as a measuring cylinder is understood to contribute to a teacher and child's processes of meaning making in that it provides some level of control over phenomena, such as water in a tank, and access to it from different perspectives, known as de-centring. The experience of pouring water from a measuring cylinder is thus different to allowing water to run through your fingers (Shepardson, 1999). Kozulin *et al*. (2001) explains that for Vygotsky (1978), technical tools did not exist as individual implements, rather they presupposed collective use and interpersonal communication. This is illustrated through the invention and use of tools such as wood sticks which have evolved in form and function as a result of generations of

cultural development and adaptation. Consequently, they are claimed to have transformed human thinking and contributed to differing outcomes for individuals, depending on their context.

Vygotsky perceived objects used in children's play to hold a role in supporting the development of mental representations. Though these only occurred when the meaning of objects was separated from their physical form (Bodrova and Leong, 2015). For example, in young children's play they may use replicas of objects as symbolic representations (Gajdamaschko, 2005). That is, children may use a toy hobby horse as a representation of a real horse in their early stages of play. Later, objects such as a stick may be used as a replica for a horse. Then, a child may simply enact riding a horse. In this form of play most substitution takes place through speech or gestures with no physical objects present. Vygotsky (1978) believed that learning to operate without real objects but with symbolic representations, contributed to the development of abstract thinking and imagination on an intramental plane. Thus, it was through action that meaning was made (Gajdamaschko, 2005).

It is of note that materials were perceived as 'tools', that humans had invented to master nature (Vygotsky, 1978). This dialectal perspective also perceives materials as passive and inert. They support the advancement of culture and transform thinking but from a perspective which privileges humans. As with the Piagetian perspective of human senses as meaning makers rather than the object itself, materials only support the end goal of concept formation and abstract thinking.

Socio-cultural, dialectal mediation whereby adults or peers play an active role in knowledge construction to mediate internal cognitive development is an entrenched perspective on development and learning within early childhood education (for an illustrative sample of the numerous articles and books see, Anning *et al.*, 2004; Brennan, 2016; Edwards, 2005; 2009; Hedges and Cullen, 2012; McLean, 2020; Smith, 1993). It sits in uncomfortable competition not only with child-centred ideology viewing the adult as passive and aside of children's autonomous discovery, but also in tension with the Piagetian agentic child who constructs knowledge internally. Whilst a posthuman, new material stance concurs that knowledge (making) occurs

both within and outside ‘of the skin’, it does not perceive humans as dominant in such practices, nor cognitive beings as separate from the environment. Cognitive, intellectual progress is not recognised as the ultimate destination for knowledge making. Rather, it is argued, we come to know through making particular *things* matter from within entangled material engagements *within* the universe, to which we are related (Barad, 2007, p.379).

Contemporary ECEC, as informed by developmental psychology, is underpinned by tensions between child-centred and constructivist *and* constructivist and socio-cultural epistemologies. Debates within the field which examine ‘best practice’ for supporting children’s learning and development can veer between constructivist versus child-centred approaches, or socio-cultural versus constructivist theories. They are repetitive in their heralding and criticism of key Piagetian and Vygotskian theories and subsequently give rise to questions about early childhood pedagogy and practice. These tend to focus on those such as: should an early childhood practitioner intervene or stand back from a child’s creative scientific enquiry? (constructivist v child-centred); should a practitioner talk or not talk to support a child’s scientific understanding? (Piaget v Vygotsky and/or constructivist v child-centred); or should they facilitate the environment to ensure expected developmental progress or promote free play? (child-initiated v child-led and/or dev psych v child-centred). Despite what seems age-long disquiet and questioning amongst early childhood practitioners, there is no reconciliation to be made between the positions. Differences between the respective epistemologies are profound and debates go round and round in circles never quite coming to a resolution. This study challenges such conflicting and dominant discourses as limiting. It aims to look beyond this debate by exploring the potential for alternative conceptualisations of young children’s creativity in science enquiry. Through a diffractive methodology, it seeks a reconfiguration of dominant ways of seeing knowledge making practices within science education by foregrounding materiality.

Early Childhood Science Education

This section of the review examines more closely the tensions between constructivist, socio-cultural (cultural-historical) and child-centred epistemologies, as

they manifest in pedagogy and practice within the context of early childhood science education. Specifically, there is a focus on potential pedagogical dilemmas such as: whether practitioners should talk or not talk; children should learn 'scientific ideas' or explore their own thinking; and the role of materials within the environment, to support a child's scientific understanding.

Although there are a small number of recent texts on early childhood science education (see for instance, Davies *et al.*, 2019; Tunnicliffe, 2015; Russell and McGuigan, 2016), there has been debate about a limited pool of literature for early childhood practitioners (see for example, Christidou and Hatzinikita, 2006; Cumming, 2003). Fleer and March (2009) suggest that a traditional developmental view of teaching and learning in early childhood may be a cause, as this has tended to ignore the value of science for young learners. Arguments for a focus on science education in children's early years of education are strong and well established. Academics claim that young children are 'natural' scientists and should thus engage in science as early as possible (see for example, Duschl *et al.*, 2007; French, 2004; Harlen, 2014; Metz, 2009; Pendergast, Lieberman-Betz and Vail, 2015). Gopnik (2009) and Areljung and Kelly-Ware (2016) expound the point, stating that young children are intuitive scientists who observe, ask questions, investigate and theorise to form an understanding of the world. The field of neuroscience has also been used to add gravitas to arguments for early science education. For instance, Kallery (2015) suggests birth to nine years as a sensitive period and states that the 'window of opportunity' for science closes early. Such claims are not without controversy and, as such, have provoked a number of debates within the field. Particularly, that they hark back to traditional developmental psychology which positions children as deficient (Vandenbroeck, 2017).

Given the dominant influence of the constructivists on (early childhood) education, it is not surprising that Fleer and March (2009) claim much of the early science education literature to be framed through these perspectives. They state that researchers have concentrated largely on children's conceptual development, metacognition, the teaching of appropriate content, and the importance of the informal learning context. In their seminal paper, Driver *et al.* (1994) suggest that science education has long been underpinned by the constructivist traditions.

Specifically, those which claim that scientific knowledge is gained through individual (personal) and social processes. Indeed, across the literature, the range of constructivist accounts demonstrate the continued dominance of the theories in contemporary early science education. This is despite recent aforementioned alternative perspectives which contest the authority of such positions within early childhood education. The Piagetian (personal) perspective, whereby learning in science is viewed as a developmentally appropriate pursuit in which children construct scientific knowledge and build theories through interaction with the world, is evident throughout the literature (see for instance, Chaille and Britain, 2003; Kubli, 1979; Kallery, 2015). A Vygotskian, socio-cultural position, particularly that which recognises scientific knowledge as built through co-construction and discursive practices is manifest in a number of texts (see for example, Areljung and Kelly-Ware, 2016; Turner and Williams, 2020; Vartiainen and Kumpulainen, 2020). Additionally, cultural-historical perspectives which advocate science as a community and culture with a body of knowledge into which young people are apprenticed are also evident, though they are primarily authored by Fleer (see Fleer and March, 2009; Fleer and Pramling, 2015; Hao and Fleer, 2016). A number of science 'text' books for early childhood practitioners also draw on these perspectives (see, for instance, Brunton and Thornton, 2010; Davies *et al.*, 2019; Devereux, 2007, Seefeldt *et al.*, 2010; Tunnicliffe, 2020).

Driver *et al.* (1994, p.5) state that that there is no simple 'single nature of science' and as a result of multiple constructivist influences, there is a need for clarification on the relationship between the positions and consideration to be given to the implications for pedagogy. This search for clarification appears unresolved, as argued in the previous section on early childhood education. Building on this, I argue below that irreconcilable constructivist positions create ever muddy waters through which practitioners must negotiate pedagogy and practice within early childhood science education. This is presented as a thematic examination of pedagogical dilemmas which emerge from tensions between constructivist positions, set within established child-centred ideals. Significantly, I claim that such pedagogical dilemmas potentially position early childhood practitioners as lacking in their practice, and that they distract from a focus on the role materials might play in children's creative scientific enquiries - beyond constructivism.

The learning environment and the role of materials

A Piagetian position appears foundational within early childhood science education: 'hands on, minds on' investigation within the environment is highly valued and considered to mirror the strategies used by scientists seeking to understand the natural and man-made world (Harlen, 2014). Early childhood practitioners are encouraged to translate Piagetian theory pedagogically through careful planning of learning environments designed to build on prior learning and create cognitive dissonance (Driver *et al.*, 1994). For instance, Hedges and Cullen (2012) and Peters and Davis (2011), draw attention to how early years practitioners respond, extend and complicate, as well as disrupt and provide spaces of uncertainty for children. This may occur through, for instance, encouraging observation of open-ended materials in differing environments, categorising objects in different ways and subsequently collecting evidence (Tunnicliffe, 2017).

Competing with such an approach, is the socio-cultural perspective in which the objects of science are not the 'phenomena of nature but constructs that are advanced by the scientific community to interpret nature' (Driver *et al.*, 1994, p.5). Pedagogically, this perspective is enacted through the establishment of a learning community and sense of belonging to a space (Fleer and March, 2009). Stavroula *et al.* (2015) explain that such communities should emphasise investigation and problem-solving, with practitioners modelling to help children construct nuanced understandings of the world around them. Drawing on cultural-historical perspectives, Fleer and March (2009) suggest that imitation is used as a cultural tool through which difference (for instance, not being able to do something that an adult can) can be overcome. Also, within this frame, Hall and Schaverien (2001), claim that early childhood science should look beyond the school context to family environments. As such, it should be rooted in real-world and everyday life (Fleer and March, 2009; Larsson, 2013). Children are, from this position, not expected to know science concepts but to understand science as something important and meaningful within society. This requires early childhood practitioners to plan for the use of everyday objects which enable children to 'begin looking at materials in new ways' (Fleer and March, 2009, p.39). For instance, rather than using materials to support concept formation, books and real objects are encouraged for problem-solving in real

world contexts. Fleer and March (2009) further suggest that construction kits such as Lego, a computer, and a science table with items from nature, as meaningful ways to support children's enquiries in science.

Such a mix of pedagogical approaches presents a dilemma for early childhood practitioners who are commonly aware of importance placed on ensuring that, for instance, they do not over plan or present preconceived opportunities for learning (Ephgrave, 2018). Instead, they might typically 'plan in the moment' and facilitate multiple pathways to learning, using open-ended natural or synthetic materials such as 'loose parts' (Daly and Beloglovsky, 2014), as advocated in child-centred pedagogy. Although there are commonalities between the constructivist pedagogical approaches, such as in the playful exploration of materials and access to rich learning environments during enquiries, such a competing mix of pedagogical choice is challenging to navigate within the environment. A key conflict in approach appears between the adult making room for playful exploration with objects or adopting a modelling role to promote knowledge through human relationships, not objects.

To talk or not to talk

Adding further complication to pedagogical choice is the socio-cultural perspective which has informed understanding that science is a discursive practice. As such, talk features centrally as a vehicle for learning. Pedagogically, Siraj-Blatchford (2001) and Johnston (2008, 2014) suggest that talk for scientific understanding needs to occur in 'concrete' sustained social experiences and shared investigation (Johnston, 2008, p. 26). Tunnicliffe (2020) adds that, within such contexts, teachers should encourage talking and naming objects and organisms, promote the development of explanations and questions, and expand new vocabulary as it is heard. This position is manifest in a multitude of literature and research (see for instance, Alexander, 2008; Frejd, 2019; Harlen, 2013; Mercer, 2000; 2019). Talk in the form of dialogue, discussion and argument is advocated as an effective pedagogical strategy for co-construction of meaning (Harlen, 2014; Alexander, 2008; Eccles and Taylor, 2011). Scaffolding by a teacher or peers, whereby support is offered through cultural mediation (Campbell-Barr *et al.*, 2018), is encouraged as a means to facilitate such discourse (Bruner, 1986; Hackling and Barratt-Pugh, 2012). For example, Havu-Nuutinen (2005), cited in Kallery (2015), reported that social discussion during

experimental explorations helped children develop more scientifically complete theories of flotation and contributed to changes at a cognitive level. From a cultural-historical perspective, Fleer (2010) introduces contextual intersubjectivity in her discussion of the mediating role of teachers. This translates as spaces of interaction with children in order to enhance conceptual learning. It is enacted within a science context by providing children with the opportunity to reflect and present their own emerging ideas about phenomena without any correct explanations from the teacher. However, directed questions are encouraged, to contribute to children's ideas. Engagement in such practices is claimed as socialisation into a scientific community of knowledge; a process described as a cultural apprenticeship (Rogoff, 1990).

This is at odds with the Piagetian view in which practitioners provide opportunities for children to engage with materials, that they might build understanding of phenomena for themselves. Rather than dialogue and debate to co-construct meaning, social interaction between children and early childhood practitioners, from a Piagetian perspective, involves elicitation in the form of open-ended questioning to promote thinking and reflection at an individual level (Tunnicliffe, 2015). Peers primarily support exposure to conflicting perspectives, as opposed to ensuring immersion within a scientific community. Even further removed from a socio-cultural version of dialogic interaction, child centred practices advocate for early childhood practitioners to take a holistic approach and, at times, stand back from children's enquiries in order that they develop at their own pace (Thulin and Jonsson, 2014).

Faced with such positions, practitioners may encourage children to explore materials freely but then feel conflicted if required to elicit existing knowledge to plan for further sequences of learning. Not scaffolding through dialogic interaction could result in instrumental concerns such as children not making adequate 'progress' in learning, as measured against the early learning goals of the EYFS (DfE, 2017). Within early childhood science, such dilemmas culminate in practitioners' questioning whether to 'stand back or intervene' in children's enquiries. This is an issue which practitioners expend much energy trying to resolve and accommodate but find difficult to overcome (Cherrington, 2016; Fisher, 2016).

Although engagement with materials is espoused as foundational to learning in science, it is possible their positioning in relation to knowledge making is overlooked as practitioners grapple with which pedagogical choice may be best suited for encounters with children. Indeed, a defined role for materials within Piagetian and Vygotskian constructivism frames is at best contradictory. Drawing on Baradian perspectives and research in early childhood education exploring the child-material relationship, this study recognises materials as living intra-active matter. In doing so, there is a search for insight and different perspectives on the potential materials hold in contributing to young children's creative scientific knowledge making practices.

Should children develop their own ideas or should they be enculturated to established scientific ideas?

From a socio-cultural position, Driver *et al.* (1994) state that established and 'taken for granted' truths within the science community have been constructed as a symbolic world. As such a particular language is attached to particular concepts (for example, atom, gene) and learning in science involves being initiated into scientific ways of knowing. This is argued as best enacted through meaningful experiences (Watts *et al.* 2016). Cultural-historical perspectives echo this position. For instance, in Fleer's (2010) discussion of 'conceptual intersubjectivity', she suggests that teachers should focus on concepts that they would like children to develop with them and then ensure that these are connected to real, playful contexts, which take account of children's interests and motives. Therefore, early childhood practitioners adopt a mediating role so that children can make personal sense of scientific ideas and practices. In doing so, practitioners are encouraged to focus on facilitating children's move from 'common sense' discourses to scientific ones. This is illustrated in Tunnicliffe's (2017) study in which she comments that unless highlighted by a facilitator, children's direct observations of Earth science can remain part of the background of 'place'. Additionally, Kallery (2015) claims that a teacher's role is to redirect children's attention from object to material property, to support developing understanding of concepts around floating and sinking. This is a very different stance to a Piagetian, empiricist perspective on knowledge making whereby children make sense of the physical world through content-independent, logical structures.

The socio-cultural/cultural historical perspective generates a compelling argument for early childhood practitioners to hold secure understanding of science specific language, or risk ineffective enculturation for children and subsequently low scientific literacy. Indeed, through a socio-cultural lens, practitioners have been accused of not adequately supporting children's development. For instance, where talk has been perceived as impoverished or lacking, links have been made to insufficient adult intervention through scaffolding (see for instance, Johnston, 2009; Siraj-Blatchford *et al.*, 2002) or to a lack of subject specific knowledge (Andersson and Gulberg, 2012; Hedges and Cullen, 2005; Pendergast, Lieberman-Betz and Vail, 2015; Worth, 2010). This is then inevitably associated with young children being undereducated due to low levels of cognitive demand being placed on them (David, 1990 cited in Kallery, 2015, p. 50).

Driver *et al.* (1994) attempt to reconcile the differing constructivist positions by suggesting what appears as a two-tier system for learning science. That is, firstly children need to be secure in personal ideas (Piagetian) about learning science, and then be introduced to the scientific community so that they might be socialised into established discourse and the ways of practicing science (Vygotskian). She also claims that these two positions can be applied in different domains of science, as they require different kinds of learning. However, the authors do not acknowledge that the relationship between views of learning and pedagogy is problematic and that no simple principles for pedagogical practice emerge from a constructivist view of learning. Given the range of pedagogical dilemmas illustrated above, there is potential that practitioners' practice is tentative and without pedagogical cohesion.

What is particularly consequential in the literature taking a constructivist stance on early childhood science is that it is largely underpinned by an interpretivist approach to research. The interpretivist paradigm sits well with constructivism, given that it is underpinned by a relativist ontology and a subjectivist epistemology whereby knowledge is grounded in particular lived experiences (Levers, 2013) and is 'guided by the researcher's set of beliefs and feelings about the world and how it should be studied' (Denzin and Lincoln, 2005, p. 22). However, its dominance in these studies results in understanding of knowledge making practices within early childhood science education being further compounded by a narrow frame of reference. One

which is underpinned by anthropocentrism. This study claims that an interpretivist/constructivist approach to research yields little insight into early childhood science education. First through analysis of the findings from empirical data collected in an interpretivist study and later through '(re)turning' (Frigerio *et al.*, 2018) empirical data in a diffractive analysis.

This first part of the review has explored the emergence of new materialism in the context of early childhood (science) education, amidst the dominance of developmental psychology, constructivism and the interpretivist paradigm. Additionally, it has established that child-centred practices and the differing epistemologies of constructivism, conflict and appear irreconcilable, resulting in challenging pedagogical dilemmas for early childhood practitioners. Notably, attention was drawn to the neglect for consideration of materiality in young children's scientific endeavours.

In the next section, the focus moves beyond the constrictions of developmental psychology and constructivism in pursuit of perspectives on materiality. In doing so, research question one is examined:

- What representations of creativity exist within and beyond the field of (early childhood science) education?

Creativity

This part of the review begins with an examination of the literature on creativity within the domain of education. Following this, creativity as conceptualised within early childhood science education is explored. Finally, with materiality in mind, concepts of creativity beyond those in education are considered. The domain of the arts is the focus of this section of the review. Artists have long experimented with materials and thus place value on their interactions with them. Indeed, many have cited creativity as a relationship which exists between the maker and the material (see for instance, Malafouris *et al.*, 2014). Recently, as within early childhood education, the arts have engaged with new materialism (see for example, Barrett and Bolt, 2013; Robertson and Roy, 2017). This is particularly significant to this study which actively seeks to

examine the position of materiality within children's creative scientific enquiries. As such, the influence of new materialism in art is explored at the end of this section.

Creativity in education

Numerous explorations have been made into the origins of creativity within education. Of note is Megalakaki *et al.*'s (2012) discussion of historical perspectives which identifies the discipline of psychology (and its ontological and epistemological roots within positivism and interpretivism) as a significant authority. This parallels earlier discussion by Craft (2001a) who describes four major traditions within this area: psychoanalytic; cognitive; behaviourist; and humanist, all with different conceptions of creativity including: personality; cognitive; psychometric; psychodynamic. Extending these concepts, Megalakaki *et al.* (2012) identify nine distinct approaches which draw on Sternberg (2003). These include mystical, pragmatic, social-personality, evolutionary and confluence as well as humanistic, psychodynamic, psychometric and cognitive. Other historical efforts to categorise conceptualisations of creativity in education include a review of literature commissioned by Creative Partnerships (Banaji *et al.*, 2010) which, along with other studies (see for instance, Duffy, 2006; Hayes, 2004; Kampylis *et al.*, 2009), recognise that both the terms 'creative' and 'creativity' are widely and casually used in everyday life with a broad range of meanings and assumptions. Responding to this finding, Banaji *et al.* (2010) identify nine 'rhetorics' of creativity: creative genius; democratic and political creativity; ubiquitous creativity; creativity as a social good; creativity as economic imperative; play and creativity; creativity and cognition; the creative affordances of technology; and the creative classroom. The authors also identify limitations in these terms, acknowledging that other rhetorics such as divine creation have not been considered. Although such a diversity of categories touches only the surface of historical perspectives on creativity in education, they indicate that there have been a multitude of interpretations. It is not surprising then that creativity has been described as a nebulous concept (Davies *et al.*, 2014; Kampylis *et al.*, 2009; Sawyer, 2006; Sefton-Green *et al*., 2000), informed by a myriad of definitions (Bolden *et al.*, 2010). Notably, they almost entirely stem from an anthropocentric frame.

For example, within these broad concepts creativity within education has been described as the ability to produce original and unexpected work which is useful and adaptive (Sternberg and Lupart, 1999 cited in Megalakaki *et al.*, 2012, p.1038); 'self-actualisation' or the ability to be 'lost in the present' (Nakamura and Csikszentmihalyi, 2002; Maslow, 1987); a cyclical process (see for instance, Cropley and Cropley, 2008), divinely inspired; coming from within the self as part of both conscious and subconscious action (Craft, 2002); a measurable cognitive test linked to divergent or lateral thinking (Megalakaki *et al.*, 2012); and linked with personal, socio-cultural and motivational factors (Vass *et al.*, 2008), to cite but a few. Although wide ranging, varied and informed by different paradigmatic positions, Bolden *et al.* (2010) and Runco and Jaeger (2012) suggest that a dominant theme running throughout the definitions is that creativity is a personal activity intended to produce something new.

Of interest to this study, which focuses on creativity in science enquiry in the context of early childhood settings, are democratic, collaborative and social conceptualisations of creativity within education. Democratic perspectives on creativity are well versed within early childhood education (see for instance, Beghetto and Plucker, 2006; Bruce, 2011; Craft, 2002; 2008; Duffy, 2006; Rinaldi, 2006). They speak to human rights agendas, such as egalitarianism and fit very well with child-centred ideals. Whereas collaborative and social positions place dialogue centrally, aligning with sociocultural influences. The influential report All Our Futures: Creativity, Culture and Education (NACCCE, 1999) drew attention to the democratic view of creativity which had emerged towards the end of the 20th Century and reiterated a message which claimed learning as a creative endeavour accessible to all. This perspective is particularly embedded within early childhood education through Craft's (2001b) concept of 'little c' creativity which she claims involves route-finding and making choices in everyday life using imagination, innovation and conscious action. Little 'c' thus presents creativity as a 'life-wide' and vital skill that everyone has the capacity to develop, across all domains of learning. Associated with this is Craft's (2000, 2002) concept 'possibility thinking' which she describes as imaginative thinking around a problem, characterised by questions such as 'what if' and 'as if', posed by practitioners within playful and narrative contexts (Craft *et al.*, 2012). The focus on questioning from multiple perspectives interconnects with the

extensive literature referring to how teachers and children, and peers interact (Chappell *et al.*, 2008). Such literature includes recognition that creativity emerges from dialogic encounters (see for example, Magalakaki *et al.*, 2012; Miell and Littleton, 2008; Sawyer, 2017; Vass *et al.*, 2008). This resonates with Wegerif's (2014) theorising of 'dialogic space' whereby the potential to create new insight is enhanced through multiple, differing perspectives held and expanded in spaces 'in-between' dialogues. Of significance is that, although a human centric frame on creativity is maintained with language and thinking as vehicles of meaning making, there is a shift in understanding creativity as existing in spaces 'in-between'.

Despite such shifts, the anthropocentric framing of creativity in education remains embedded within dominant neo-liberal and global discourses; as illustrated in the announcement of a PISA test focused on young people's creative thinking from 2021 (OECD, 2020), and the OECD's (2018) declaration that creativity and creative thinking are key skills for 2030's learners. Neo-liberal discourses on creativity are not without contention and there is ample literature which draws on moral and ethical perspectives to contest an association between economic development and creativity (see for instance, Chappell and Craft, 2011; Craft, 2005; Howard-Jones *et al.*, 2008). Banaji *et al.*, (2010) draw attention to the rationale within the NACCCE report (NACCCE, 1999) which firmly positioned creativity in the global economy and in the development of a flexible workforce. Such a position has been heavily criticised as reducing (early childhood) education and care to a market with consumers, competition and a high focus on individuals, rather than to a collective (see for example, Kalin, 2018; Harris and Ammermann, 2016). These concerns are echoed in research exploring perceptions of creativity (see for example, Craft *et al.*, 2008; Jeffrey, 2003, Chappell *et al.*, 2016) where it has been argued that without a collective perspective, such as those respected in Eastern societies, the value of creativity in education is questionable. Illustrating the point, Banaji *et al.* (2010) state that ideas of collective creativity and inclusivity often have an emphasis on process over outcome which can then be translated into the classroom as value for group work and the importance of children taking pride in their work regardless of outcomes. The view is, to some extent, reiterated by Craft *et al.* (2008) and Chappell *et al.* (2016) who, in their discussion of a relationship between creativity and wisdom (deemed wise, humanising creativity), place value on process but also argue for an

examination of the impact of the outcomes of creative endeavours. Taking account of this, the recent CREATIONS project identifies eight features of creativity in education to guide 'teaching for creativity. These include dialogue, empowerment and agency, interdisciplinary, possibility, risk, immersion and play, balance and navigation, ethics and trusteeship, and individual, collaborative and community activities for change (Hetherington *et al.*, 2019). Creativity as both a social phenomenon and an ethical issue is explored in studies such as Rojas-Drummond *et al.* (2008) who examine an interplay between individual and communal creativity which both recognises and accepts difference, and embraces notions of interdependence and relationship. This openness to difference and acknowledgement of the relationship between two potentially opposing positions is of consequence to this study in which difference is understood as critical to understanding creative knowledge making practices. Also of significance is Chappell's (2018) discussion of the evolution of her positioning of creativity in her research within education and the arts. Drawing on her early work, she identifies creativity as an embodied dialogue rooted in spaces of interaction from which new possibilities can emerge. As an embodied dialogue, she claims that it allows for different views to interrelate from inside and outside the body and provide transformative potential for new world views. Chappell's (2018) positioning of the self as relational in creative endeavour is also important to later diffractive analysis in the research design chapter.

A relationship between materials and creativity is rarely touched on in the education literature. Indeed, in their recent review of creative pedagogies, Cremin and Chappell (2019) identify seven characteristics of creative pedagogies as: generating and exploring ideas; encouraging autonomy and agency; playfulness; problem-solving; risk-taking; co-constructing; and collaborating and teacher creativity. Although a number of studies recognise open environments with time to explore resources as a stimulus for the generation of ideas (see for instance, Craft *et al.*, 2012; Cheung, 2012), these are framed through common child-centred or constructivist/sociocultural positions. However, scholars (Chappell, 2018; Roussell *et al.*, 2018) do draw on new materialism within the context of creativity and art education to consider 'other-than-human-actants' such as objects and environments as sources of creative action - points which are developed below in the section on creativity in art.

Creativity in (early childhood) science education

Despite debates within the literature concerning a dominant association between creativity and 'the arts' (see, for instance, Banaji *et al.*, 2010; Cropley, 2014; Claxton, 2006, Moyles and Worthington, 2011, Newton, 2012; Runco, 2007), science has long been identified as a creative practice (see for instance, Davies, 2011; Hetherington *et al.*, 2019; McComas, 1998; Osborne *et al.*, 2003; Simonton, 2004). Indeed, according to Glăveanu (2017), science-based creativity has been shaped by the Enlightenment, thus it has been defined in terms of value and utility, often expressed as problem solving and associated with analytical, rational thinking. As within the domain of education, neo-liberal discourses have absorbed this position and creativity in science education has been subsequently argued as a necessary thinking skill for the 21st century (see, Havu-Nuutinen *et al.*, 2017). This is a perspective manifest in policy frameworks such as the Early Years Foundation Stage (EYFS) (DfE, 2017) where creativity is recognised as synonymous with critical thinking. It is also acknowledged in projects such as the EU funded Creative Little Scientists (CLS, 2014) and those led by Oxford Brookes University (see, for example, McGregor *et al.*, 2017 and Hanley *et al.*, 2015) which identify the knowledge economy as drivers for interest in creativity and science education. Although there are assertions that regulatory frameworks such as the EYFS prioritise 'school-readiness' over developing creativity (Cohu *et al.*, 2019); arguments which accuse education discourse of reducing creativity to rhetoric (see for example, Hadzigeorgiou *et al.*, 2012); and conceptualisations of creativity which indicate that it is the result of a complex interplay of several factors, including, intellectual, domain specific knowledge, personality traits, motivation and *environment* (Sternberg, 2006), creativity within (early) science education remains shaped almost exclusively through humanist and instrumentalist epistemological perspectives (Havu-Nuutinen *et al.*, 2017). This results in a perception of creativity as solely an intellectual pursuit, highly dependent on the cognitive domain.

It is notable that, whilst research on early childhood science education has seen a small shift to new materialist understandings of child-material relationships, associations between creativity and materiality in early science education appear to be almost absent. Instead, dominant constructivist and sociocultural perspectives are

more evident in recent research on creativity in early childhood and early science education. For instance, the recent Durham Commission (Cohu *et al.*, 2019, p. 47) on creativity in education makes only a cursory mention that creativity in early childhood involves experience of new sensations and materials; stating that careful attention should be paid 'to the physical, sonic and tactile environment and the resources that scaffold creative thinking and learning'. This Piagetian/Vygotskian perspective is manifest in the extensive literature reviews on creativity carried out by the Creative Little Scientists project (CLS, 2012). For example, creativity in early childhood education is claimed to have origins in constructivist/sociocultural perspectives in that physical and hands-on opportunities to access materials and build physical, social and mental connections to ideas are promoted (CLS, 2012). Following reviews of literature and research of practice, the Creative Little Scientists project identified pedagogical synergies between creativity and inquiry-based science education. These were subsequently conceptualised within a framework as a dynamic interplay of play and exploration; motivation and affect; dialogue and collaboration; problem solving and agency; questioning and curiosity; reflection and reasoning; and teacher scaffolding and involvement (see, Cremin *et al.*, 2015). Here constructivist and sociocultural influences are plentiful. For instance, dialogue and collaboration are espoused as critical in supporting children to develop thinking, consolidate ideas and reason in both science and creativity. Whilst play and exploration involving hands-on experiences are claimed to encourage children to make connections to science and their surroundings, and open-ended environments to promote creative endeavour. Such conceptualisations of creativity in science enquiry bind understanding of young children's knowledge making practices to epistemologies which are human centric and dualist by nature. Effectively, creativity in science education produces 'more of the same' understanding about children's knowledge making practices, paralleling what is already known and dominant within the field. When categorised in frameworks which are underpinned by routinised theories such as constructivism, there is a risk that pedagogical approaches recommended for creativity are underpinned by the same paradoxical epistemologies which create tension and dilemmas in practice within early childhood science education. This study looks beyond common conceptualisations of children's creativity in science enquiry to consider the materiality of children's creative knowledge practices. To do this, I draw on Barad's (2007) claim that the details of

one discipline can be read attentively and with care through another, in order to illuminate differences that enable the potentiality of new knowledge.

Creativity in art

Chappell *et al.* (2019) illustrate a relationship between the arts and sciences as transdisciplinary through the CREATIONS project which aimed to engage teachers and students in scientific research through creative approaches that are based in art (see, Chappell *et al.*, 2017). In this study, looking to the arts offers the possibility to explore conceptualisations of creativity which may support insight into the materiality of children's creative knowledge making practices in science enquiry; an area which has received little attention.

Considering the arts broadly, Glăveanu (2018) argues that the way creativity is understood is heavily influenced by Romanticism. As a result, Glăveanu claims, spontaneity, originality, novelty and divergent thinking are foregrounded. However, acknowledging the myriad of genres within the arts, such a wide-ranging conceptualisation does not take account of the subtle differences and nuances in artists' creative process. For instance, visual artists may perform similar actions such as painting, drawing, printing, sculpting but have variations in approach. Indeed, informed by activity theory and sociocultural perspectives, Botella *et al.*'s, (2011) interviews with artists yielded insights into multi variants in the creative process. These included cognitive, conative, emotional, environmental and situated components. As such, the creative process was defined by a series of thoughts and actions. Within this frame, creative processes also took account of an 'in-between space' which included creator and environment and creator and society. The identification of an in-between space is of interest to this study. Particularly the assumption that a creative process might include spaces between creator and environment as opposed to solely spaces between dialogues, as articulated with the domain of education. Considering creative 'spaces' in such a way moves beyond Wegerif's (2014) theorising of dialogic space to include material as implicated in meaning making. Hetherington and Wegerif (2018, p.39) describe this in their conceptualisation of material-dialogic as 'an awareness of how matter enters into and...extends the dialogic space'; in alignment with the Baradian concept material-discursive. Together with Barad's (2007) concern for relational differences which are

created within material-discursive intra-acting entanglements, the notion of spaces between creative processes, creators and environment are of significance to the consideration for children's creative knowledge making practices within this study.

Looking at the arts, the field of cognitive science has explored embodied creativity with a focus on person-environment dynamics (Malinin, 2019). For example, in Glăveanu *et al.*'s (2013) extensive study of creativity across five domains, artists who readily engage with materials in their work are described by Glăveanu (2014, p. 64) as referring to how, 'after a certain point, the material that they engage with seems to take over and lead action to its completion'. Drawing on Bruner (1962), Glăveanu (2014) considers such perspectives as distributed agency. That is, an artist 'shares' agency with an object or material and it responds and changes to the intentions and goals of the creator. However, although there is acknowledgement of materiality, it is of note that, material and human are positioned as separate. Indeed, agency is 'shared' by a human with a perceived external object in the creative process. Other academics exploring materiality within this field, however, have claimed that agency 'is the emergent product of action, not its cause' (see, Malafouris, 2014, p. 154). Similarly, Ingold (2007) describes the materiality of objects as what makes things 'thingly'. He claims that objects partake in the processes of the world's ongoing generation and regeneration. Arguing that cultural theorists stifle and still the flux of materials in their presentation of the world as made of solid objects, he draws on Pels (1998, p. 94) to challenge the notion of agency as an animating principle understood as additional to the material object on which it has been bestowed. Rather, he claims, the power of agency lies with materials' materiality itself. For instance, stoniness is not constant. It is 'endlessly variable in relation to light, shade, wetness or dryness, and the position, posture or movement of an observer' (p.14). Stone emerges through its involvement with its surroundings. This positioning is closer to a Baradian (2007, p.141) perspective in which agency is not an attribute of something or someone, rather it is a material distributed enactment. However, although Ingold (2007, p. 12) argues that 'things are in life rather than life in things', taking us beyond the innate, static world of constructivism, a discourse which separates the mental and the material still resides.

Creativity involving engagement with materials as defined from a more relational position is considered by Malafouris *et al.* (2014) who claim that localising creativity to cognitive processes is limiting. The authors identify that the basic definition of creativity has seen little change and call for a review of the assumption that positions creativity solely 'inside the head'. In their special issue of Pragmatics and Cognition (2014), they bring together a number of perspectives to explore the material dimensions of creativity in terms of human cognition, brain mapping, and ecological, anthropological and embodied aspects of the creative process. Within the issue Ingold (2014, p.124), drawing on music, calligraphy and lace making, argues that creativity lies not in humans but rather in their 'attending to the world in formation'. That is creativity is becoming which is realised in the forming and making of things. Describing the creative process, Ingold goes on to claim that both the 'thing' and the idea of it emerge together from the performance of making. Similarly, Malafouris (2014, p.143) describes creative 'thinging' as a dialogue between maker and material. Using claywork as a context, he argues that the creative process is enacted in a hylonoetic space, whereby the mental and physical are inseparable; a position which resonates with that espoused by Botella *et al.* (2011). These conceptualisations in which creativity emerges through material and human within spaces defined as mentally and physically inseparable are far from those in the education domain. Rather than emphasising creative enactment within the cognitive domain through 'thinking skills', dialogue and manipulation of materials, they expand the exploration of materiality in young children's creative science enquiries through a frame which recognises materials and humans as inherently connected through intra-acting phenomena; as matter which emerges within the world in its 'differential becoming' (Barad, 2007).

Chappell (2018) argues that such conceptualisations of creativity in the arts, which identify embodiment and states of becoming, resonate with posthumanist perspectives; particularly Barad's (2007) notion of becoming. In her posthuman reading of creativity, Chappell draws from her CREATIONS project to describe how humans and materials can 'enmesh' in the creative process. That is, humans, environments and objects are both embodied and agentic, emerging through intra-actions. Within this posthuman space, creativity is a material process in which makers are making and being made. Artists working within new materialism pay

close attention to the materiality of their creative process. Laszlo (2018, p.31), writing about Jeanette Scharing's artwork, explains how Scharing describes her creative process as 'being caught in your tracks', the 'call of the thing', and experiencing being part of materiality. This is a position echoed across new materialist literature on the creative process within the domain of art. For instance, textile artists such as Britta Matakatt-Labba and Sheila Hicks articulate their creative engagement as material; a journey through the memory of materials, which explores how stories are told, modified and developed through different techniques such as knitting, weaving and embroidery. Other artists such as Lehmann (2017) and Garber (2019) examine the material transfer of human and non-human knowledge and experience as a process, and how materials partake in the meaning of art. In Penfold's (2019) discussion of children's creative learning processes within the context of art, she draws on Ingold (2011) to describe artists' experiments with materials as fostering new relations between materials, concepts, emotions and tools (see for instance, Flavin and Philipsz' works). Of note is Penfold's argument that creativity arises from multiple sources and timeframes which lead to dynamic relationships between people and materials over time. Drawing on Lenz Taguchi (2012) and Odegard (2012), Penfold attributes encounters with materials as possessing the ability to open divergent learning opportunities (though with the assumption that materials offer particular, pre-determined learning experiences. For instance, play with wooden blocks offers insight into balance and height).

Of particular interest are Chappell's (2018) articulation of humans and materials enmeshing in the creative process; Lehmann (2017) and Garber's (2019) consideration for the material transfer of human and nonhuman knowledge and experience; and Penfold's (2019) claim that materials offer divergent learning opportunities. Such theorising is returned to in the later diffractive reading of shared understandings of young children's creativity in science enquiry.

Thus far, literature related to this study has been reviewed across new materialism - with reference to Baradian philosophy - and the fields of early childhood and early science education. Conceptualisations of creativity have also been explored both within and beyond the context of education. Noted is the neglect for the role of materiality in relation to children's creative scientific enquiries. A dominant focus on a

small range of theoretical positions within early childhood science education were argued as a key factor contributing to this issue. A mix of epistemologies were claimed to create a number of pedagogic dilemmas for early childhood practitioners which potentially contribute to incoherence and confusion in practice. Creativity and creative processes were explored in search of insight into materiality in creative knowledge making practices. However, within the domain of education, creativity was found to be largely underpinned by the same dominant theories as early childhood science, leading to potential for similar tensions in pedagogy and practice. Although also influenced by developmental/cognitive psychology and socio-cultural theory, conceptualisations of creativity within the domain of art which acknowledged materiality were argued as insightful alternative perspectives. In particular, those which place emphasis on the inseparable relationship between human and material and the contribution of spaces in-between to the creative process. The material nature of creativity offers opportunities to read attentively conceptualisations from the discipline of art through those in early childhood science, and to move beyond dominant constructivist/socio-cultural debates.

Research with Early Childhood Practitioners

The final part of the literature review explores practitioners' knowledge making practices with particular reference to research question two and the early phase of the research design:

What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

Early childhood practitioners engaged with the research as an active participant with a desire to deepen understanding of science pedagogy and practice. As such, the review includes literature which focuses on the field of early childhood practitioner professional development as well as that relating to practitioner knowledge making practices. Specifically, communities of practice; dialogic talk and dialogic space; critical reflection and video technology are examined. Much of the literature within

this section informed the initial research design, data collection and early meaning making phase of analysis within the study, which was situated within an interpretivist paradigm. It was reviewed at the outset of the study and as such it reflects my early thinking. Such thinking is further discussed in the 'early meaning making' section of the research design chapter.

Professional development in early childhood education and care

Informing the initial research design were a number of approaches to teacher professional development which had been identified as successful models. In particular, several studies which discussed the conception of a school as a learning community, with opportunities for increased social capital through teachers' observations of one another and the co-construction of professional practice over time (for example, Crockett, 2002; Dana and Yendol-Silva, 2003; Snow-Gerono, 2005; Vescio *et al.*, 2008; Spelman and Rohlwing, 2013). Also influential and focused specifically on early childhood settings were Cherrington and Thorton's (2015) study which found enablers for professional learning communities to include a shared focus; commitment and research orientation; opportunities for dialogue, deprivatisation of practice and stimulus of new ideas; Brown and Rogers' (2015) exploration of knowledge creation as a way of developing evidence informed practice; and Horden's (2014) theoretical discussion of professional knowledge within early years communities. A number of studies which both implicitly and explicitly identify that a 'reflective' or 'critically reflective' approach leads to action and development in teaching and learning, were also explored (see for example, Cornfold, 2002; Creemers *et al.*, 2013; Golby and Viant, 2007; Mitchell and Cubey, 2003). Of particular relevance was Campbell *et al.*'s, (2004) collaborative model of reflection for professional practice, involving critical friends who support and challenge through asking questions, articulating each other's beliefs, listening and providing feedback. Though, Wiliam's (2014) argument that evidence does not support the idea that collaboration with other teachers will always be the best way for every teacher to improve their practice, was acknowledged. In designing an approach in which I was both participant and researcher, I noted the Sutton Trust's (2015) suggestion that schools could work more closely with 'knowledgeable others'

such as universities and education foundations which hold strengths in supporting evidence-based research and practice.

To support professional development through engagement in collective Video Stimulated Reflective Dialogues (VSRD) (Moyles *et al.*, 2003) and to respect ethical protocol, I intended that early childhood practitioners would collect video footage (see research design chapter). As such, Chou's (2011) discussion on the trend for action research in professional development was explored alongside Thorton (2009) and Mitchell (2003) who advocate action research in their small-scale studies of early childhood teacher networks. Also reviewed was research which found use of digital technologies which encourage 'standing back' and viewing practice from 'differing perspectives' to be fruitful in developing practice (see for example, Brantley Dias *et al.*, 2008; Fisher *et al.*, 2006). Though it was noted that studies within early childhood education indicate that practitioners' actual use of digital technologies is limited (for instance, Nuttall *et al.*, 2015).

Communities of practice

Wenger's (1998, p.6) conception of a community of practice, defined as 'groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly' and Senge's (1990) development of a 'learning organisation' as sites where new and expansive patterns of thinking are nurtured were used to describe the three 'case studies' for this research. Drawing on Lave and Wenger's (1991) Situated Learning theory, the early phase of the study was influenced by the assertion that within such communities of practice knowledge is distributed between persons and symbolic and physical environments. This position was also explored in Simons *et al.* (2003) who propose that professional communities of practitioners have capacity to co-create educational and pedagogical meanings, and Vescio *et al.* (2008, p.81) who assert that professional learning communities should be grounded in the generation of 'knowledge of practice'. As such, it was considered that knowledge needed to 'teach well' was generated when teachers treat their schools as sites for intentional investigation, and for interrogation and interpretation. Though, in the early phase of meaning making Wegerif's (2014) argument that knowledge can never really be situated as every situation is defined and located from a dialogue, was adopted. In line with this, Korthagan's (2010,

p.104) notion of ‘concientizacao’ was considered. That is, critical consciousness about reality which suggests that knowledge is developed through active dialogue within a community and thereby enables effective action. Also explored was Lipman’s (2003, p.95) suggestion that the higher order thinking skills ‘critical, creative and caring’ can be developed in a social situation where a community of learners has joined together to share perspectives and reach a deeper personal understanding. As the early phase of the study was particularly concerned with practitioner development of critical reflection within a community of practice, these theoretical perspectives directly informed the examination of the contribution that video reflective dialogue potentially made in encouraging practitioners’ to ‘see’ practice by standing back and reviewing a real-time event; generating multiple perspectives on practice; and creating new understandings through reflective and dialogic interaction. Limitations of the notion of a community of practice were acknowledged. For instance, as argued by Fuller *et al.* (2005), a community of practice can be interpreted as an ‘ideal type’ whereas in reality people are members of multiple communities of practice and these are located in complex socio-political contexts which may enable or constrain learning. In response to this I sought to maintain a critical and reflexive perspective, taking the nuances and complexities of the contexts into account throughout the data collection and early analysis phases of the study. However, this perspective radically shifted as I engaged with new materialist philosophy which challenges reflexivity as holding ‘the world at a distance’ and mirroring mirrored perceptions of reality (Barad, 2007, pp 87-88).

As a participant in the communities of practice, I considered variations around the concept of ‘group think’ (Janis,1982) and the potential for communities of practice to distance themselves from processes which establish knowledge validity (Winch *et al.*, 2015; Young and Muller, 2014). However, issues of knowledge ‘trustworthiness’ were in part addressed through each case's relationship to me as researcher and ‘critical friend’ with a defined position within the community (Lincoln and Guba, 1985). Additionally, in my role as researcher, I actively encouraged reflection on perspectives from research on creativity and science enquiry.

Dialogic talk and dialogic space

The role of talk and dialogic relationships within a community of practice were initially foregrounded in the study and developed as a framework for interpreting the ways in which practitioners engage with multiple perspectives to collectively construct meaning and new understandings. Littleton and Mercer's (2013, p.10) assertion that talk is a social mode of thinking and tool for constructing knowledge, creating ideas, sharing understanding and tackling problems collaboratively, was influential. Additionally, theorising on cumulative discourse which is characterised by repetitions, confirmations and elaborations (Mercer, 2008) and 'exploratory talk' involving reasoning, questioning in pursuit of joint goals, and constructively challenging ideas (Mercer, 2000), was identified as a starting point for critical reflection. Further review of talk included Mercer (2002, p.6), who builds on Vygotsky's (1978) Zone of Proximal Development to suggest that when thinking takes place as the result of exploratory dialogue and social activity, then individuals move into an 'Intermental Development Zone' where 'interthinking' takes place. As well as Littleton and Mercer's (2013, p.11) definition of interthinking as a means of using talk to pursue collective intellectual activity, whereby people can combine their intellectual resources to achieve more by collaboration than as an individual. Talk as both dialogues and dialogic was examined by tracing back to Bakhtin's understanding of the world as socially structured semantic orientations as opposed to an ordered system of monologic thought (Sullivan, 2012). With regards to dialogism, Wegerif (2007; 2008; 2014) was drawn on as a key point of reference. For example, Wegerif (2007) discusses dialogues as possessing two sides to them; one which is monological and another which is dialogic and assumes that dialogues are not determined by space or time and that there are always multiple voices at play within them. Thus, there is never any fixed meaning within a dialogue. Wegerif's (2014) theorising on dialogic space as existent between the multiple relationships of dialogues that are infinite and open to infinite potential for meaning was influential. Indeed, key to the early phase of the study was Wegerif's (2014) suggestion that when different perspectives are held together intentionally, then the likelihood of new creative insights which support seeing in new ways is increased, as multiple perspectives can aid people in questioning the narrow set of assumptions which frame ways of knowing. A dialogic approach also accommodated the role of

practitioners within the research process and held potential to reaffirm practitioners' professional identities in relation to others. This was considered of significance as professional identities within Early Years education are described by Georgeson and Campbell-Barr (2015) as critical to effective professional development yet fragmented and often underdeveloped. As such, a dialogic space was considered to hold the potential to promote equality through emphasising shared spaces and shared thinking as opposed to favouring a hierarchical process of knowledge acquisition.

Critical reflection

The first part of the study was underpinned by a position which advocates critical reflection as key to meaning making and thus the continual development of practice. Critical reflection has been widely recognised as an essential component of practitioner professional development (see for instance. Appleby, 2010; Creemers *et al.*, 2013; Zeichner and Liston, 1987). Within early childhood education it has been established as a means for developing both individual practice and as a force for moving forward established cultures and practices within settings (Moss, 2011). Indeed, an ability to engage in critical reflection has been identified as a key characteristic in successful leadership of change within early childhood settings (Paige-Smith and Craft, 2008). Critical reflection is historically rooted in constructivist theory (Kitchenham, 2008). Dominant conceptions have evolved from the seminal works of Dewey who first recognised critical reflection as a cognitive, systematic meaning-making process (Dewey, 1933) and later, from Schon who described professional thinking involving both reflection on and in action, to identify and solve problems by considering 'alternative modes of framing' (Schon, 1987). Considered during the early phase of the study was the work of Mezirow (1997, p.7), who in the constructivist tradition, proposes that frames of reference are transformed through 'critical reflection on the assumptions upon which our interpretations, beliefs, habits of mind or points of view are based'. This process, described as 'perspective transformation' (Meizrow, 1991) involves examining established meaning schemes and perspectives in order to reinterpret and reconstruct with new meanings and perspectives formulated in thinking. Equally pertinent to the early phase of research was critical reflection as understood from socio-cultural perspectives. In particular, the works of Korthagan (2005; 2010) who argues that during the reflection process,

unconscious gestalt behaviours can be made conscious and concepts become interrelated to create schemas which are grounded in concrete experience with potential for theory development. This position was considered to echo Bakhtin's proposition that ideas exchanged are actually lived rather than abstract and that consequently they are full of personal values and judgements (Bakhtin, 1993 cited in Sullivan 2012, p.2). Related to this was Gomez-Zwiep and Benken's (2012) claim that settings which encourage exploration of current thinking support the potential to question defined ontological and epistemological categories and grow professionally. Brookfield's (1995) recommendation that a wide variety of held assumptions can be challenged by critically examining perspectives with others beyond technical realms, to include social and political contexts, was explored alongside the sociocultural perspectives of Ottesen (2007) and Rantatalo and Karp (2016). Ottenson's (2007, p. 31) stress on 'collaborative communicative action through which an object of reflection is constructed and expanded by the participants' and Rantatalo and Karp's (2016) discussion of collective reflection involving 'specular', dialogic' and 'polyphonic' reflective processes were particularly influential in conjunction with dialogism.

Video technology

As the study was concerned with how video footage is used within communities of practice to prompt dialogue; provide a basis for critical reflection and continuing professional development (Roth, 2009); and support with accessing the characteristics of 'invisible' phenomena (Schubert, 2006), processes used in video elicitation (see Jewitt, 2012) provide a useful, overarching description of the use of video footage in this research. Specifically, Video Stimulated Reflective Dialogue (VSRD), developed as both a research tool and a professional development strategy in the Study of Primary Interactive Teaching (SPRINT) project by Moyles *et al.* (2003, p.4), was employed as it had previously proved to be a powerful means of 'digging deeper into teachers' knowledge, perceptions, views, beliefs and understanding of a range of pedagogical practices'. It was also important to acknowledge the study's relationship to videography in that it seeks to understand and use both the video camera and footage as a tool to 're-orientate the power of the researcher gaze and to give voice to research participants' (Jewitt, 2012, p.3). A number of authors reviewed (see for example, Flewitt, 2006; Knoblauch *et al.*, 2006;

Heath *et al.*, 2010) argue that video footage is a powerful tool for researchers interested in the multimodal character of social interaction. Jewitt (2012, p.6) suggests that this is because it provides a 'fine-grained' record of an event and, as a real-time sequential medium, it enables time to be both preserved and interfered with by slowing down and speeding up video recordings to see 'naturally occurring events in new ways'. This view was considered particularly pertinent to the research as it sought to examine the potential for video footage to offer different perspectives for critical reflection and thus 'agitate' and potentially question participant's existing meaning schemes and perspectives.

In their study of the role of digital video technology in reflective practice, Brantley-Dias *et al.* (2008, p.1) suggest that video footage can act as a mediating agent between practitioner and a 'scaffold guide'. Taking a multidimensional approach to reflection that embraces the use of different lenses, such as constructivist and socio-cultural, they propose that a reflection guide and a focus on 'critical incident analysis' can support practitioners in accessing different types of reflection (for example, technical, contextual and critical). As such, critical incident analysis (see, Harrison and Lee, 2011, p.200) was drawn upon in the research and used alongside VSRD (Moyles *et al.*, 2003) with an emphasis on 'knowledgeable research partners' as active participants in reflective dialogue on video footage. Additionally, acknowledging the rich potential of visual data, Tobin *et al.* (2009) method of 'video-cued' multivocal ethnography' whereby video footage acts as a rich non-verbal cue that stimulates critical reflection was considered in terms of processes through which significant moments might be identified. Indeed, it was acknowledged that videography is often considered as a multi-modal tool which enables insight into a wider spectrum through which children communicate (Flewitt, 2006; Knoblauch *et al.*, 2006; Heath *et al.*, 2010).

Thus, the focus on VSRD within the situated context of communities of practice in early childhood education was considered to hold the potential to encourage practitioners to 'stand back' and critically reflect on practice from multiple perspectives, thus supporting an expansion of existing dialogic space and creating potential for new meanings (Wegerif, 2014). However, although several studies examining the affordances of digital video technologies further indicate the potential

of video footage for documenting the rich contexts of teaching and learning (see for instance, Fisher *et al.*, 2006; Wang and Hartley, 2003) and its ability to inspire deep reflection which is more critical than technical in nature (see Jensen, 1994; Myers, 2004; Sherin and VanEs, 2006), limitations and issues that may arise from engagement with video footage as data were identified. Partiality, as video footage includes and excludes elements due to the nature of the camera lens and the choices made. To some extent, this is addressed through acknowledgement of Goldman's (2009, pp.3-32) criteria for the evaluation of video-based research projects. This includes attention paid to 'wholeness/particularity', which refers to the need to ensure that video footage is sufficiently detailed and fully presented to capture the essence of a particular event, and ensuring 'perspectivity' which emphasises clarity of the videographer's point of viewing. Within the study, it was anticipated that perspectivity might be enhanced through the multi-perspectives that were generated by the data that each member of the community of practice brought to collaborative reflective dialogues. Another potential issue lay within the large amounts of rich data that use of video footage generates as this can potentially lead to weak and overly descriptive data (Gibbs *et al.*, 2002). To address this, iterative cycles of data collection and analysis were employed to refine and focus data collection as recommended by Jewitt (2012, p.6).

It is of note that the reviewed literature, relating to (early childhood) practitioners' knowledge making practices, was largely reflective of the constructivist and socio-cultural theories which dominate understandings of young children's meaning making within early childhood science education. As such, they mirror the anthropocentric and logocentric position argued as limiting knowledge making practices to representations of perceived knowledge in a static world. More recently, however, individual practitioners have begun to challenge such conceptualisations and explore their own practice from a new materialist perspective (see for instance, Hill, 2017). Moreover, Giorza and Haynes (2018) have experimented with human and non-human materials in knowledge creation whilst researching storyworlds with groups of practitioners.

This chapter introduced Baradian philosophy of new materialism and identified key concepts underpinning the theoretical framework for this study, as related to

research question three. Literature focused on early childhood (science) education was discussed with reference to this framework and it was argued that anthropocentric perspectives dominate current conceptualisations of young children's knowledge making practices. Research question one informed the review of literature on creativity in the domain of education and field of art. It was considered possible that conceptualisations of creativity in art be read through research on early childhood science education to gain insight into the materiality of creativity in science enquiry. The outcome of this reading is revisited in the conclusion. Although representative of the early thinking that went into shaping this study, the literature reviewed which explores early childhood practitioners' engagement in research is considered relevant to research question two and the later discussion of the findings in chapter four.

The next chapter, research design, maps early approaches to meaning making, the emergence of an ethico-onto-epistemic framework and new approach to diffractive analysis in educational research.

Chapter Three: Research Design

Introduction

The philosophy of new materialism was introduced in the previous chapter. A Baradian position was foregrounded. Barad's theory of *agential realism,* an *ethico-onto-epistemological* position, and the concepts *phenomena and intra-activity*; *material-discursive practices; apparatus and agential cuts; and diffraction* were positioned as underpinning the theoretical framework used to explore children's creative knowledge making practices within the context of early childhood science education. Literature which examines existing understanding of both children's and early childhood practitioner's knowledge making practices in early science education was illuminated as largely human centric; limiting meaning making to 'representations of things in the world as they are or "objects" that are the product of social activities' (Barad, 2003, p.806).

The chapter also paid particular attention to research question one:

- What representations of creativity exist within and beyond the field of (early childhood science) education?

Conceptualisations of creativity in art were argued as offering insightful perspectives on the creative process. It was suggested that such conceptualisations could be read through existing research on early childhood science education to gain understanding of the materiality of creativity in science enquiry.

This chapter accounts how new materialist and post-human perspectives - primarily those of Karen Barad (2003; 2007) and Hellvi Lenz Taguchi (2008; 2012; 2013) - influenced the emergence of an ethico-onto-epistemic position (Barad, 2007) in this study and subsequently a new approach to diffractive analysis in educational research.

The chapter is divided into two parts. Part one illustrates 'early meaning making' which was situated within an interpretivist framework and informed by constructivist

and socio-cultural perspectives which dominate understanding of both children's and practitioners' knowledge making practices. This includes the initial approaches informing data collection and the first phase of data analysis. Early childhood practitioners' discursive practices are discussed, as represented within communities of practice seeking shared understandings of young children's creativity in science enquiry. Attention is also drawn to how an interpretivist/constructivist framework produced little new insight in relation to the research questions; and how it provided a structure which constricted both knowledge making and understanding of knowledge making practices.

During the second part of the chapter, a new materialist ethico-onto-epistemic position is introduced. This is presented as a phase of 'later knowledge creation'. Baradian (2003; 2007) perspectives, particularly on diffraction as a knowledge making practice, have deeply influenced my thinking during this study. They are a significant shift from the interpretivist perspectives which informed the data collection and first phase of analysis. Therefore, new materialism and related concepts introduced in the literature review are built upon in part two of this chapter, with particular reference to diffractive methodology. The study is repositioned beyond the initial focus on discursive practices attributed to and shared by individuals. There is discussion of the consideration that was given to the relationships between video footage, researcher and early childhood practitioners during the final phase of data analysis. This is followed by an introduction to a new approach to diffractive analysis in educational research which I developed during the later phase of analysis.

The process through which a new approach to diffractive analysis evolved is mapped from a plural stance - 'and, and, and' - as opposed to a search for 'truth' by linear approaches which favour 'this perspective, not that one' (Braidotti, 2017; St. Pierre, 2011, p.622). From this stance, I do not depart from what was gained by drawing on interpretivist approaches for data collection and the first phase of the analysis. Instead, I tell the story of initial meaning making and add to it through the later new materialist positioning. As such, rather than dismissing perspectives in order to find a final, fixed position from which to draw meaning, I take inspiration from Deleuze and Guattari (1987) and seek connections that provoke something new to be thought.

This is akin to Barad's (2007) diffractive approach as discussed in the latter part of the chapter.

Research Design Part One

The first part of this chapter, Early Meaning Making, focuses on the initial interpretivist stance within which the study was situated. Early methodology and methods, including data collection and the first phase of analysis are discussed. Part two of the chapter, Later Knowledge Creation, maps a new materialist position, a new approach to diffractive analysis, and the second phase of data analysis. For clarity the two paradigms informing the study are presented distinctly and then brought together in the findings chapter.

Early Meaning Making

For some time, the methodology for the study sat comfortably within an interpretivist paradigm (Guba and Lincoln, 2005). There was a clear aim to seek insight into how pedagogical content knowledge (Shulman, 1987) is created and expanded by early childhood practitioner's perspectives, generated within the social structure of video reflective dialogues (Sullivan, 2012; White, 2013). Thus an assumption was made that video reflective dialogues are underpinned by constructivist epistemology and knowledge could be created subjectively, following active participation in the environment (von Glasersfeld, 2000; Navarro, 2013). As such, the research set out to realise how understanding of pedagogical approaches is essentially constructed from the inside. This construction was not solely recognised from the perspective of individual early childhood practitioner's actions, but as part of their engagement in video reflective dialogues, which contributes to form the way in which practice is understood (Kemmis and McTaggart, 2005). The study also assumed perspectives stimulated by video reflective dialogues as 'real' in their effects. By this, there was acknowledgement that perspectives are not permanent and unchanging. Rather, that they are the product of underlying relationships that have an existence. Thus, the early phase of the study took an ontologically dualist position, with a subject separated from an independent world and subjectivity recognised as individual intentions and desires connected to social structures and discourses (Parker, 1997, p.21; Sullivan, 2012). An interpretivist stance which recognises reality as pre-existing

and knowledge as a mental representation of that reality (Rowlands *et al.*, 2001) fitted well within these social constructivist and socio-cultural perspectives. Indeed, the widely acknowledged relationships between interpretivism and constructivism (see for example, Gray, 2014, p.24; Mertens, 2005. p.12) underpinned the starting points of this study.

Later, as I participated in video reflective dialogues with groups of early childhood practitioners to collect data, the social constructivist principle by which knowledge is built on an intermental and subsequently an intramental plane, troubled me. I noticed the relevance of practitioner's *different* perspectives and was drawn to Wegerif's (2008, 2014) deconstruction of dialectics. Wegerif (2008) argues that a Vygotskian stance on knowledge construction is dialectic and falls within a modernist framework. Significantly, he reasons that dialectic ontology acknowledges difference but seeks to overcome or synthesise this difference internally, in a process towards individual identity formation. By contrast, challenging a dominant focus on the individual subject as meaning maker, Wegerif draws on dialogic perspectives which recognise, for example, the world as socially structured semantic orientations (Sullivan, 2012). This position offered a new insight into the connection between the social and the individual, and to the role of relationships between practitioners' dialogues when seeking shared understandings.

I had also tuned into notions of critical reflection; widely recognised as an essential component of professional practice and meaning making in early childhood education (see for instance, Appleby, 2010; Creemers *et al.*, 2013; Moss and Petrie, 2002), and a means by which a practitioner can examine and transform their thinking (Mezirow, 2000; Korthagen, 2010). Brookfield's (1995) claim of critical reflection as a process by which early childhood practitioners could challenge assumptions appealed to a strong ethical conviction that I held to respect practitioners' expertise and agency in a sector which is dominated with competency-based approaches and lack of recognition for the demands of a complex role in education and care (Oberhuemer *et al.*, 2014; Waters and Payler, 2015). It also aligned with the acknowledged desire amongst early childhood practitioners to move beyond target driven models towards something deeper that supports working with young children (Georgeson and Campbell-Barr, 2015). As I moved towards a dialogic position, I

questioned a conceptualisation of critical reflection as individual schemas which hold potential for ‘perspective transformation’ (Mezirow, 2000). Instead, I began to embrace perspectives such as those of Rantatalo and Karp (2016) and Ottesen (2007, p.31) who consider the reflective process to involve ‘collaborative communicative action through which an object of reflection is constructed and expanded by the participants’. Limitations of constructivist perspectives which locate knowledge making, growth and change solely within the individual were reinforced as I continued to engage in video reflective dialogues. The ontological position of the study shifted from a monological exploration of dialogues on the outside, to a dialogic one which acknowledged multiplicity and polyphony (Holquist, 2002).

The notion of multiple voices within video reflective dialogues formed basic tenets for analysis, and as Bakhtin asserts, dialogues - in this case between early childhood practitioners - became less determined by a fixed space or time (Holquist, 2002). From an epistemological perspective, I became less concerned with finding fixed meanings within practitioner’s dialogues, instead recognising meaning as having the potential to arise in the *context of difference*. Difference was not something to overcome; it was something to be sought (Wegerif, 2008). Of particular relevance to this theorisation of knowledge making practices was Wegerif’s concept of dialogic space. Wegerif (2014) explains that the perspectives emerging from within dialogues are infinite and thus open to infinite potential for meaning. He argues that when different perspectives are held together intentionally, the likelihood of new creative insights which support seeing in new ways is increased. Thus, for this study, the more perspectives offered through video reflective dialogues the greater the potential for challenge to assumptions which frame our ability to see and understand. This frame, argued by Wegerif as ontological, informed the data collection and initial analysis points in the study.

Constructivist *and* dialogic perspectives shaped the epistemological and ontological frames for the first part of the study. A position was taken whereby knowledge is recognised as constructed within social space through differences which exist in the relationships between dialogues. This position was triggered by the lived experience of engaging in video reflective dialogues with early childhood practitioners. It provoked a shift from a focus on the individual voice to curiosity for the potentials of

plural perspectives on practitioners' discourses and (subsequent) the creation of shared understandings.

Emergent at this point in the study was a concern for the limitations presented by focusing on individuals as active knowledge constructors within what appeared as a somewhat passive world. The assumption that early childhood practitioners could co-construct understanding of children's creative scientific enquiries based on their perceptions, and of my ability to interpret this construction appeared highly subjective and arrogant. It implied that the video footage of children's experiences within the world were fixed and that knowledge making as a practice was enacted solely through discourse. Increasingly, I questioned the place and the role of 'other' perspectives, not necessarily held by the time or space in which the study was situated. For instance, what of 'others' not directly involved in the video reflective dialogues such as headteachers, policy makers, parents, and what of objects such as the video device and footage? Most importantly, I began to be concerned that a focus on individual practitioners' different perspectives would obscure noticing the potential that *spaces of difference* held.

Conceptualisations of multiplicity and difference were to become crucial factors in the analysis phase of the study, as evident in the diffractive approach introduced in the latter part of this chapter. Eventually, my perceived limitations of constructivism became irreconcilable. As a theoretical position, it proved incompatible with the direction in which the study progressed. It is thus revisited and further critiqued in part two of the chapter.

Methods

This section of the chapter outlines three distinct aspects which inform the research methods, namely: research context; participants; and the process of data collection. Ethics are introduced alongside the first phase of data analysis, as informed by interpretivism. The section concludes with a discussion on the limitations of the first phase of data analysis.

As I initially sought to gain understanding of multi-layered social phenomena from different, individual perspectives emergent from video reflective dialogues,

exploratory case study provided a useful frame for the first phase of the study (Yin, 2009). The early childhood education settings involved in the research were selected purposefully in order to represent some contrasting demographic and geographic features, and to allow for some comparisons to be made through representativeness and relatability (Patton, 2002; Stake, 2000). Principles of representativeness and relatability were later disrupted, along with ethics, as an ethico-onto-epistemic position was adopted within a new materialist and diffractive framework. This is mapped in the second part of the chapter.

Context

The study took place across two early childhood education settings: a nursery school and children's centre; and a primary school. Participants included twenty-five teachers, learning support assistants and early childhood practitioners[1], and fifty children aged from two to five years. Groups of participants who worked together were bound as case studies as follows: case study one, practitioners who worked with children under three years of age in the nursery and children's centre; case study two, practitioners who worked alongside children aged three to four years in the nursery and children's centre; and case study three, practitioners who worked with children aged three to five years in the primary school.

The nursery and children's centre (case study one and case study two)

The nursery and children's centre is located in a mid-sized city in South West England. The centre is in the 30% band of the most deprived areas in England. Ethnic minorities represent 60% of children registered at the centre and on average 12 different languages are spoken (Ofsted, 2014; School Data). Children between the ages of two and four years attend. They are grouped into under three years and three - four year olds. At the point of data collection, there were 56 children under three years in both full and part-time attendance. These children were attached to one team of five early childhood teachers and practitioners. 84 full and part-time three to four year olds attended alongside eight early childhood teachers and practitioners. In total 13 practitioners took part in the study.

[1] the collective noun for research participants is 'early childhood practitioners'

The centre purports an ethos which values difference and relationships, and children's right to childhood: to be listened to and to learn through play (Unicef EO, 2018). In 2013 it became a National Teaching School and therefore, at the time of data collection and subsequent analysis, had a remit to offer professional development for teachers and support staff within and beyond their setting. The centre has an established research base which actively encourages practitioners to engage in study. A number of practitioners attached to the centre were undertaking their Masters degree. As such, relationships between theory and practice, reflection and professional dialogues were highly valued and informed practitioners' daily encounters with children. This is illustrated in one participant's comment that the centre 'strives for early childhood education to be recognised as a true profession' (CS1 - interview 2: teacher).

The primary school (case study three)

The primary school is a smaller than average-sized setting which is part of a Multi-Academy Trust consisting of three schools. It is located in a rural town in South West England. The vast majority of children attending the school are White British and most speak English as their first language. The proportion of disadvantaged children eligible for the pupil premium[2] funding is well above the national average, as is the proportion of children who have special educational needs and/or disabilities (Ofsted, 2016). The Nursery and Reception classes, and the Early years resource base - which provides specialist provision for children with a range of complex needs - took part in the study. At the time of data collection there was one teacher and one support assistant supporting 30 full time children in the reception class. One Early Years Teacher and one learning support assistant were attached to the nursery up to 20 children attending part time. One teacher and two learning support assistants supported up to 20 children in the early years resource base. In total three teachers and seven learning support assistants participated in the study.

The ethos espoused by the school centres on nurturing children's happiness, security and safety (School Data). Opportunities for children to play, explore, be active, be creative and to have their ideas taken seriously are foregrounded. The

[2] Pupil premium is additional government funding to support children known to be eligible for free school meals and children who are looked after.

school has been affiliated to a National Teaching School within the Multi Academy Trust since 2014. It therefore has access to ‘school to school’ support and continuous professional development provision. The school is at the beginning of its journey in actively promoting professional development and engagement in research.

Participants

Each early childhood practitioner in the study identified up to 10 children to which they were a key person (DfE, 2017). As a key person, practitioners have a responsibility to offer children a secure base from which attachments and settled, reliable relationships can be established, in the absence of the family. They also have a remit to ensure that education and care is tailored to individual needs. This includes listening and responding to children’s interests, motivations and concerns, and to the family through reciprocal communication (Elfer *et al.*, 2011). In this role, practitioners also have a remit to observe and assess children’s progress in relation to learning and development goals outlined in the Early Years Foundation Stage (DfE, 2017).

Across the settings, practitioners’ experience varied from less than one year of teaching to more than 27 years’ experience in the field. All bar two were female, and their ages range from mid 20s to late 50s, which is representative of the early childhood workforce (Bonetti, 2018). Prior to their current setting, practitioners had worked in a range of settings including primary schools, pre-schools, nurseries and children’s centres. Some participants had also worked as child-minders and one as an advisory teacher. Children participated in the study via video footage which was taken by their key person. The implications of this are discussed in the ethics section below.

Data collection

There were three distinct stages of data collection for the study, all of which were situated within the early interpretivist position:

Stage	Description	Date	Purpose
1	Identifying shared starting points 1 visit to each setting	September - October 2015	Meeting with participants, sharing provocations of early science education and creativity
2	Developing shared understandings Visit 1 Visit 2 Visit 3 Visit 4	October - June 2016	video reflective dialogues
3	Review of participation Visit 5	July 2016	Informal discussions
	Review of participation Visit 6	July 2017	Informal discussions

Figure one: Stages of Data Collection

These phases of data collection were informed by research question two:

- What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

As such, I was conscious that the data collection occurred within a 'community'. To initiate this, phases one and two spanned over the course of one academic year, with each setting visited five times, so that the participants could regularly interact (Senge, 1990; Wenger, 1998). On every visit, groups of practitioners engaged in Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) which lasted for up to 1.5 hours. I was particularly interested in Video Stimulated Reflective Dialogues as the approach had previously proved significant in accessing teachers' knowledge and understanding of a range of pedagogical practices, in a research context

(Moyles *et al.*, 2003). My own experiences with the approach had revealed strengths in its respect for practitioners as experts of their own practice, and recognition of them as agents in processes of change. I was thus keen to explore its potential beyond individual professional development and to gain insight into its usefulness with groups of practitioners, as they grappled collectively to make sense of young children's creativity in science enquiry.

Considering Fuller and Unwin's (2004) recommendation of gradual transition into full teamwork with groups of educators, the first visit to settings was used to gain insight into the existing ideas that practitioners held about the nature of creativity in science enquiry. As such, open discussion was used with educators to build relationships and to come to shared starting points on the nature of creativity in science enquiry, and its associated pedagogical approaches. Eager to support the creation of a professional learning community grounded in knowledge in practice (Vescio *et al.*, 2008), participants were invited to consider the abstract of Andersson and Gullberg (2012) in the first session. Statements about creativity were also selected from a wide range of academic sources to use as provocations for this discussion, which was filmed using an ipad. The use of academic literature also ensured that 'shared understandings' were informed by multiple perspectives; supporting the potential for dialogic space from which 'new' knowledge could be created Wegerif (2008). I also anticipated that, by presenting academic perspectives which may deliberately provoke established viewpoints, we might avoid 'groupthink'.

During stage one of data collection, participant and setting profiles were gathered and field notes were made to provide additional data, initially for the purposes of triangulation (Yin, 2009). Documentation such as the setting ethos statement and Ofsted reports were also collected to provide contextual information, as well as to augment data gathered during video reflective dialogues (Yin, 2009).
In each of the settings, practitioners collected and selected five cycles of video footage of children, and their interactions with children, whilst they were engaged in science enquiry. This provided an opportunity for genuine collaboration in the process of data collection supporting the participatory 'community' approach foregrounded in the study (Kemmis and McTaggart, 2005). It has also helped to address issues relating to the use of video footage as data such as immediacy and

hypermediacy (Bolter and Grusin 2000) as practitioners had the opportunity to engage with video footage in their own time and assimilate immediate responses to phenomena such as hearing one's own voice and observing personal interactions (Moyles *et al.* 2003). The contexts for science enquiry were defined by practitioners and linked to perspectives that emerged during video reflective dialogue sessions. After each set was collected, practitioners identified critical incidents (Harrison and Lee, 2011; McAteer *et al.*, 2010, p.107) which illustrated creativity in science enquiry based on evolving, shared understandings of its nature, and associated pedagogical approaches. Pre-selecting significant pieces of data further enabled the development of a defined community space grounded in knowledge in practice (Vescio *et al.*, 2004). It also supported pragmatics within the study, such as manageability, and mitigated against selective choice within videography, as multiple perspectives were offered by practitioners within each setting (Jewitt 2012).

For the video reflective dialogue sessions, practitioners came together as a group within their respective community of practice to watch clips of video footage, and to engage in collective, reflective discussions, which were filmed. All participants shared a clip of video footage with the group at least once over the course of sessions. In the role of researcher, I brought perspectives from the field of science and early childhood education, and fully engaged in dialogues. At this point, I was confident that this combination of being both participant and researcher was well suited to the case study approach as, by nature, interactions were action oriented and thus allowed for understanding to be directly interpreted and put to use for professional learning and formative evaluation (Mills *et al.*, 2010).

During video reflective dialogue sessions, there was a need to respect practitioners' differing levels of engagement in dialogue. This posed the question of how all practitioners' voices might be considered. Member checking (Yin, 2009), using a simple agreement scale and opportunity for commentary on emergent perspectives was a means of ensuring that all perspectives were represented. From the perspective of case study, it also provided a check to the trustworthiness and thus credibility of patterns I had identified (Lincoln and Guba, 1985). The scale, entitled Generalised Perspectives, was shared at the beginning of each video reflective dialogue session and subsequently analysed before the next session, establishing a

cyclic process of verification throughout the second phase of data collection (see appendix one).

Phase three of data collection took place during the end of the last session, and in two subsequent review visits. In these sessions, practitioners were invited to reflect on their participation in the study in relation to research question two. In particular, on the potential of VSRD as a tool for collective meaning making. The format in which this data was collected mirrored phase one. By this point in the study, VSRD was an established approach and participants were familiar with the format of recording sessions. The review visits also served as an opportunity to share initial insights with participants so that they might challenge any assumptions made of the data (Kelly and Yin, 2007; Yin, 2009). Up to 18 months after the final data collection session, return visits were made to the settings to share progress with the study. In one setting, one to one meetings were held with participants keen to engage with the theoretical perspectives which informed the later phase of analysis (see appendix two).

As participants in the research, I assumed that both myself and early childhood practitioners were able to construct knowledge as we interpreted children's creative engagement in science enquiry (Thompson and Pascal, 2012). However, as the study moved from data collection to analysis, accepting knowledge making as grounded in our own particular experiences, subjective and bound to the community in which we operated (Alvesson and Skoldberg, 2009; Denzin and Lincoln, 2005) became an increasingly difficult position to rationalise.

Ethics

Institutional approval

Ethical protocol was framed using the University's Research Ethics Regulations (Institute for Education Research Ethics Committee, 2014), and The British Educational Research Association Guidelines for Educational Research (BERA, 2011). Participation in the study was initially agreed with the head and a self-identified 'lead educator' within each setting. Individual participant consent was then sought both verbally and in writing at the beginning of the study. The aims,

processes and outcomes of the research; the level of confidentiality and anonymity offered to participants; the responsibility of the researcher and the participant in the research process; and a statement of assurance that the data would only be used for this particular research project were shared with participants (see appendix three). Time between the first and second data collection sessions was also offered, for potential participants to consider their involvement. Each early childhood practitioner understood their right to withdraw from the research process at any time. Assurance was provided on issues surrounding safeguarding children when using video footage as data and the researcher collaborated with practitioners to seek informed consent from parents for their children to be involved in the study. To gain children's informed consent and communicate right to withdraw from the research, early childhood practitioners followed ethical guidelines as identified within their respective settings. Time was dedicated to working with practitioners in each setting to compose a letter to parents in order to seek assent for children's participation (see appendix three).

Ethical attunement

It was particularly important to acknowledge that children might dissent from the filmed sessions in the study. With respect to this, it was agreed that practitioners act as ethical 'guardians', drawing on their high levels of attunement to help them make decisions about whether or not to pursue filming in order to collect data. As such, a decision was made that I would not undertake any filming of children. Adopting a role of ethical 'guardian' enabled early childhood practitioners to focus attention on what Nutbrown (2010), in articulating an ethics of care, describes as a caring rather than overprotective role. Moreover, in seeking a respectful view of children, Nutbrown's (2010, p.11) argument for recognising children as 'other-wise' was embraced. Specifically, practitioners and I discussed the importance of acknowledging that we might learn from children's wisdom; 'beginning with their wonder' whilst reviewing and interpreting video footage. This seemed particularly important given that whilst there is acknowledgement in studies involving videography, of the plurality of ways in which children make meaning (see for instance, Flewitt, 2006; Loizou, 2005; 2007; White, 2015; Shoecraft *et al.*, 2018), adult-child dichotomies and hierarchies prevail, with children commonly conceptualised through the interpretations of knowledgeable adults (Derry *et al.*, 2010). However, despite the intentions of an 'ethics of care', addressing such hierarchies in practice was a significant challenge. For instance,

although there was conscious awareness that interpretations of video footage were, at least partially subjective and assumptive (Spencer, 2011), both practitioners and I, as participant researcher, stayed within a limited and common frame of reference when interpreting children's scientific encounters - a point discussed further in the findings and discussion chapters.

My ethical stance

Also problematic was the ethical stance that I strove to achieve during the early meaning making phase of the study. That is, I had, somewhat ideologically, considered that video dialogue sessions should be situated within a participatory, democratic paradigm, as influenced by Pascal and Bertram (2012) and Larsson *et al.* (2019). With reference to Pascal and Bertram's (2012) praxeological position, I endeavoured to ensure that my ethical values should be transparent, well-articulated and understood by those involved in research. Whilst I discussed ethics from such a position emphasising the importance of participation, attentive listening and respect for anonymity beyond the sessions, in reality implicit narratives such as power imbalances, created challenges (Makau, 2018). For example, not all participants talked in every video dialogue session. Rather, there were occasions when a few dominant practitioners held the space. To address this issue, I adapted data collection by collecting generalised perspectives, as noted by individuals at the beginning of sessions (see appendix four). However, I acknowledged how the decisions such as these made throughout the research process would impact the nature of the data collected and positionality of those involved (Cutter-Mackenzie *et al.*, 2015). Such power imbalances were not limited to this example and, as such, I return to this issue at the end of this chapter.

As the study developed, my position on ethics shifted as influenced by Baradian new materialism and an ethico-onto-epistemic stance. Barad's view on ethics differs significantly from common perspectives within interpretivist research in the field of early childhood education, which consider ethics a question of being ethical or acting ethically in the best interests of others (Davies, 2014; Schulte, 2013; Thompson, 2017). Rather, ethics is considered a 'doing'; an act which requires taking responsibility (Kaplan, 2019) as discussed in the later knowledge creation section of this chapter.

Data Analysis

Initial data analysis consisted of two phases. It was informed firstly by research question two:

- What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

Later in the initial analysis phase, attention shifted to research question three:

- What insights are gained from a diffractive analysis of current understandings in literature and of empirical research of young children's creativity in science enquiry?

At an early stage, Kathy Charmaz's (2006, p.10) grounded theory resonated with me as it assumes that 'we are part of the world we study and the data we collect'. It provided a clear structure and a process which acknowledged the situational and social context from where the data had emerged. As such, I began by observing what the video footage of the reflective dialogue sessions revealed, using an inductive approach. This entailed coding to identify themes, consistencies and exceptions within the data. I constructed initial codes using Atlas. Ti software which had the advantage of being able to support large bodies of video footage. Using the software was also an efficient way of organising memos into themes and families, and easily categorising my tentative findings within the three guiding research questions. In line with case study approach, I employed a simple pattern matching and explanation building technique which Yin (2009) claims can strengthen trustworthiness.

At this point of data analysis, I continued to be influenced by dominant constructivist perspectives. I aimed to identify early childhood practitioners' meaning schemes. This included when or where they reinterpreted and reconstructed new meanings and perspectives about creativity in science enquiry. Thus, I coded 'what was said' by practitioners, relating to research question two. These provided a summary of

points about creativity in science enquiry and established generalised beliefs, values and suppositions about how science enquiry was enacted by children. It also related to understanding of associated pedagogy (Cohen *et al.*, 2007).

Alongside this, insights and developments which occurred in my own thinking and learning were recorded to support transparency and, as Lincoln and Guba (1985) suggest, to increase the credibility of the study. Later in the study, this reflexive stance was challenged through Barad's (2003) onto-epistemic position which claims that single, separate perspectives which mirror or reflect a perceived reality do not exist.

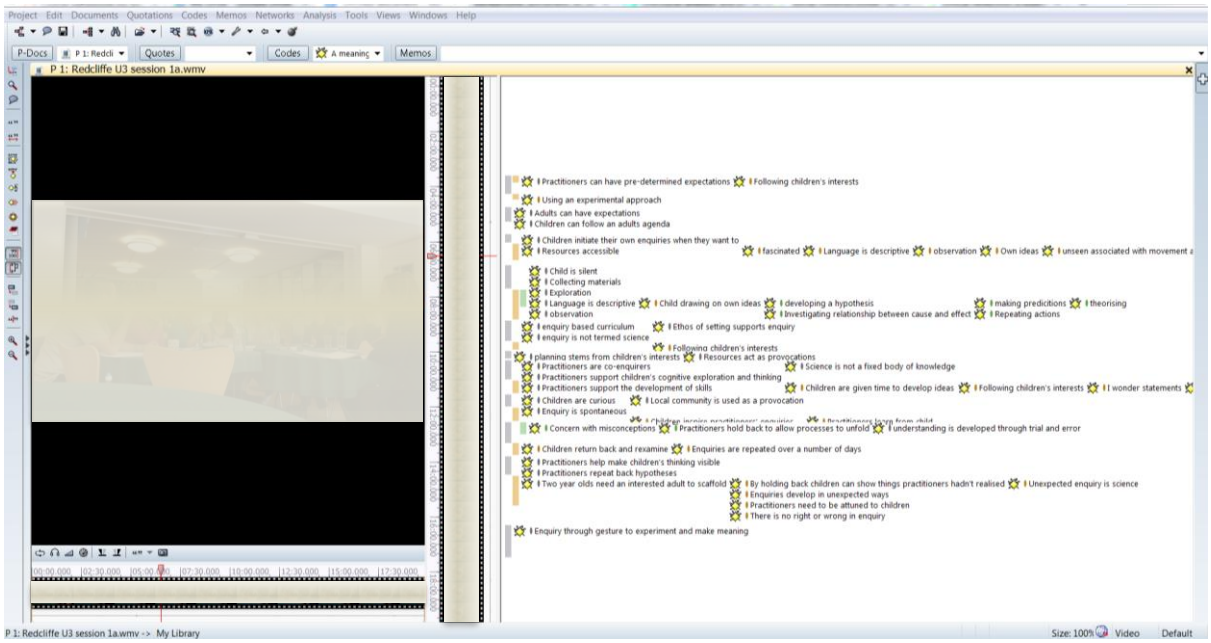

Figure two: Extract of initial coding case study one: session one a

Group discussion opened with LS stating that some practitioners can have preconceived agendas and expectations about what children should learn about scientific concepts. She explained that the practice she was familiar with was following children's interests and taking an experimental approach to enquiry as illustrated in the second perspective presented by Andersson and Gullberg (2014). LA contributed that her previous experiences were similar to the first perspective in that adults often had fixed agendas and would steer children's explorations as a result.	Two discuss and reflect to present a perspective that children's interests should lead enquiry (EYFS, Piaget). LS/LA gestalt evolves to schema through content reflection? LA (project lead) leads with strong agreement conveyed non-verbally by some and by verbal encouragement to share by others. Scientific enquiry begins with children's interests.	Perspective agreed and held in dialogic space. Perspective starts as a gestalt made a conscious schema through shared content reflection. Related to the meaning perspective: 1. Child-centred paradigm/ Child perspective paradigm
RD poses the question: 'What does scientific enquiry look like here?' LA uses a floating and sinking example to illustrate how children start their own enquiries when they want to. This was linked to the importance of having accessible resources to choose from. Children's language is descriptive when they are following their own interests and fascinations. They use observations and when objects are unseen they feel and touch. Following a prompt by CK, LA described an example of a child exploring dams and rivers by collecting bark and pouring water. He was silent for most of the time but did use some descriptive language such as 'its stuck'. He was closely observing. The child changed the flow and direction of water. Before engaging in this physically, he began to develop predictions and hypotheses. He was drawing on his own ideas. Once engaged in the activity, he repeated actions.	LA presents several perspectives through content reflection on gestalts. Results in schema formation: - Science enquiry is self-initiated *exploration* - accessible resources support science enquiry (EYFS, Reggio Emilia) - science enquiry is exploration (Piaget) - talk/language is stimulated through self-initiated science enquiry (Vygotsky) - children engage multi-sensorally and physically with objects in enquiry - children are immersed/still during enquiry - children use gesture to convey meaning (McNeill 2005, Kress 2010) - children use process skills; observation, prediction, hypotheses, gathering evidence, pattern-seeking through repetition (Harlen 1997) Elaboration of LA's thinking is encouraged verbally and non-verbally.	Further perspectives are held in dialogic space. Related to the meaning perspective: 2. Epistemological dialogical pedagogy (Wegerif 2014) 3. Constructivist/Social Constructivist perspective/communication is multi-faceted Lead practitioner dominant. Verbal encouragement by others. Csikszentmihahyi (2002) in the flow
CK explained that the setting has an ethos which supports children in developing their own enquiries. However, enquiry is not a defined as science. EB contributed that they follow an enquiry based curriculum.	Senior practitioner presents setting approach. Acts like a summarising perspective. Meaning structure?: - Learning is not domain specific (EYFS) - Knowledge like a rhizome (Deleuze and	Senior practitioner relates perspectives to the wider setting ethos/culture. This reflects a meaning structure? Power imbalance in discussion?

Figure three: Extract of initial analysis case study one: session one a

In relation to research question two, I began to observe the way in which the group talked to each other with a particular focus on how they affirmed or challenged each other's perspectives. Drawing on Littleton and Mercer (2013, p.111), I framed talk as a social mode of thinking or 'interthinking'; a tool for constructing knowledge, creating ideas and sharing understanding. In particular, I looked for evidence of 'exploratory talk', contended by Mercer (2000) as a provocation for critical reflection and involving reasoning and questioning to constructively challenge ideas. Moreover, taking a dialogic perspective, I embraced dialogues as not holding fixed meanings. Instead, I looked to the relationships between dialogues, and to spaces open to the potential for meaning (Wegerif, 2014).

Toward the end of the initial analysis phase, my stance had shifted from dialectic to dialogic and I sought to identify the potential for change and the creation of new understanding through critical reflection conceptualised as collective and relational, rather than of the individual. I drew largely on Rantatalo and Karp (2016) who advocate for a collective perspective on reflection and differentiate amongst 'specular' (individual storytelling), 'dialogic' (testing out ideas against other's

viewpoints, sharing and promoting viewpoints) and 'polyphonic' (collective exploration of possibilities, restructuring and making collective decisions).

What is happening within the phenomenon of VSRD? (Session 2 R3-4 24.11.15)

Time	Phase	Connected by	Reflection
Episode 1 (1:41)	I – AL – AF -ST -- R - AL -- G – AL - AF --	Comments Perspectives Listening Affirmation Time – long sequence of individual storytelling	Specular Polyphonic/cumulative
Episode 2 (2.24)	I – RX – CR – AL – AF -- G - CP -- G - OP -- SU - ALL -- EXPLORATORY	Challenging comments Perspectives Shared understanding Listening Affirmation Reflexive stance Time – long sequence of individual reflexivity/critical r	Specular Exploratory Critical
Episode 3 (5:52)	R – AL – TP - Q -- I – AL - ST -- R – EG - Q -- AL – AF – G - OP -- RX – CR – I - AL -- R – S - AL -- EXPLORATORY	Theoretical perspectives Comments Questions Listening Affirmation Reflexive stance Summative Time – longer with shorter intra-actions between participants	Specular Exploratory Critical
Episode 4		Fluidity	Specular

Key
I - individual
AL - active listening
AF - affirmation
ST - storytelling
R - researcher
G - group
RX - reflexive stance
CR - critical reflection
CP - challenges perspectives
OP - opposes perspectives
SU - shared understanding
TP - theoretical position
Q - question
EG - example given
S - summary

Figure four: Phase one analysis of video stimulated reflective dialogues case study two: session two a

Limitations of phase one data analysis within interpretivism/ dialogism

As I was working with visual data, I was keen to look beyond dialogue as a verbal utterance through multi-modal social semiotic frameworks (Bezemer and Mavers, 2011; Jewitt, 2009). Such frameworks recognise patterns of gesture and routines

across the time and space of the community of practice as contributing to practitioners' meaning making (Jewitt, 2009). Focusing on research question two, I considered conditions which contributed to collective critical reflection. This included how other practitioners behaved during episodes of individual storytelling or when multiple voices were at play in encounters of exploratory talk. However, what became apparent as I attempted to identify the conditions which supported practitioners' engagement in collective, critical reflection, was the sole focus on *human dialogues*. Examining multi-modal perspectives (Kress, 2010; Stagg Peterson *et al.*, 2019) had provoked a shift in frame to consider gestures and semiotic symbols as contributing to a conceptualisation of dialogue, but, informed by interpretivist and constructivist epistemology, they were limiting in their perpetuation of a linear representation of data (Barad, 2007). Additionally, by viewing talk and gesture as fundamental to generating multiple perspectives, and dialogic spaces as the means through which shared understandings could be created, only one perspective for meaning making was made visible. Analysis was thus firmly located in the linguistic turn foregrounding language and discourse. As such, there was an assumption that language and modes of data collection were transparent (Davies, 2014) and that reality was situated within language. Essentially, at this point in the analysis, language and objects were very much separate from each other (Bozalek and Zembylas, 2017).

Questioning what other factors might influence meaning making helped to reposition video reflective dialogue sessions as phenomena rather than simply 'words and things' (Barad, 2007). This provoked a dynamic shift in the methodology of the study. I had focused on the relationships between dialogues, participants and myself as researcher but there were also connections between both the video camera and footage, researcher, participant and dialogue. These could be conceptualised as 'material-discursive entanglements' (Barad, 2007). A key determiner of this was a turn to realist perspectives and a focus on both video camera and footage as a 'structure existing beyond those who create it', both as a 'real' object and as real-time footage of children's engagement in science inquiry (Olsen, 2010). For instance, in video reflective dialogue sessions, early childhood practitioners could interpret the same phenomena differently or build on each other's perspectives to make meaning. However, the video recording would remain a constant, albeit partial, *other*

perspective which could contribute to the meaning making process. From a realist perspective, there was a relationship present between the dialogues and the object (in this instance, both video camera and footage) which potentially existed beyond 'interpretation'.

Karen Barad (2007, p.46) and others (see, for instance. Davies, 2014; Mazzei 2014; St. Pierre and Jackson, 2014) argue that constructivist/interpretivist perspectives assume an ontological separateness between 'what is represented and what is purported to be represented'. That is, reality pre-exists and knowledge is a mental representation of this. For Barad (2007), there is also a problem with realism as it takes the perspective that there are separate individual entities in the world with separate determinate properties. Drawing on Rouse (1996), she suggests realism *and* constructivism subscribe to representationalism: that realists represent nature as it 'really is', via scientific knowledge and constructivists represent culture via social activities (see earlier discussion on Vygotsky). For Barad (2007, p.37), realism is 'not concerned with representations of an independent reality but about real consequences, interventions, creative possibilities, and responsibilities which are within and part of the world'. That is, not a representation of children's creativity in science enquiry, but rather as the consequences of my actions as I collectively engaged in Video Stimulated Reflective Dialogues, for instance. Or the ethical responsibilities that both I and early childhood practitioners held toward the subjects of research, i.e. children. The responsibilities I held as a researcher in terms of what I did or did not make visible through analysis and subsequent meaning making.

I realised thus, that through an interpretivist paradigm I was not just merely representing young children's creativity in science enquiry, I was also decontextualising, fragmenting and encouraging dualism which ultimately took me back to what was already 'known' (Mazzei, 2014). This was particularly evident in the coding used during the early meaning making phase of the study whereby discourse was privileged (Nespor and Barylske, 1991, p.810; St. Pierre and Jackson, 2014). Recognising that I could go no further from this position, I came to adopt an ethico-onto-epistemology in the latter part of data analysis. One that considered ontology, epistemology and ethics as inseparable and thus entangled in their differential being and becoming (Barad, 2003; 2007).

Research Design Part two

Later Knowledge Creation

Barad (2003; 2007) argues for a need to look beyond representations of the world in the pursuit of meaning-making, or risk merely reflecting what is perceived to already exist. This was a direct challenge to the interpretivist approach that I had adopted during initial analysis. It was evident that the deconstruction of empirical data yielded some insight into young children's creativity in science enquiry. However, the insights did little more than reflect existing literature. Rather than creating new knowledge, such a framework restricted production to conventional findings, common in the texts that practitioners access to develop pedagogy and practice. They echoed the theoretical, ontological and axiological norms within the interpretivist paradigm. Ultimately, I had gained insight into how practitioner's voices represent a perceived world and, in the process, recreated dualist mind/body, nature/culture positions. Humans and their discourses were foregrounded in knowledge-making practices against a flattened and static environment.

Barad (2007, p.49) calls for a fundamental shift from this type of representational understanding to a performative, agential realist position which assumes that knowing comes from *material* engagement with the world. For Barad (2007, p.224), this means that matter is not an inert canvas ready for cultural inscription, nor does it exist to support concept formation. Instead 'matter is a dynamic and shifting entanglement of material-discursive relations'. Barad emphasises this point in her conceptualisation of ethico-onto-epistemology; parts are not separable in knowledge creation, rather they emerge from phenomena, dependent on difference in their becoming.

During the final phase of the study, I tentatively explored with regard for matter as 'always already' entangled with discourse (Barad, 2003, p.822). Initially focusing on research question two, I considered video reflective dialogues as both within and generating the phenomenon of 'shared understandings'. Rather than simply reflecting back what practitioners articulated, as in the early meaning making phase of the study, attention was given to the performativity of relationships within the

phenomenon. Taking this position was not without challenge. Barad's post-human perspectives disrupt familiar boundaries relating to cause and effect and normative understandings of the world. Simultaneity in being and becoming meant repositioning agency beyond the individual and beyond dialogic spaces, and being open to a performative understanding of discursive practices (Barad, 2003, p.803). This understanding would require the exploration of unexamined habits of mind and shift my focus to 'questions of diffraction rather than reflection'. This was challenging; the concept of reflection is ubiquitous in the field of education (see for example, Appleby, 2010; Brookfield, 1995; Creemers *et al.*, 2013). Alongside constructivism and interpretivism, it is dominant in its influence on how we have come to understand practitioners' approaches to meaning making. However, the shift to an ethico-onto-epistemological position was to transform approaches used during data analysis. For example, my understanding of reflexivity was changed. During the data collection phase of the study, I had noticed incongruence between being a full participant in video reflective dialogues and the assumption that I should stand back and reflect for the purposes of credibility and reliability (Yin, 2009). Exploring these contradicting positions from an agential realist perspective repositioned my role to one in which I was more than just 'part of a picture' represented through data. I was actively contributing to it; I was both within it and creating it as opposed to simply looking back at myself. Indeed, during the final part of the study, I engendered a much more active relationship with the data. I began to pay attention to materiality and 'relations of difference and how they matter' (Barad, 2007, p.71). My understanding of the analysis process was also reshaped. For instance, thematic approaches, which had once served as a coherent structure, appeared logical, tight and predictable from a stance which required more openness to uncertainty, non-linear movements through data, and awareness of unpredictable patterns from which new knowledge might emerge.

Using the phenomenon 'shared understanding' as the focus for analysis, I began to attend to the practices that might contribute to its meaning, beyond dialogues. Focusing on phenomena helped me to maintain a stance that recognised shared understanding not as the property of individuals or as pre-existing. The phenomenon was instead assumed as a complex network of material-discursive practices. I focused on the entangled state of agencies of participants, researcher, dialogues,

theories of science and creativity, and video footage of children's enactments in the context of science enquiry. Less foregrounded, but still acknowledged, was an awareness of the practices of history, society, culture, politics, trust and disposition, which all could play a role in knowledge production and shared understandings, depending on what meaning was made visible.

My starting point was the video footage. This was largely because I had privileged both early childhood practitioners' discourse and the notion of a dialogic space in earlier analysis. Initially focusing on the practitioners working alongside children aged three to four years, I used a pencil and tracing paper laid on the screen to trace significant parts of the video footage, where children enacted their enquiries and where practitioners had identified critical incidents. This provided a crude 'object of difference' in the form of visuals. I layered these drawings over my initial analysis of the dialogic interactions between practitioners. The drawn and written data layered on top of each other acted like a framework which enabled me to maintain consideration for difference and for materiality. The images appeared to me as landscapes created from the intra-action of material paper and the act of tracing, and the material-discursive transcripts. Listening, looking and feeling, I began to note perceived patterns and emergent entanglements. For instance, where theoretical perspectives and researcher questions in video dialogues; video camera and footage as 'lively matter' (Bennett, 2010) and children's dialogic encounters; storytelling, laughter and immersion in a shared space, potentially enacted agential cuts through the data. Crucially, throughout this process I was not looking to represent what appeared on video footage but rather for 'an enactment of flows of differences' (Lenz Taguchi and Palmer, 2013, p.616), between dialogues and video footage. However, although this supported a focus on 'difference' and phenomena, what I had created still reflected back, and thus represented, what had already been.

Dissatisfied with this process to identify difference, I turned to Barad's (2007) claim that differences are evident in transdisciplinary positions. I took what is known 'best' (Barad, 2007) about science education, early childhood education and creativity, and mapped them across the apparatus of video footage and early childhood practitioners' discourse. I spent time reading through each of them and moved back

and forwards looking for ‘where differences get made in the process of reading data into each other’ (Lenz Taguchi and Palmer, 2013, p.616).

Figure five: Phase three analysis case study two: session four

A diffractive analysis

What followed was the development of a new approach to diffractive analysis in educational research. It shows how existing conceptualisations of young children’s creativity in science enquiry are affected by critical points of difference, created by interference and the enactment of boundaries in a diffractive encounter. To do this, I moved away from the established practice of mapping through and across data to make new meaning, and instead I explored points between data to reveal their potential to create difference and make knowledge.

This new approach followed recent experiments which diffract qualitative data and develop alternative methodological narratives to interpretivism (see for instance, Bozalek and Zembylas, 2017; Davies, 2014; Frigerio *et al.*, 2018; Jackson and Mazzei, 2012, Lenz Taguchi and Palmer, 2013 and Mazzei, 2014). As knowledge making practices, these analyses do not re-present or reflect assumed realities. Instead, new boundaries for meaning making are enacted through the process of

diffraction. This is akin to the ripples which spread out, overlap and form new patterns when pebbles are dropped into a pond (Lenz Taguchi, 2010). With these enactments, difference is created. Through difference, it is argued, comes insight and the potential for new knowledge (Barad, 2007). Thus, within these diffractive experiments, data collide with each other to create new patterns which reveal something different, and new. Rather than grounded in essential categories such as epistemology/ontology, nature/culture or adult/child, difference is assumed full of creative potential, to be embraced not overcome. Significantly, for my own approach to analysis, this meant a shift to noticing where difference is created and, as advocated by Lenz Taguchi (2012, p.268), avoiding asking interpretivist questions such as 'what does it mean', and instead focusing on 'how does it work' and 'what does this text or data produce'. Indeed, I acknowledged that the analysis may generate new questions as much as any new insights.

The approach that I developed was grounded in Barad's (2007) conception of diffraction which is partly derived from Niels Bohr's challenge to long-established accounts of causality in quantum phenomena. Of particular interest to my analysis was that through his experiments with light, Bohr suggested that measuring apparatus used to 'see' both contributed to and created a particular set of conditions, which leads to determining visible properties. For instance, as defined through complementarity theory, depending on the apparatus used and the conditions created, light can be seen as a particle or a wave. Thus matter (in this case, light) can be understood as a field taking forms and spaces simultaneously and, depending on the apparatus and the conditions, it will behave in particular ways, affecting how it is seen. Bohr also recognised that in creating conditions for seeing, particular existences matter, e.g., light as a wave, whilst other behaviours of that matter are necessarily excluded, e.g. light as a particle. Hence, we never see all matter at the same time. Bohr suggested then that the apparatus and the conditions determine the visible properties of matter as phenomena. Indeed, prior to using a measuring apparatus, light does not exist in a fixed state. Hollin *et al.* (2017), drawing on Barad (2007) explains this as ontic indeterminacy. Also significant was Barad's (2003, p. 815; 2007) focus on the relationships that exist between matter within phenomena, and their performative enactment of what is made visible. That is, in ontological relationship, light in a particular state; the particular measuring

apparatus; conceptual framework; and ‘scientist’ all emerge from experimental entanglement and do not pre-exist them.

Of equal importance was Barad’s (2007) explanation that waves act differently to particles. While particles cannot occupy the same space, waves in diffraction can collide and interfere and occupy the same point in time and space. This is a concept defined as superposition. In superposition, the new emergent wave has properties which result from the combination of prior colliding waves (Barad, 2007, p. 76). Superposition indicates a state of entanglement which leaves ‘interference traces’ that mixtures do not (Barad, 2007, p.285). However, ‘upon measurement, the superposition appears to “collapse” into a mixture’ (*ibid*, p.280). Nauha (2017, p.280), describing the philosophy of performance, articulates such a mixture as traces and representations which consist of complementary binaries. These explorations of superposition have been particularly important as a means through which to both understand and articulate a ‘space’ in which new knowledge/ways of seeing might reside, albeit indeterminately. Related, is Barad’s claim that apparatus enact agential cuts in an attempt to ‘measure’ and produce boundaries, making ‘manifest the extraordinary liveliness of the world’ (Barad, 2007, p.91). Murris and Bozalek (2019) explain further, drawing on Barad (2007, p.168), that when an apparatus measures, ‘cutting together apart’ in one move, it changes the nature of the observed phenomenon. However, this is not static but rather an ongoing performance. Hence, knowledge production is a feature of the world in its differential becoming.

Accordingly, within the phenomenon of the later stage of my analysis, I acknowledged an intra-acting entanglement of relationships which act as a site of knowledge production. In particular, the entanglement of researcher and data was made visible, and what is presented was recognised as inevitably emergent from and created by the material-discursive apparatus of theory, research(er) and empirical data. Indeed, it is acknowledged that I, as researcher, am of the diffractive pattern (Murris and Bozalek, 2019). There is recognition that in making something matter, other matters will be necessarily excluded. Thus, what is offered will be one moment of mattering. As such, and with respect to Barad’s (2007) assertion that an onto-epistemic position is necessarily ethical, responsibility is taken to make

transparent the apparatus that ‘cut together apart’ meanings about young children’s creativity in science enquiry in this study. It is also acknowledged that other ‘matters’ of children’s creativity in science enquiry are excluded, as might be defined through *different* apparatus such as political, gendered or cultural positions, for instance.

The study is clear in its aim to challenge dominant constructions of children within early childhood science education and questions whether such constructions may contribute to ‘complementary representations’ of young children’s creativity in science enquiry, mixed within superpositions. Hence, new meaning was sought through diffraction to ‘study the practices of knowing as they are enacted in the materiality of the world’ (Bozalek and Zembylas, 2017, p.118). However, rather than exploring data through, for instance, multiple perspectives (Davies, 2014; Jackson and Mazzei, 2012; Mazzei, 2014) or across multiple times, spaces and collaborations (Bozalek and Zembylas, 2017), this approach introduces and explores *critical points of difference* as created within a diffractive encounter. These points of difference are argued as sites of potential for new knowledge which are affected and expanded by data understood to be both material and discursive.

Informed by research question three:

- What insights are gained from a diffractive analysis of current understandings in literature and of empirical research on young children’s creativity in science enquiry?

This approach to diffractive analysis focused on, i) empirical research data of shared understandings held by early childhood practitioners, ii) existing research on early childhood science education, and iii) conceptualisations of creativity. Both the researcher questions and I as researcher and participant in the study, are also acknowledged as of and influencing apparatus, shaping the approach and the outcomes of the analysis. They are presented as entangled material discursive apparatus contributing to the conditions which determine a different insight into young children’s creativity in science enquiry. They are a phenomenon of shared understandings of young children’s science enquiry.

Taking Lenz Taguchi's (2010) use of Barad's metaphor for diffraction, of pebbles dropping into a pond with waves rippling out from and interfering with each other, and Young's Double Slit Experiment, it is possible to visualise patterns intra-acting and emergent within the phenomenon of shared understandings. This is illuminated in figure six below as concentric circles overlapping to reveal spaces 'in-between'. Originally, laying circles in such a way emerged from a connection to concepts which provide a compelling argument for spaces in-between as holding the potential for the creation of new knowledge (see for instance, Ma (Ferguson and Kuby, 2015); dialogic space (Wegerif, 2014); and conceptualisations of creativity (Malafouris *et al.*, 2014). However, these were eventually considered valuable insights but 'neither here nor there, this or that', (Murris and Bozalek, 2019, p.9) in terms of diffractive analysis. Rather, the overlapping circles indicate spaces of superposition; emergent new waves which are composed of aspects of prior intersecting waves. The concentric circles themselves illustrate material-discursive apparatus (the inner circle) and associated constructs of the apparatus (the outer circle). In this case the apparati are shown as, conceptualisations of creativity; research on early childhood education; and video reflective dialogue. Figure six also indicates where points of difference emerge, as enacted through a diffractive reading. Focusing on the points where data collide with each other is of significance as it is in these particular encounters that conditions are created for difference. These points determine the outcome of what is made to matter in a diffraction thus they hold the potential to make something new matter, including 'new visions of nature and reality' (Chappell *et al.*, 2019, p.300).

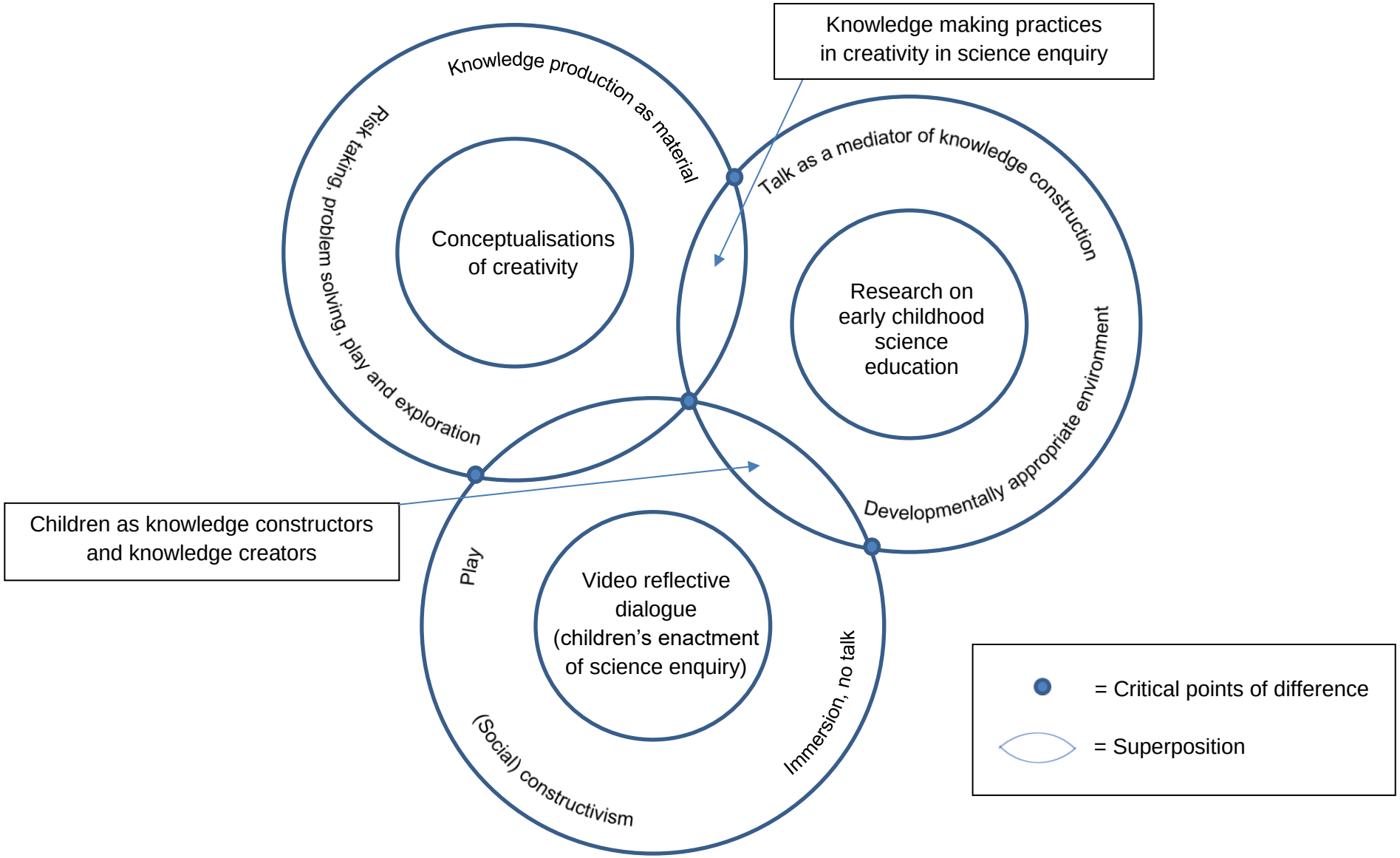

Figure six: Critical points of difference and superpositions within the phenomenon of practitioners' shared understandings of young children's science enquiry

Figure six also illustrates a critical point of difference as created and emergent from the apparatus i) existing research on early science education and creativity, which situates children's knowledge making within the confines of the individual, and ii) broader conceptualisations of creativity, outside of the discipline of education. In particular, those within the domain of art which articulate creativity as enacted through engagement with materials (Malafouris *et al.*, 2014). Materials, in this instance, are recognised as acted upon but also as acting on the creator to enable the production of something new. Thus, a critical point of difference in this diffraction lies between a material perspective on creativity and cognitive perspectives on creativity in science enquiry. A second point of difference in figure six appears between the apparatus i) video footage illuminating practitioners' concern over the role of talk - provoked by footage of children deeply immersed with materials - and ii) existing research on early childhood science pedagogy, creating disturbance in established and normative approaches to supporting young children's knowledge making in science enquiry.

The critical points of difference illuminate entangled points from which there is potential for new material-discursive configurations and understandings to be created. A boundary - an 'agentic cut' - which 'is determinate for a moment where exteriorities emerge into the world' (Barad, 2007, p. 148), supports this enactment and the creation of something new from these differences. That is, in this analysis agentic cuts are made of and through the phenomenon of shared understandings of children's creative knowledge making practices in science enquiry using the material-discursive apparatus of theoretical conceptualisations and video footage. Here new cuts are enacted as critical points of difference collide and diffract as 'waves' to create superpositions which are later explored in the findings chapter.

Towards an ethico-onto-epistemological position: a pause to consider ethical entanglement

In this study, diffractive methodology is understood as a critical practice for making a difference in the world (Barad, 2007, p.90). As such, it is acknowledged as entailing a commitment to considering 'which differences matter, how they matter, and for whom'. It is also recognised that as I engage in research to make knowledge, I 'participate in reconfiguring the world' (Barad, 2007, pp. 90-91). From this

perspective, I am not simply observing or telling the story of a diffraction pattern but rather I am co-constitutive of the apparatus that measures and creates knowledge (Murris and Bozalek, 2019, p. 9). Thus, as Barad (2007) argues, in an entangled relationship I am in some way responsible for agential cuts that reconfigure the material-discursive becoming of the world.

Whilst pondering the act of diffractive analysis from this perspective I have questioned;

How, then, will I take responsibility for what is made visible and necessarily invisible within a phenomenon, and, How will I responsibly explore the/my entanglement and the differences that this makes?

The importance of transparency as an act of taking responsibility has emerged from these questions of visibility, invisibility and entanglement. In their diffractive analysis, Chappell *et al.* (2019) describe this as a necessary 'different' standpoint to ensure rigor. Concurring, I have recorded experiments with ideas and created visual and textual documentation which illustrates the emergence of a new approach to diffractive analysis (see appendix five). I have also made visible motivations for experimenting with new materialist concepts. These inevitably produce ways of seeing young children's creativity in science enquiry and affect what is made visible or invisible, or rather that which might 'not yet [be] known' (Davies, 2020, p.148). In analysis and the subsequent search for a deeper understanding of creativity in science enquiry, I have foregrounded and made visible an empathic approach which asks, 'what is it to be this?' (Davies, 2014, p.738), attempting to shift away from a moral position which judges or relates values to interpretivist and diffractive readings. However, while this empathic stance is affective in that it exposes ethical dilemmas that are part of knowledge making processes (Bell and Vachhani, 2020), it is also not without complication. For instance, in Kaplan's (2019, p.168) troubling of the location of ethics in new materialism, she questions what entangled ethical responsibility might be, given that new materialism 'decentres the subject from its human position of privilege'. Exploring this issue through Barad (2007) and Bennett (2010, p.6), Bell and Vachhani (2020) offer an ethics of mattering as affective in material encounters. Foregrounding matter as relational, they suggest that ethics could be considered in

terms of ‘what associations matter makes and what capacities it has to affect its relations’. These appear relevant points with regards to this study which engages with the material of theory and empirical research. In particular, they resonate with my experiences in selecting fragments of literature to read diffractively. Along with Bennett’s (2010) claim that the starting point of ethics is acknowledgement of human shared vital materiality, Bell and Vachhani’s (2020) position become an interesting starting point for further exploration in the findings chapter.

To summarise, for much of the first part of the research *I* framed ethics and *my* ethical position through dualist perspectives and values advocated within the field of early childhood studies. An ethical relationship could thus be established between separate subjects: researcher and participant; participant and child. Relationships appeared to me as ethical in nature if I acted with care and respect, and promoted democracy and participation (Larsson *et al.*, 2019; Pascal and Bertram, 2012; Nutbrown, 2010). For instance, I invited participants to co-present with me at an EECERA conference (2017, 27th EECERA conference, Bologna, Italy). Two were keen and together we drafted a paper exploring emergent ideas about children’s relationship with the agency of the landscape. One participant and I eventually presented the paper. It was a rich experience which engendered a sense of achievement. Ethically speaking, I had adhered to a code which foregrounded respectful relationships, co-creation of meaning and attention to differing perspectives in knowledge making processes. These were ways of being which aligned with the interpretivist methodological position that I had embraced.

However, ‘enacting’ ethics in these terms gave rise to irreconcilable tensions. For example, the participatory, democratic stance that I had adopted was ideological and productive of power imbalances, which manifested in the ‘active’, interpreting researcher and the ‘studied’ participant. Such imbalances were not resolved by co-presenting at a conference or in seeking ways to include all voices (as discussed in part one of the chapter). Rather, in *being* researcher and participant an inequitable relationship was (re)produced. The key issue was that my ontological position understood ethics as static and informed by epistemological separations. Binaries split subjects into autonomous and agentic individuals and ethics was my human ‘possession’. In my role of researcher, I was guided by a framework which fixed my

behaviours. Through morals and judgement, I was bound and contained as a ‘good’ researcher, and, in attempting to employ a framework, I had removed myself from taking responsibility for the consequences of what was made to matter. Indeed, the framework told me what mattered and I paid little attention to consequences. Caring, respectful relationships were reduced to rationalised attributes.

As I have engaged with new materialist thinking, my understanding of ethics has shifted. That is, I consider ethics as entangled and emergent in phenomenon. Subsequently, in reading the phenomenon of shared understandings of young children’s science enquiry diffractively, ethics has moved subtly from a being to a *doing* (Kaplan, 2019). For example, as I attuned to relational, affective experiences in the diffractive encounter, I was aware of interruptions and differences in colliding intra-active fragments of text and video footage. I attended to my entanglement in these interruptions, noticing how I experienced moments of intensity and uncertainty. This was an uncomfortable and unknown space which was easy to avoid or silence (McGregor, 2020). However, staying there and ‘letting go’ gave rise to ethical dilemmas.

This is illustrated in a critical point of difference which emerged though the diffracting apparatus i) existing research on early science education and creativity, which situates children’s knowledge making within the confines of the individual, and ii) broader conceptualisations of creativity, outside of the discipline of education. Here I registered affect in an ethical encounter with text and video footage which produced children and practitioners through constructivist perspectives. That is, children as agentic *and* disempowered *and* in need of guidance; becoming through contradictory authorities which cast early childhood practitioners as both powerful *and* weak. The binary created in current dominant discourse was stark in its disempowerment and discipline. Moreover, from my original, binaried position which foregrounded an ethics of care, I could feel how I reproduced children as agentic but disempowered, and adults as knowing but lacking. I was complicit in creating adult/child hierarchies.

From an ethico-onto-epistemic position, I recognise that ethical dilemmas cannot be fully anticipated. Rather, it is necessary to be alert to the register of affect in a moment which is made to matter, so that ethical responsibility can be taken for

agential cuts that reconfigure the world in particular ways. By focusing on entangled material discursive intra-actions rather than pre-established categories and hierarchical binaries, ethics is co-constitutive of phenomena in its differential becoming (Barad, 2007).

Broadly speaking, presented in this chapter as ‘early meaning making’ and ‘later knowledge creation’ are two apparatus responsible for two distinct agential cuts. The first, using the apparatus of interpretivism, reflects existing knowledge and understanding as conceptualised within the dominant discourse of constructivism. Making a ‘cut’ using these tools creates a mirror to that which is already known. A second cut with the apparatus of new materialism illuminates knowledge making practices as enacted from a position in which difference is performative and creative. Rather than constricted and bound to conventions which encourage the deconstruction and reduction of data, experimentation is emphasised (MacLure, 2017). The introduction of a new approach to diffractive analysis draws on this position, centring on the critical points of difference which mark where apparatus collide and superpose to create new indeterminate meaning, depending on the agential cut (Barad, 2007).

The following chapter turns to the findings of the study. Each of the three guiding research questions is considered though attention is paid to research question three and the diffraction of the apparatus made visible within the phenomenon of shared understandings of creativity in science enquiry:

i) empirical research data of shared understandings held by early childhood practitioners, as illustrated through video reflective dialogues in which children’s enactment of science enquiry was interpreted as immersive with no or little talk; playful, individual engagement with materials; or through talk with practitioners or peers.

ii) existing research on early childhood science education, in which science enquiry is commonly perceived to be enacted through a developmentally appropriate environment in which an agentic child manipulates materials for concept formation; and/or through language as a mediator for knowledge construction.

iii) conceptualisations of creativity including those within early science education which draw attention to, for instance, risk taking, problem solving, play and exploration; and within art which recognises materials in the creative process.

Chapter Four: Findings

Echoing the structure of the Research Design chapter, the Findings are presented in two distinct parts. The first, early insights, focuses on research question two:

- What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

Thus, key interpretations of early childhood practitioners' shared understandings of young children's creativity in science enquiry which emerged from thematic analysis are outlined. Findings which relate to the potential that Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) hold in contributing to practitioners' perspectives are also presented in the first part of the chapter.

The second part of the chapter is entitled diffractive readings and focuses on research question three:

- What insights are gained from a diffractive analysis of current understandings in literature and of empirical research of young children's creativity in science enquiry?

Outlined, in relation to this question, are findings from a diffractive analysis of i) current literature on early childhood science education, ii) creativity as conceptualised within the domain of art, and ii) fragments of the empirical research presented in the early insights section of the chapter. The diffractive readings are inclusive of my voice. This contextualises the empirical data and illuminates my entanglement within the apparatus in the phenomenon of shared understandings of young children's creativity in science enquiry. Making my voice visible in such a way is a register of ethical affects. Although it is partial and considered, it enables me to take some responsibility for my presence and influence within the practice of knowledge making through diffraction.

Findings Part One

Early insights

As research question two, centring on early childhood practitioners' shared Video Reflective Dialogues (Moyles *et al.*, 2003), guided the initial phase of data collection and analysis, the findings presented below are reflective of my early meaning making. The interpretivist approach used in this phase was later considered to contribute to the reproduction of existing knowledge, as opposed to any new perspectives (Barad, 2007). Nevertheless, the findings presented here are significant both as an illustration of an 'agential cut' through the data which defines a moment of how I came to understand shared perspectives on young children's creativity in science enquiry, and as a means through which a diffractive reading might later be enacted to produce a *different* moment of insight into young children's creativity in science enquiry.

The findings below are presented with particular reference to firstly, my interpretation of early childhood practitioners' shared understandings of young children's creativity in science enquiry, and secondly the potential Video Stimulated Reflective Dialogues VSRD (Moyles *et al.*, 2003) holds in contributing to these understandings. They are drawn from three key pieces of data i) coded and analysed dialogues between practitioners within the three case studies, which drew on Charmaz' (2006) approach to constructing Grounded Theory and dialogic methodology (Sullivan, 2012); ii) analysed simple agreement scales which formed generalised perspectives and; iii) revisiting the raw video footage. Pseudonyms are used to support anonymity.

Influence of constructivist perspectives and child-centred approaches

It is important to note here that, in my role as participant and researcher, I positioned myself as part of each case study by engaging in video reflective dialogues. This position supported and influenced my understanding of practitioners' shared perspectives and ways of making sense of video footage. Whilst my ongoing interpretations were discussed with practitioners at the beginning of each video reflective dialogue session, to validate my insights, what is presented here are essentially my interpretations of frames of reference that practitioners drew upon in dialogues to develop shared understandings.

Beginning with a broad picture, early childhood practitioners' video reflective dialogues which focused on children's engagement in scientific enquiry, appeared to align with familiar perspectives in early childhood science texts (see for example, Davies *et al.*, 2014; Harlen and Qualter, 2018; Tunnicliffe, 2015). The most common themes are illustrated below. They are taken from perspectives that practitioners agreed upon as a group within their respective case study, following video stimulated reflective dialogue sessions.

Practitioners in case study one (under three years in the nursery and children's centre) and three (three-four and four-five years in the primary school) described science enquiry as underpinned by a process involving specific skills.

> *'Children under three years use process skills: observation; prediction; hypotheses; gathering evidence; and pattern-seeking through repetition in science enquiry.'*
>
> (Generalised perspectives on session 1: case study one, session two)

> *'Science enquiry is a structured process involving skills.'*
>
> (Generalised perspectives on session 1: case study three, session two)

Although not an explicitly shared perspective, practitioners in case study two (three-four years in the nursery and children's centre) also identified that children demonstrated science skills during their enquiries both in video reflective dialogues and in agreed perspectives, as illustrated below.

> *'Children can take on the role of knowledgeable other following modelling – e.g. by developing hypotheses through imitation of the knowledgeable adult.'*
>
> (Generalised perspectives on session 2: case study two, session three)

Within case study two, practitioners described science enquiry in terms of collaboration and co-research. Related, the term 'co-construction' was used intermittently by practitioners in all three case studies. There was also agreement in

all cases that science enquiry is a human, social endeavour which includes thought, talk and the sharing of ideas.

> *'When co-research is promoted, science becomes more powerful as it involves discovery and making meaning.'*
>
> (Generalised perspectives on session 1: case study two, session two)

> *'Science enquiry involves sharing ideas.'*
>
> (Generalised perspectives on session 1: case study three, session two)

Practitioners within the three case studies also identified the process of science enquiry as supporting the exploration and/or development of scientific knowledge.

> *'There is a relationship between 'schemas' and scientific concept development – this is closely linked to the process of enquiry, e.g. repetition and experimenting with a dropping schema can be related to an early enquiry about physics/gravity.'*
>
> (Generalised perspectives on session 2: case study two, session three)

> *'Children can repeat activities multiple times and in different ways or cycles when immersed in a science enquiry' and 'children can explore the same concept in different ways.'*
>
> (Generalised perspectives on session 2: case study one, session three)

> *'Knowledge is created through enquiry and can develop over a period of time.'*
>
> (Generalised perspectives on session 1: case study three, session two)

Practitioners within case studies one and two made links between science enquiry and sensory experiences. This included consensus that children use their body and resources to make meaning. Although this was less apparent in case study three, reference was made to activities involving sensory exploration such as making bubbles and dough.

> *'Children can seek a sensory and some a whole-body experience. However, there are children who don't physically immerse themselves in a science enquiry.'*

(Generalised perspectives on session 2: case study one, session three)

'Children use space to illustrate meaning and understanding, e.g. by moving across and lying over the book to emphasise the trajectory of a meteorite.'

'Children use resources to make meaning, i.e. in the video clip, buttons were used to experiment with and to illustrate theories in surprising ways.'

(Generalised perspectives on session 2: case study two, session three)

The practitioners in case studies one and three explicitly agreed science enquiry as needing to include opportunities for children to take the lead.

'Science enquiry involves self-initiated exploration.'

(Generalised perspectives on session 1: case study one, session two)

'Enquiry should be led by children's interests.'

(Generalised perspectives on session 1: case study three, session two)

Recognition that children engage in and develop their own lines of enquiry was implicit in some of the perspectives agreed by practitioners in case study two. For instance,

'Adults respond to children's questions to support children in developing their lines of enquiry.'

(Generalised perspectives on session 3: case study two, session four)

Practitioners in all three case studies agreed, to a lesser or greater extent, that science enquiry involves process skills and the exploration of scientific concepts, which are developed through thought, language, co-research or co-construction. There was general agreement by practitioners in case studies one and three that children should lead scientific enquiry. Although practitioners in case study two recognised that children develop enquiries, discussion about this was often focused on the relational role of the practitioner. Practitioners in case studies one and two made an explicit association between science enquiry and sensory experience

and/or use of resources, to promote meaning making. This theme is further explored later, through the finding focused specifically on children's engagement with materials in science enquiry. Attention is first given to the findings which illustrate my interpretation of practitioners' implicit use of constructivist, socio-cultural and child-centred perspectives to make sense of children's engagement in science enquiry.

Weaving perspectives

Piagetian, Vygotskian and child-centred perspectives appeared to contribute to the frames of reference that practitioners drew on to interpret young children's engagement in science enquiry. Indeed, at times, all three perspectives seemed entwined in dialogues. This was particularly apparent in practitioners' reference to the importance of promoting rich and varied environments; a perspective which reflects widely recommended practice in both The Early Years Foundation Stage (DfE, 2017) and science texts for early childhood practitioners (see for instance, Burton and Thornton, 2010; Johnston, 2014). For instance, in the excerpt below, a practitioner in case study one reflects on one child's fascination with water and her subsequent focus on ensuring open access to resources for exploration. The excerpt is taken from the first video reflective dialogue session in which seven practitioners shared their broad experiences of working with children in the context of science enquiry using the abstract from Andersson and Gullberg (2012) as a stimulus for discussion.

> *Lilian*: I have a boy who is very interested in water at the moment, since September actually, his explorations with water. He is very much into floating and sinking at the moment. But he explores it when he wants to...the resources are all around so when he wants to go and explore these concepts he can, there is no sort of I have set it out for you, I might have set them up around him that he can choose to if he wants to and he knows it is there when he wants to and he does.
>
> (Excerpt of video footage case study one: session one a, 05:40-06:05/20:00)

Practitioners in case study three also advocated for rich and varied environments. For instance, in the following excerpt from the fifth video dialogue session, four practitioners discussed children's engagement with open-ended resources, the importance of allowing children to direct the route of enquiry, and children's

collaboration with resources. The excerpt is taken from a longer discussion about links between art and science which was stimulated by video footage of a group of children colour mixing with paint on paper. Prior to the excerpt, discussion had shifted to the use of resources as provocations for learning.

> *Anna*: ...on one of the tables was a big tray of bubbles and water and they [*the children*] just explored that for a good hour and a half, all of the different children just going in and blowing the bubbles and trying to work out what was in the different types of bubbles and lot of them tried to get into this big mountain of bubbles, but again it was very open ended and very simple but they could spend a really long time exploring that in loads of different ways. They could see each other through the bubbles which was really nice.
>
> *Charly*: It's interesting that sometimes you actually give them [*the children*] an idea because you were talking about them going to see what would happen when you mix them but other times you just leave it and see what happens. We just put oil and water and paint in a builder's tray and that was amazing because they made dough and it just turned into a completely amazing different activity and they were amazed by it. No direction was given there at all, we just left them. Sometimes it's just lovely to see what they come up with.
>
> (Excerpt of video footage case study three: session five, 12:23-13:19/28:00)

Within the context of the wider video dialogue sessions, such commentary seemed underpinned by a mix of theoretical positions. This is illustrated in the excerpt from case study one in that the practitioner places the child at the centre, pre-determines resources to support concept development and also stands back. Such a combination of positions echo both a democratic child-centred view in that children should direct their own learning and a developmentalist position on child-centred practice as influenced by Piaget (Chung and Walsh, 2000). In the excerpt from case study three, Piagetian perspectives which are suggested in the practitioner's creation of a stimulating environment for learning, access to a range of resources, and a specific focus on learning (Fleer and March, 2009), seem positioned alongside a more democratic view of child-centred practice in which children are able to access resources to support their autonomy, 'natural' curiosity, and freedom to explore with the practitioner alongside (Campbell-Barr *et al*., 2018).

Piagetian perspectives

The early video reflective dialogues of practitioners in case study one (sessions one and two) continued to echo Piagetian perspectives on young children's scientific enquiry. For example, in the following excerpts taken from the first session, a practitioner firstly describes a child hypothesising and experimenting with water and sand to create water channels and dams. Then, in the second excerpt, an account is given of the same child exploring the phenomena floating and sinking in different conditions. The excerpts are taken from a longer discussion in which children were described as hypothesising, making links and pattern seeking with materials, mirroring literature on early childhood science (see for instance, Areljung and Kelly-Ware, 2016; Gopnik, 2009). Piagetian perspectives appeared implicit in the description of a child's hypothesis and subsequent sensory exploration of different materials in the world around them.

> *Lilian*: He [*the child*] was also interested in runners of water. He was exploring making dams and he was doing it by collecting bark off of the floor and he was silent, and I could just see him watching and I filmed him, well sort of filmed him. But he was silent, and I could just see what he was doing. You know, he was making the dam and he was pouring the water here and watching down here to see the thing and then a...you know there were small snippets of language such as 'it's stuck', I think. Um, yeah it was fascinating. He has done it in the sand as well - making rivers in the sand, having the water flow and saying I'm trying to make it go over there. He was trying to control the flow um….and he has his own sort of ideas. He hypotheses a little bit because he found a...back at the water runs there is a guard...they come with dams and one of them has a hole in it and he picks the up the guard and said, he'd been thinking about what he would do with the part, and he said 'it will go through the hole' so he tried it out and it went through the hole and then there is a solid guard and he said 'it not go through'. So that was his ideas before he actually did the physical exploration.
>
> (Excerpt of video footage case study one: session one a, 06:50-08:22/28:00)

> *Lilian*: You know, one day we had sort of this very murky water and the fact that he [*the child*] couldn't see it sinking was fascinating to him and he had to rummage around the bottom to feel to the object whereas the next day he had the clearer water so he could see the object sinking and it was all from his own ideas and I couldn't have brought that to him.

(Excerpt of video footage case study one: session one a, 06:22-06:43/28:00)

In the excerpt below, from the second video dialogue session with case study one, a practitioner and I also appear to interpret children's engagement and explorations with magnets in alignment with Piagetian perspectives on sensorimotor stages of learning. That is, science considered as a multi-sensory, hands-on and minds-on experience (Harlen, 2013; Fleer and March, 2009) which involves physical engagement with materials to support problem solving. Prior to the excerpt, seven practitioners in the session had watched video footage of a small group of children exploring giant magnets and paperclips on a table and on the floor in a busy room. They had also discussed children's general immersion in the enquiry and had begun to focus on cognitive engagement.

> *Re*: Looking at some of the comments we reviewed, there are so many parallels in that one [*the video clip*], particularly about the multisensory experience and physically engaging with objects being important in enquiry. Another theme that you talked about a lot last time is the cognitive aspect, thinking and curiosity. Do you think that aspect is evident in the two clips?
>
> *Maddie*: It's quite hard to think, especially when you know he [*the child*] may have these ideas but may not recognise them. But through his actions, I mean it's our interpretation, we might have a completely different interpretation. But it seems to me there was some cognitive thinking, it wasn't all multisensory actions. There was some thinking about what it is; I'm going to change the speed, I'm going to change the height, what will happen?
>
> *Re*: And with repetition as well, there was quite a lot of repetition in your clip as well, with magnets. That first section, the wonderment, let's do it again. Perhaps that links with cognitive concepts as well? Consciously repeating an idea.

(Excerpt of video footage case study one: session two, 26:10-27:39/30:00)

Most notable in this excerpt is practitioners' connection between the word cognition and a multisensory experience. That is, a child's exploration of paper clips and magnets appears to be perceived as a catalyst for ideas and thought building. A tentative association is also made between the child's repetition in their enquiry and

cognitive development suggesting that materials might be used to collect data and support the development of ideas.

Vygotskian Perspectives

In the first and second video dialogue sessions with case study one, practitioners also appeared to mirror Vygotskian perspectives which position the early childhood practitioner as a mediator of scientific knowledge and understanding through use of language. For instance, in the excerpt below, from the first session, seven practitioners and I listened to one practitioner's reflection on a young child's enquiry around floating and sinking. The practitioner had explained that the child had been fascinated by this phenomenon and had repeatedly come back to water to explore the ways in which objects reacted when dropped into it.

> *Lilian*: He [*the child*] goes to it and the language that he uses is about swimming on top so I can introduce then, 'oh, they are floating' and he is just fascinated by all the different ways.
>
> (Excerpt of video footage case study one: session one a, 06:07-06:20/28:00)

Sociocultural ideas which influence common understanding about the nature of science as a discourse (Driver *et al.*, 1994), that is language and communication are essential for learning, also seemed evident in the following excerpt from the second video reflective dialogue session in which seven practitioners and I focused on children's use of everyday language whilst discussing their experiences of magnets. In the excerpt two practitioners and I consider how children's talk illustrated their experiences and emergent understanding of the concept of force.

> *Maddie*: She [*the child*] also called it an iron, she called a big magnet an iron. She also amazed me actually, saying a hoover.
>
> *Re*: That seems to be about making a lot of connections going on in that clip as well.
>
> *Maddie*: And I've never thought of a magnet like being able to hoover, until she [*the child*] said it. So I thought ok, I'm wishing everything is magnetic.

> *Lilian*: I loved it when…did the [gestures pulling back with her arms] behind his back. You could never have planned that. The way he [*the child*] did that was incredible. You could really see that force [*gestures by pulling closed fists away from each other*].
>
> *Maddie*: And when he [*the child*] actually said, I know, obviously, it's not all about language, he felt quite empowered by being able to say 'pull'. Even though English was not his first language and he's got loads of language in his first language…. I really felt that he felt empowered by being able to go pull [*draws a breath and calls out ooh, ooh, ooh*].
>
> (Excerpt of video footage case study one: session two, 24:23-25:24/30:00)

Early childhood practitioners' interpretations about children's engagement with magnets also appeared to reflect Vygotskian perspectives in this final excerpt from the second video dialogue session. Here, emphasis seemed placed on the importance of human social activity to support learning (Vygotsky, 1981). The excerpt is taken from the end of the discussion which was focused on two children's interactions with a set of powerful magnets.

> *Lilian*: It's really nice to see the interactions in the group as well, a big group playing together getting ideas from each other. They may see other children try out an idea and try it out. Getting ideas from each other.
>
> *Maddie*: A nice bit as well, where Kai had one magnet and Petie had another and they were trying to pull them away from each other. But they didn't have equal strength, so they couldn't. In the end they both fell and started giggling. They persevered again and they did separate them.
>
> (Excerpt of video footage case study one: session two, 27:49-28:21/30:00)

The socio-cultural perspective positioning the role of early childhood practitioners as mediators of knowledge through language and scientific discourse (Driver *et al.*, 1994; Mercer and Littleton, 2007) also appeared evident in the video reflective dialogues of case study two. For instance, in their second session eight practitioners, reflected on video footage in which one practitioner had engaged playfully with a group of five children exploring mirrors. The excerpts below are taken from the dialogue which began immediately after the video footage had been watched. In the

excerpts, a practitioner articulates her role using terms associated with constructivism. This includes ‘facilitator’ to support initial lines of enquiry and ‘scaffolder’ to support the development of ideas.

> *Tish*:...and then, that effect that you see lots of reflections, so they [*the children*] were involved in that. I facilitated that to begin with, then they took over. And then, they took over, and then I held a big mirror behind. They held a small mirror to manipulate the movement of multiple reflections. And then we put it under our noses and Emris fell over because she was walking on the sky. We came outside and did lots of climbing with it and underneath the trees. And then we talked about what was happening, lots of technical language coming out about reflections and things like that. It was a good line of enquiry. That actually came from a mirror that is constantly in our room and lots of them were starting to do different things like looking behind them. So we did lots of things, there’s another video where Harry is lying on his back and realising he can see children without having to move his head, just move the mirror. That was over a couple of days.
>
> (Excerpt of video footage case study two: session 2a, 00:19-01:41/12:00)

In this first excerpt, the practitioner guides the interaction between children using the mirror to initiate the enquiry and then talk as a tool for sharing ideas. Additionally, the practitioner appears to place value on supporting children to build scientific understanding through her connection between the term ‘technical language’ and a ‘good line of enquiry’.

> *Molly*: I loved the idea that you brought the perspective that you brought the horse on, so you could see the horse’s tummy, and suddenly, I thought that opened their [*the children’s*] minds up. Because you had given them that thread, that way to look at it differently. Because then they brought lots of different things on didn’t they?
>
> *Tish*: Exactly, that’s when the technical language came out.
>
> *Jamie*: Lots of experimenting then, isn’t it?
>
> *Tish*: Yes, I often find that, especially at this time of year, you are presenting something and then they [*the children*] follow their own lines of enquiry at this point. It all comes out from something initially, but it’s extended as part of that scaffolding, there’s a next sort of perspective on it.

(Excerpt of video footage case study two: session 2a, 03:49-04:39/12:00)

Building on the first excerpt, the practitioners' dialogue makes reference to how the learning environment can be maximised to promote interactions and new thinking. Children's use of 'technical', scientific language is linked to this and the practitioner's talk positioned as a scaffolding tool which can be used to develop children's understanding.

This perspective which foregrounds talk as a mediator of learning was agreed with by other practitioners in the group and summarised by me in the following session.

> *'The role of the adult is to pick up on critical incidents and use them as discussion points for learning, e.g. the unexpected happening with mirrors (children stumbling over objects, children being able to use mirrors to see things outside of their usual sightline).'*
>
> (Generalised perspectives on session 2: case study two, session three)

Practitioners also agreed that adults and children mediated learning through modelling the science process:

> *'By bringing knowledge and conceptual understanding to the enquiry practitioners enrich children's experiences and provide an enabling structure to work within.'*
>
> *'Children can take on the role of knowledgeable other following modelling, e.g. by developing hypotheses through imitation of the knowledgeable adult.'*
>
> *'Parents play an important role as knowledgeable others: lines of enquiry can be extended through talk and objects at home.'*
>
> (Generalised perspectives on session 2: case study two, session three)

Similarly to case study one and two, early childhood practitioners within case study three seemed to draw on sociocultural perspectives as a frame of reference in their interpretations. In particular, the role of the adult as a 'More Knowledgeable Other' appeared evident. For instance, in the following excerpts from the third video reflective dialogue session, practitioners defined their role as a 'scaffolder' who

mediates knowledge through language. It is notable that there seemed a subtle shift in emphasis from shared enquiry as appeared in case study one and two, to a focus on the imparting of predetermined scientific knowledge. This might have been due to the differing age groups and settings in the study. For instance, in case study one and two practitioners worked alongside children aged under three years and three to four years respectively, in a nursery and children's centre. Whereas practitioners in case study three, worked with a mix of children aged three to four years and four to five years in a primary school. Whilst emphasis was placed on children's own discovery framed within the Early Years Foundation Stage (DfE, 2017) in all cases, the primary school context of case study three was closer to the National Curriculum (DfE, 2013) and subsequently well documented top-down pressures such as ensuring that children are 'school ready' (see for example, TACTYC, 2017).

This first excerpt from case study three is taken from a reflective dialogue which emerged in response to watching video footage of a practitioner and a child investigating mirrors and reflections. The group had initially focused on the child's awe and wonder at discovering his reflection. Discussion had then moved to the experimentation and problem-solving that seemed evident in the enquiry. Finally, dialogue centred on the importance and position of talk.

> *Melissa*: I think it's because you are either scaffolding like Olivia was doing in the first one. So you're extending their [*the children's*] thinking or you're reinforcing what they are doing. But even so, Mark, who was in the first video, quite often when he is doing things you would say for example, 'look, you are putting them on top of each other'. You might see that they [*the children*] aren't balancing, but you say, how you've noticed the sun is bouncing off it.
>
> *Anna*: Reflecting
>
> *Melissa*: Is reflecting off it. So it's giving them [*the children*] words to explain what they are doing.
>
> ……
>
> *Melissa*: I know I used to do in year one, we still did the same.

Anna: I think it's because they [*the children*] might not have those words in their vocabulary yet. So, it's about scaffolding, giving them that bit of knowledge of what they are doing and just extending that for them.

(Excerpt of video footage case study three: session three, 15:35-17:00/32:00)

Later in the same dialogue, practitioners' dialogue focused more specifically on the relationship between language and scientific concept which appeared to mirror the sociocultural perspective that scientific understanding is developed through discourse (Kelly, 2016).

Re: ...using the language about what you are seeing but you are thinking very carefully about what the science concepts are, what's behind it. That you are eliciting and watching what to develop with. It's really very sophisticated, isn't it? Really when you think about it, what the adult is doing, it's complex.

Olivia: Yes, that's what we are doing, we are building on their [*the children's*] understanding. Building their knowledge and understanding. Yes, you do really have to think about what you are saying to do it with them.

All: Agree

Melissa: Quite often I phone over to the school to the science leader or to the English leader because you don't want to get it wrong. Because if you get it wrong in year r[*eception*], they [*the children*] are going into year one with these concepts that are wrong.

(Excerpt of video footage case study three: session three, 17:57-18:41/32:00)

To summarise, whilst acknowledging my interpretation of implicit references to theoretical perspectives in practitioners' dialogues, it appeared that a Piagetian position which determines children as scientists who hypothesise and collect data through repetition (Cakir, 2008), informed understanding of early science enquiry in case study one and, on occasion, case study three. Although not returned to in later dialogues, practitioners in case study two also appeared influenced by Piagetian perspectives in their agreement that schematic and scientific concept development are closely related.

'There is a relationship between 'schemas' and scientific concept development – this is closely linked to the process of enquiry, e.g. repetition and experimenting with a dropping schema can be related to an early enquiry about physics/gravity.'

(Generalised perspectives on session 2: case study two, session three)

Vygotskian perspectives seemed interwoven in interpretations of science enquiry across the three case studies. In particular, practitioners appeared to place emphasis on the role of language to support enculturation into a scientific community and the co-construction of knowledge. A social dimension to learning was also considered and practitioners seemed to position themselves and, at times, children as More Knowledgeable Others. Within case study one and two there appeared an emphasis on shared enquiry whilst in case study three a closer association between More Knowledgeable Other and the imparting of pre-determined knowledge. It is notable that whilst the established scientific processes of questioning, hypothesising and collecting data were discussed by practitioners, other processes of scientific enquiry were not explicitly commented on in any of the video reflective dialogue sessions. For example, the presentation of data and results, and the development and justification of developing theories did not feature. Though, children's repetitions might be understood as an early expression of the latter part of science enquiry.

Pedagogical dilemmas in practice

Throughout the video reflective dialogues practitioners across the three case studies identified pedagogical dilemmas in relation to their role in supporting children's creativity in scientific enquiry. These were framed through questions as to whether practitioners should:

- stand back or interact
- talk or not talk

The dilemmas reflect literature focused on early childhood education. In particular, Cherrington (2016) who draws attention to the challenge early childhood practitioners face in re-positioning themselves from passive to active partners in children's learning experiences, and Fisher (2016) who questions whether early childhood practitioners interact or interfere when engaging with children.

For instance, in the first video dialogue session for case study one a tension emerged between learning alongside children as ‘co-enquirers’ to support cognitive exploration and thinking, and holding back to allow children to investigate independently at the risk of perpetuating ‘misconceptions’ in science. This is illustrated in the following excerpt which followed a discussion about the value that practitioners in the setting place on an enquiry-based approach to the curriculum. Seven practitioners and I were present.

> *Marie*: And we learn from the child. We may know more about it, but actually when you look at the child, hear what they are saying and doing.
>
> *Maddie*: Actually, the child inspires your own enquiry because it could be all sorts of things that if you weren’t with the child that you would walk past. But the children are inspired, oh yes, I wouldn’t have thought of that. So, we are both enquiring together.
>
> *Lilian*: I often find myself holding back quite a bit to enliven processes. Yes, if that makes sense. I know the answer, I know what they are trying.
>
> *Jay*: [Interjects] So you won’t be concerned about misconceptions then?
>
> Group laugh
>
> *Lilian*: No, I don’t know, but you know, I don’t feel that I have to give them [*children*] all the information. I want them to find out for themselves. After trial and error.
>
> *Maddie*: So, they [*children*] will understand, rather that you try to lead them.
>
> (Excerpt of video footage case study one: session one a, 12:00-13:19/20:00)

The dilemma of whether to intervene or stand back arose again in case study one’s second video dialogue session. For example, in the following excerpt, seven practitioners and I discussed the role of the adult and when intervention may be necessary in response to video footage of a young child’s enquiry with different objects and water. The video footage was solely focused on the child’s encounter with materials; the practitioner filming the enquiry had not engaged in talk but rather

positioned himself behind the camera. Prior to the excerpt, discussion had focused on the sustained nature of the enquiry, and the child's exploration of different variables.

> *Re*: It would be interesting, at what point, because it's really lovely that there's a piece of footage where there's no adults, because of intervention, at what point, because there is always tension isn't there of holding back, standing over. At what point do you step in?
>
> *Jay*: Yes and I really thought that was one of the obvious things that I was keeping silent through the whole thing.
>
> *Maddie*: Was that because you were videoing do you think? That you were purposely standing back?
>
> *Jay*: I don't know why exactly why it was but I didn't, looking back, I didn't feel too bad about being silent because he [*the child*] was so immersed. But I still think I could have been, especially after it was sometime, I mean exploring his ideas, maybe.
>
> (Excerpt of video footage case study one: session two, 14:30-15:17/30:00)

For case study one, the tension of whether to stand back or intervene was entwined with questions of whether or not to talk whilst children were immersed in scientific enquiry. In the following excerpt, which occurred after the one above, practitioners continued to reflect on video footage of a child's enquiry with objects and water. Here, their discussion touched on the effects that a practitioner's talk might potentially have on children's enquiry.

> *Lilian*: [*Talking to Jay*]. You know you said that you were quiet in that [*clip*]. I quite liked it.
>
> *Bella*: Yeah, I liked it.
>
> *Lilian*: I liked it and I was saying that because I was saying...I filmed myself with the magnets and I was on the other side of the room for that session and I was talking to her [*an early years consultant*] about it and she was saying that I used a lot of language didn't you and anticipated their [*the children's*] thinking instead of giving it to them and I whenever watched the video back, as you know because you were there with me, I hated it because I was spoke the whole time and it wasn't natural to me, though I do talk a lot [*laughs*] but it

was different and I had missed so much of that immersed stuff that I really really stopped it. Stopped them [*the children*] being immersed.

Bella: I don't think that child needed you to...You know he had ideas, he knew what he was doing and his ideas were changing. He didn't need you to give him that support, he was actually working out his own ideas. Anything you would have been adding would have been what you thought he was thinking not what he actually wanted to do…

(Excerpt of video footage case study one: session two, 16:55-18:00/30:00)

Later again in the same session, the practitioners reflected on video footage of three children's lively exploration of magnets. In the footage a practitioner talked consistently to the children, mirroring their language and using her voice affirmatively. Practitioners' dialogues focused on when and how adult's talk might be enacted in children's enquiries. Additionally, one practitioner reflected on the use of talk in relation to subject specific vocabulary and concepts.

Maddie: [*Referring to herself on the video*] And that's an example of talking too much!

Re: And something that again came out last time we met, was that children are individuals, and they all engage in different ways, and interactions tend to be different according to the context, and you know, it seems absolutely right and valid that is how you talked to them.

Jay: It seems to me that they [*the children*] talked when they wanted to, whenever they looked at you, or showed you something, or they looked at something to pick up. It seems that was when they talked.

Sarah: I really liked the fact that you said, the magnets liked each other. Because I always find it a bit strange that those magnets, like, it's really a scientific concept. That you are teaching them [*the children*] that they attract but saying it in everyday vocabulary. I never really thought to describe it like that. It's really good, I liked that.

(Excerpt of video footage case study one: session two, 23:00-24:03/30:00)

Related to the practitioner's comments about the use of scientific vocabulary and teaching of scientific concept in the excerpt above, a tension between whether

children should develop knowledge of established scientific concepts or explore and develop their own ideas was identified by practitioners in case study two.

> *'There is a tension between supporting the development of knowledge and concepts through explanation and encouraging children to develop their own theories through experience.'*
>
> (Generalised perspectives on session 1: case study two, session two)

The pedagogical dilemmas of whether to intervene or stand back, and how and when to talk were to become concerns which were returned to repeatedly during the study for practitioners in case study one. For instance, in the following excerpt taken from the third video dialogue session, a practitioner who had shared video footage with a group of six practitioners, grapples with both whether to intervene or whether to talk. The dialogue took place after the practitioner had reflected on the footage in which she had positioned herself 'off camera' whilst a child played with water. The practitioner had spoken intermittently and tentatively to the child, asking closed questions, mirroring the child's language and using positive affirmations.

> *Re*: Thinking about the language, I noticed that you [*Ally*] did quite a few pauses - there were moments when the first crash of water happened...my immediate reaction would have been - woah! - but you paused - you really waited for her [*the child*] to have her reaction before [*you gave yours*]. Was that purposeful? How important was that do you think?
>
> *[PAUSE]*
>
> *Ally*: I was thinking it was more, I knew I was talking a lot and I just wanted to be quiet - it's hard to judge when you shouldn't and when you should talk. There is that big debate on [*referring to the group*], are we part of it? Should we be talking? Should we be using that language? I think part of me wanted to be part of it and then part of me wanted her [*the child*] to talk.

(Excerpt of video footage case study one: session three a, 23:44-24:28/01:04:00)

Practitioners in case study two also discussed when it was necessary to stand back and not intervene, or whether they should talk. For example, in the following excerpt, taken from the third video dialogue session in which eight practitioners had watched video footage of children playing with strips of material and bags on a windy hill, two practitioners described their experiences and reactions whilst children were

immersed in scientific enquiry. It is of note that, rather than identifying a dilemma, they presented standing back or intervening in terms of a choice that had resulted from their attunement to children engaged within ‘a moment’.

> *Tish*: And I tried to steer it to a more verbal response and it wasn’t happening was it?...So I think that that is something that was a factor.
>
> *Barney*: They [*the children*] are too much in the moment, experiencing it.
>
> *Tish*: Yes, exactly…so I realised that I should step back.
>
> *Jamie*: But you were respecting the children's responses, not saying, hang on everyone stop and think.
>
> (Excerpt of video footage case study two: session three, 14:30-15:00/48:00)

In the fourth video dialogue session for case study two, a group of six practitioners discussed the wider consequences which influence the dilemma of whether to talk or not talk in interactions with children during their scientific enquiries. Their dialogue countered literature which identifies a link between perceived insufficient adult intervention through talk and scaffolding and an impoverished early childhood education (see for instance, Johnston, 2009; Siraj-Blatchford, 2009). The following illustrative excerpt is taken from the dialogue. It began after I had given a summary of emergent themes about immersion in enquiry, spaces for enquiry and talk.

> *Re*: This role of the adult as a presence and the importance of allowing children space to be able to show you [*practitioners*] their interests in science non-verbally. Which I know is part of your established practice, but I also know this is not what’s widely seen.
>
> *Tish*: No, in a lot of settings that I have worked at you would be seen as not engaging in that instance, not interacting. That wouldn’t be a positive observation of your practice. Yes, it is very skilful and there needs to be cultural support and understanding of that within the setting that you are working.
>
> *Jamie*: Well, there seems to be a lot of literature that, like you are saying puts the onus on [*talk*], and in fact, there’s the whole sustained [*shared*] thinking idea that was based on that direct intervention.

Re: And then there is all the 80:20 stuff, you know about adult interaction, but that gets in the way of some of that.

Tish: And also, the pressures of data collection. That is very, very prevalent in schools. And then for you to be sort of not verbally interacting or even in that way is not seen as positive.

Re: And I suppose by nature talking and language is one of our primary means of communication. And that holding back but still being very much in the moment is really skillful. It takes a lot not to interrupt.

(Excerpt of video footage case study two: session four, 05:32-07:26/53:00)

During the last two video dialogue sessions with case study three, early childhood practitioners turned to the dilemma of whether to talk or not whilst children were immersed in scientific enquiry. For example, the fourth video dialogue session began with a practitioner sharing video footage of a small group of children investigating a large number of objects in a water tray. Following this she discussed an emergent pedagogical dilemma linked to questioning with the group of four practitioners and me. This is illustrated in the following excerpt.

Lena: About the questioning, I obviously, I didn't really know whether to and you know when he [*the child*] didn't reply to me..I just..but that was the whole..I didn't know whether to go in and try and get a bit more or whether to just kind of, you know, [*step back*] so it was a bit like seeing…

Melissa: I like that you left it rather than going in.

Lena: Yeah, I know that is why I left it because I thought, do you know what he [*the child*] is just engaged in what he is doing and he doesn't want, he doesn't really need. It might have been that he didn't know how to put into words what he was doing, but um, yeah.

Anna: I think that it was his [*the child's*] initial exploration though, I think he needed that time to initially explore it so that he could then build the language to then tell you. Especially with that child who stammers anyway um because he rushes to get out what he wants to say….

Lena: As our roles sometimes, you are a bit unsure, do I question do I leave so sometimes you have to just kind of dip in and out.

(Excerpt of video footage case study three: session four, 07:46-08:51/47:00)

In the same session practitioners' talk shifted to focus on how such pedagogical dilemmas might be resolved in practice. For instance, staying attuned to children's cues to 'co-construct' knowledge were described as a strategy to support making decisions about when to interact and talk with children. The discussion also focused on how practitioners decide to question whilst a child is immersed in a science enquiry. This led to a broader discussion about the 'middle ground' in which practitioners find themselves, in light of being bound to the Early Years Foundation Stage (DfE, 2017) and National Curriculum (DfE, 2013). Such 'middle ground' was suggested as potentially involving 'a line' between encouraging co-constructed exploration and pre-determining the outcome of an enquiry. In order to manage this, practitioners described acting vaguely in their interactions with children. Such interactions would subsequently be developed with use of resources such as books to build and extend learning.

> *Anna*: It's really important as well, to co-construct with children, co-constructing their ideas. Sometimes not having all the answers, you might know the answers, but I think it's really valuable for the children to see you thinking the same as them. And sometimes I think you get a lot more of their own thinking and the direction they want to take it.
>
> *Charly*: Or how you respond to their [*the children's*] questions, because they are asking you something and then it's how you hand that back.
>
> *Anna*: Yes, and I think that's when like you said, with the mirrors, there's a lot of talk when I ask questions, we [*the practitioner and a child*] were exploring it together; and then that's when we saw that moment where he [*the child*] found that it was reflecting. I think that's really valuable, because you are still present, and you are still questioning but the children see you on a different level.
>
> *Re*: Yes, I think being present is a really important theme that's coming out. And like you were saying, about handing the question back. When you ask a question, you don't hand it back when you have all the knowledge. Because that alters the balance, doesn't it? But that's really hard within the Early Years Foundation Stage, isn't it? Because there is knowledge and there is a determined route isn't there? For you to be heading towards.

> *Melissa*: What I tend to do is give a sort of vague answer. There was something to do with snails, I can't remember exactly, something to do with the shell is their house, and then we [*practitioner and a group of children*] went to and found the snail book and looked in that together to find more information. So, you are giving them [*the children*] a little bit so that they still trust that you are the person they can go to if they have questions. But thinking across the curriculum using non-fiction books is a massive part of it as well. So, you have to think of other ways to link that knowledge in as well.
>
> (Excerpt of video footage case study three: session four, 39:50-41:57/47:00)

In line with literature about common pedagogical dilemmas which arise in early childhood education, practitioners across the case studies identified a key dilemma about whether to intervene or step back from practice (see for instance, Cherrington, 2016; Fisher, 2016). Relating particularly to early science education was the dilemma of whether to talk or not, and *how* to talk with children whilst they were immersed in creative science enquiry. For instance, talk appeared to be a point of confusion for a practitioner in case study one who questioned how early childhood practitioners should support the development of scientific understanding through subject specific vocabulary. Related, practitioners in case study two agreed that a tension exists between whether children should follow their own explorations or develop understanding of established scientific ideas. Within case study three, pedagogical dilemmas emerged during the last two video dialogue sessions. There was also an emergent dilemma relating to the tension caused by the Early Years Foundation Stage (DfE, 2017) and the National Curriculum (DfE, 2013) which pre-determine outcomes and outline key knowledge and skill acquisition, potentially conflicting with the direction in which children might develop their own enquiries. Practitioners in case study two identified this as a tension that exists in schools. They cited the influence of policy, accountability and early childhood education literature as contributing to the emphasis placed on using talk to support knowledge construction, no matter the context.

Creativity as embedded within science enquiry

It was of interest that although practitioners across the study agreed that science is creative, echoing findings by Hetherington *et al.* (2019), dialogues exploring a link

between creativity and science enquiry were often prompted by me as researcher; spontaneous links were rarely made.

When creativity was discussed, it was predominately considered to be enacted by humans within the cognitive domain. This was apparent across the three case studies and is illustrated throughout the quotes and excerpts in this section. Within the context of early childhood science, all the case studies, at differing points, agreed creativity as children's curiosity, experimentation, problem solving, making links and taking risks. The following quotes illustrate these conceptualisations sequentially. For case studies one and three, they are taken from the first session during which practitioners were invited to discuss their understandings of creativity and science enquiry.

> *Lilian:* ...Creativity requires a curious mind.
> *Maddie:* And enquiry.
> *Lilian:* Yeah, sort of thought processes and thinking and playing with ideas.
> *Maddie*: Asking questions in your own mind, isn't it?
>
> (Excerpt of video footage case study one: session one b, 01:24-01:44/12:00)
>
> *Marie*: I think that it is part of the human condition to be curious. I see it as something that is quite innate. Babies are curious, aren't they?
>
> (Excerpt of video footage case study one: session one b, 03:27-03:37/12:00)
>
> *Jay*: Creativity is intrinsically experimentation. The more I think about it they are basically the same thing.
>
> (Excerpt of video footage case study one: session one b, 06:23-06:30/12:00)
>
> *Melissa*: [*reflecting on creativity in science enquiry*]...Children always like having a problem to solve, you know they've got a mission and then it gives them a purpose and challenge and it gives them more ownership. I completely agree it [*creativity in science*] should encourage making connections.
>
> (Excerpt of video footage case study three: session one, 09:16-09:30/23:00)

Melissa: The only way that you learn in science is by taking risks and by trying out new things.

(Excerpt of video footage case study three: session one, 12:41-12:50/23:00)

Perceptions in these excerpts appear to reflect some synergies between science and creativity identified by Cremin *et al.* (2015). In particular, in the first two excerpts, aspects of questioning and curiosity seem evident through children's innate sense of curiosity and their questions which might be expressed through 'the mind' as they think and play with ideas, equated by Wood and Hall (2011, cited by Cremin *et al.*, 2015, p. 5) to 'intellectual' play. Details of problem solving and agency are also mirrored in the fourth excerpt in that creativity in science enquiry seemed linked to children's competence in engaging with problems which fostered agency and ownership of learning.

The following quotes from case study two were made during their third video dialogue session, in response to a question I had posed to the group about links between creativity and science enquiry. The group had watched video footage of children playing with bags and strips of material on a windy hill, and discussion had been focused on children's immersion in science enquiry; their pattern seeking and experience of cause and effect.

Tish: Its [*creativity is*] making links as well, I think that's a really fundamental part of it, they [*the children*] were making links between an experience of something and making sense of it for yourself [*themselves*]…

(Excerpt of video footage case study two: session three, 41:56-42:12/48:00)

Tish: [*Reflecting on creativity*] The taking of the risk was that [*the children*] accidentally let go of the bag but then they actually chose to. That could have been a risk.

Molly: Another risk is when it came behind her [*the child*] and she spent some time trying to wrap it around trying to recreate it, but she didn't manage it.

(Excerpt of video footage case study two: session three, 19:11-19:35/48:00)

Here, synergies between science and enquiry as articulated by Cremin *et al.* (2015) appeared to mirror aspects of play and exploration in that playful, hands-on enquiry in an exploratory context was understood as encouraging children to make links with their surroundings (Cremin *et al.*, 2015). Additionally, although not identified in the literature as synergic with science enquiry, comments focused on taking risks reflected a long association with creativity and creative processes (Burnard *et al.*, 2006; Craft *et al.*, 2007; CLS, 2012).

For case study two, the relationship between creativity and science enquiry also appeared to align with Craft's (2000) concept of possibility thinking. For example, in the following excerpt creativity is expressed as involving surprising, light bulb moments alongside 'wondering' and trying out different ideas. The excerpt is taken from the second video dialogue session in which eight practitioners reflected on video footage of a small group of children exploring toy figures on a large mirror with a practitioner.

> *Re*: …One of the things, as you know, that I am interested in is the links between creativity and enquiry like that. And I wonder if you, if anyone, could pull anything out from it? For me, for instance, I thought that they [*the children*] were making all sorts of links and that is something that people suggest is, you know, being a creative process when you make links in that way. Did anyone spot anything else that we can hear from your observations?
>
> *Jamie*: I thought that the way they [*the children*] responded, you often get surprise as a reaction, don't you? When it's and how you, you know, if you are surprised by something, it means that you were kind of expecting something else or there was something that you hadn't thought of before or something like that. So, there was a lot of that wasn't there. And a few, kind of, light bulb moments. So, I think that there must, you know, have generated some creative ideas, you know, something in science particularly the element of surprise and...
>
> *Molly*: [*Interrupting*] The unexpected…
>
> *Jamie*: Yes, the unexpected, it is quite basic really.
>
> *Tish*: Yeah, he [*the child*] started to hypothesise, didn't he? Afterwards, because he is a child that really focuses on…he picks up concepts and new

> language and new ideas really, really fast and he obviously, when I put the knight on and I said I wonder what happens, oh no, the horse, sorry. [*I said*] I wonder what happens if we put it upside down and we did a lot of experimenting, and then he brought in something and he started saying I wonder what happens if we convert it, yeah, so he is obviously followed that so he had started, he was starting to make his own…but he wasn't verbalising it so he was just wondering I suppose, which is a creative exploration.
>
> (Excerpt of video footage case study two: session two a, 07:13-09:13/12:00)

All three case studies held democratic, ubiquitous conceptualisations of creativity (see, Banaji *et al.*, 2010; Beghetto and Plucker, 2006; Rinaldi, 2006). For example, perspectives appeared to align with Craft's (2002) position on little 'c' creativity in that practitioners considered all children to have the capacity to engage in a creative process.

> *Anna*:...I think creativity happens everywhere. I guess, you know, some children enjoy painting more than other children but who is to say that they are more creative than the other children...it doesn't have to be just painting, they could be moving, and they could be creative without realising that they are being creative…
>
> (Excerpts of video footage case study three: session one,16:56-17:20/23:00)

> 'Creativity is inherent in everyone; it occurs all the time. We are always making new meaning.'
>
> (generalised perspectives on session 3: case study two, session 4)

Practitioners across the case studies also explicitly discussed creativity as embedded within science. In case study one, it was rooted within the cognitive domain and described as visible in children's ideas, and in their thoughts and subsequent actions. It was also highlighted that there might be creative thought processes that are not accessible. This position is represented in the following excerpt from the final video dialogue session in which six practitioners reflected on participation in the study.

> *Re*: What seems to have evolved throughout the study is this understanding...that for me….it [*creativity*] has been really focused on the

process of enquiry, with an understanding that creativity is just sort of there like a constant. With all those things like, problem-solving, risk-taking, playfulness...there was the girl with the interaction, are all forms of creativity that seem to be running throughout. I mean what are your..do you agree with that in terms of? I mean that is something that has struck me...

Maddie: Yeah, I think I asked because I was thinking that you meant it [*creativity and science enquiry*] was separate and I was going to say no, no I'm not sure that I would agree with that and...that it is embedded...

Bella: It's the ideas that are creative, isn't it? I mean it is all the children's ideas.

Maddie: Their actions and thoughts in response to something and the words that they use.

Re: So by the very act in engaging in enquiry, you are being creative?

Maddie and Bella: [*Nodding*] Yep, yes.

Jay: That is what science is. It is not all facts at all.

Maddie: I think that there is a lot of creativity that you don't access as well. I mean that there are thought processes that you can't access that there is all that creativity that you don't get. Maybe that is okay….

(Excerpt of video footage case study one: session five, 59:45-01:01:23/01:06:00)

For case study three, creativity was considered embedded in science enquiry when ideas were brought to fruition, children repeated and tested ideas to discover something new and original, and skills were applied in a different context. The following excerpt illustrates this position. It is taken from the fourth video dialogue session in which five practitioners were present. A practitioner had shared four short clips of children exploring objects which float and sink and discussion had focused on children's peer 'scaffolding', immersion in the water play, and when questioning might be best placed in enquiry.

Re:...Where might creativity sit in that? [*Referencing previous discussions*] In terms of being creative and risk taking and being playful and imagination, [*where was creativity*] in the clips we saw today, in terms of scientific enquiry.

Anna: I think it was throughout it all. If you look at the water tray and they [*the children*] were being creative. Even as simple as putting things together, that's creative. We didn't know that was the direction they were going to take it through the plastic. The moving it up and down, up and down.

Melissa: Seeing if it works out of the water and in the water and having it under the water and top of the water. That was repetition and testing.

Re: Yes, I really agree with that because it's like discovering something new isn't it? And that's actually creative, if you are discovering something new it's a creative act?

Charly: And how they [*the children*] are going to apply what they have done in another situation. They are using those skills creatively, like with the tube. If it was just left in the classroom, it could have been just left in the classroom, but it wasn't. They were trying to do something with that.

(Excerpt of video footage case study three: session four, 42:38-43:53/47:00)

This position echoed in the reflective dialogues of early childhood practitioners within case study two. For example, in the excerpt below the creative process appears connected to children's manipulation of materials to discover something new and to the use of imagination to transform objects. The dialogues in the excerpt also appear to reflect one of Cremin and Chappell's (2019) findings within literature; that the creative generation of ideas includes time to explore resources within an open environment. The excerpt is taken from a dialogue involving eight practitioners reflecting on video footage of a small group of children playing with bags on top of a windy hill, in the rain. The group had been asked to consider the place of creativity in science enquiry and two practitioners had identified creative 'risks' that the children had made with bags.

Barney: [*Identifying children's creativity in enquiry*] Explore different ways of filling up the bag the best way to hold it.

Molly: Yes, because some children were using two hands and some were using one.

Jamie: Just turning slightly, making slightly different movements, so they're [*the children are*] thinking, you know, they're not expressing that but they are

probably thinking ‘how am I going to make this move in a different way?’ That’s creatively manipulating a resource, isn’t it?

Molly: This material got used for a different purpose as well, they [*the children*] started rolling down the hill with it, when we [*practitioners and the group of children*] were on our way down the hill and one of them wrapped themselves – inaudible – and that was a totally different use for the same thing so again there was a creative thought of ‘oh, I can use it for this’ which was brilliant.

Barney: And we [*practitioners and the children*] tied it with sticks and made flags as well.

Tish: and then sticks, the green material and the stick became a snake, so we played a game where I was moving the snake and they were jumping on the snake. It just evolved all the way back down to the bus.

(Excerpt of video footage case study two: session three, 19:36-20:59/48:00)

Discussion about creativity culminated in this session with practitioners challenging the usefulness of the term and describing creativity and science as one and the same. The dialogue, stimulated by a clip of a child, her mother and a practitioner in the woods exploring mushrooms, also considered wider influences which influence and potentially constrain educators’ perspectives on creativity. This resonated with Hetherington *et al.*’s, (2019) claim that teachers’ perspectives on science and creativity may be affected by creativity’s positioning within the curriculum. Of particular interest in the excerpt below is consideration that the creative process might exist outside of the cognitive domain.

Tilly: Don’t you think the word creativity is a redundant word really, because a lot of the scientific...is the same thing. So what is this creativity? People are very hung up on this…

Jamie: Could it be asking questions?

Re: ...it does seem when I’m asking you for your ideas and reflections on that you're pulling out links and I’m saying where are the links? If they are the same thing, what are they? And so, going back to your clip, one example might be that, discovering something new is the same as part of an enquiry, whenever you engage in enquiry you're seeking new knowledge and understanding and the same way there that may be, for instance…

Tilly: It's the same with nearly every subject, look at maths, one of the things about maths is problem solving as it is with science and that's hugely….is the word creativity really needed?

Re: Because it's embedded?

Tilly: One of the nurseries I know talks about themselves as being creative, that they are a creative nursery but surely all the nurseries are creative?…Everybody always jumps on the bandwagon of creativity…

Jamie: I suppose if you treat creativity in quite a narrow way then you might actually be verging away from creativity, and not just see creativity as something that all human minds are naturally creative. That's what we do, we're creating all the time, creating meaning, creating images… but in the context of an educational system that can sometimes constrain that kind of thinking because it's channelling you to think in a certain way to think about a certain process and discourage you to think like that!

Barney: For me a creative question would be one that no one else has thought of and that form of enquiry and is perhaps something very unique.

Re: I agree with you that it's embedded but I'm still particularly enquiring as to how we might foster those dispositions in children, so there's a difference between being creative and a creative process or how you might engage with a creative act? To me there are such strong parallels with the science enquiry process and supporting and nurturing children's creative enquiry.

Tilly: When one talks about creativity 'oh you're creative' or 'that was really creative' it's maybe an individual thing of how you see creativity it's…so into individuals…

Jamie: I think the unexpected is quite an important thing, isn't it, something that is not conforming to a normal perspective…

Barney: It doesn't have a definite thought process, it can be outside of that, because perhaps that's where creativity lies…

(Excerpt of video footage case study two: session three, 37:15-41:57/48:00)

In summary, practitioners in all three case studies conceptualised creativity in scientific enquiry in line with literature within the domain of education. Most frequently, it was interpreted as cognitive, democratic and ubiquitous (see, Banaji *et*

al., 2010). Making links, being playful, taking risks, light bulb moments and exploring the unexpected were also frequently drawn upon to describe children's creative engagement in enquiry. Such conceptualisations mirrored literature on creativity in early childhood and science education (see for instance, Bruce, 2011; Craft, 2002; Cremin *et al.* 2015., Cremin and Chappell, 2019; Hetherington *et al.*, 2019).

Although practitioners across the case studies were in agreement that science enquiry is inherently creative, they were often prompted to identify links between the two. For case study one creativity in science enquiry was largely discussed in terms of the cognitive domain whereas practitioners in case study three identified it in terms of process; in the fruition of ideas, the repeating and testing of them, and in their application to different contexts. Holding some similarity to this, practitioners in case study two identified children's manipulation of materials and transformation of objects as illustrative of the creative process. This was expressed from a humanistic perspective. Additionally, practitioners in case study two challenged the usefulness of the term creativity, perceiving it as one and the same as science enquiry. Of significance was one practitioners' consideration that creativity may not reside within the confines of the cognitive domain.

> *Barney*: It doesn't have a definite thought process, it can be outside of that, because perhaps that's where creativity lies…
>
> (Excerpt of video footage case study two: session three, 41:52-41:57/48:00)

Materials and the environment as inert stimuli, and supporting an embodied experience

Mirroring excerpts from the first finding, practitioners' interpretations appeared to draw on Piagetian and Vygotskian perspectives when considering the place of materials in young children's creative scientific enquiries. For instance, across the three case studies, there were times where children's engagement with the environment and materials was associated with a process of collecting data and emergent theory building, reflecting a Piagetian position. The following excerpt, from the third video reflective dialogue session with practitioners in case study one is illustrative. During the session, a less experienced practitioner shared a short piece of video footage of a child exploring water. The practitioner explained to the group

that the child had gone straight to the water tank on arrival at the children's centre that morning, that she had initiated her own enquiry and played with water for a much longer period than was usual for her. The practitioner also explained that she had 'stood back' during the child's enquiry and that there was little talk between the practitioner and child in the clip of video footage. After watching the footage, a group of seven practitioners shared their perspectives. Here, three practitioners discuss the child's actions.

> *Lilian*: She [*the child*] tested out...she did different things, didn't she? As much as she was being repetitive with some things. She explored a splash - I mean, she created a splash and then she splashed some more, didn't she? And when she put it on her face, she then poured it somewhere else.
>
> *All*: [*Murmuring*]
>
> Lilian: I felt she [*the child*] was trying to discover and know about it [*the water*] through the touching it, through sensory putting it in her mouth. It seemed to be quite experimental - I thought.
>
> *All*: [*Agree*]
>
> *Bella*: I think that she [*the child*] was talking for a while and when she stopped, she wasn't doing anything for a while, but you could see that she was thinking about something.
>
> *Maddie*: I think she [*the child*] was thinking. What made it quite different was that she actually linked something with something else. So even just putting her hands in that water because that water was like bath water at home - and she said 'oh, I am washing'. But before that, she wasn't washing but she was able to relate that to something else she does with water.

(Excerpt of video footage case study one: session three a, 25:51-26:58/01:04:00)

In this excerpt, the focus on the child as a thought builder seems to render materials as passive. That is, materials are used to draw attention to the child and her actions. For instance, in the comment '...she created a splash and then she splashed some more..', the liveliness of the material is produced by the child not enacted by the material.

A similar perspective was evident in the video reflective dialogues of five practitioners in case study two. For example, in the excerpts below practitioners shared their reflections on video footage of children exploring water pools at the beach on a wet and windy day. Of particular interest to the group was a child's line of enquiry which involved repeatedly collecting water from a large pool and pouring it into a small one. Prior to the excerpt of dialogue, the group had listened to a practitioner explaining that children had been immersed in enquiry for a long time. In the first excerpt, two practitioners unpacked the child's encounters with the water.

> *Tish*: Yeah, he seemed to be trying out different surfaces, like the grass, the rocks and the height down and, you know....
>
> *Jamie*: Noticing that the water was disappearing.
>
> *Tish*: He really looked for a long time afterwards, didn't he.
>
> (Excerpt of video footage case study two: session four, 13:30-13:47/53:00)

Later in the same dialogue, discussion focused more on the child's use of science process skills in the enquiry and their manipulation of materials.

> *Re*: Seems to me that there are some parallels in footage that we have seen before. In the patterns seeking, the repetitions, the collection...in terms of science enquiry you could say it fits in with collecting data as part of the enquiry cycle that you are immersed in? Pattern seeking to see if something happens...seeing what the cause and effects are. The relationship between the land and the water. The water and the stones.
>
> *Jamie*: That's a very simple thing to do isn't it but they [*the children*] were there for pretty much twenty minutes doing that, you know.
>
> *Re*: Again, it reminds me of the clip we watched of...with the bags. The repetition and the pattern seeking, how you can manipulate something.
>
> *Tish*: Yes, they [*the children*] are doing the same thing but choosing different ways to do it. Feeling the gusts. Another thing was, you know, he [*the child*] seemed to paw the grass, I don't know if that was the whole time. But he seemed to go back on that spot. I don't know if he was really seeing the difference there because the water is pooling. Whereas it disappears in other areas. So, yes, retesting and comparing.

(Excerpt of video footage case study two: session four, 18:00-19:36/53:00)

In these excerpts, materials appear again to be static and separate in the background whilst dialogue centres on the child's skill in enquiry. For example, the child is described as trying out, pattern seeking, noticing, retesting and comparing, and the materials used to frame these actions.

A focus on children's manipulation of materials during science enquiry also seemed evident in the dialogues of practitioners in case study three. For instance, in the following excerpt both an individual child's investigation and a collaboration between two children are explained in terms of how they adapt cardboard to make it sail across a tank of water. The excerpt is taken from the beginning of the third video dialogue session, directly after practitioners had watched a short clip of video footage.

> *Anna*: I thought she [*the child*] was adapting it [*a cardboard raft*] all the time as well. Especially when she said, 'stuck to the back of the cardboard'. She then decided she had to blow the cardboard bit, rather than the sail to make it move.
>
> *Re*: That made me think of the theory of building part of enquiry when you're, like you say, adapting and changing. So, you've got a hypothesis, there's some thinking going on and that's what's happening in the moment.
>
> *Anna*: [*Nodding*] Yeah, and I think even these two guys before when they were saying, 'oh how are we going to make it flow, we need it to flow'. And Sally is moving it trying to work out how they are quite going to do that. And you can see them come back at the end to try again. They might have adapted it to have another go at it.
>
> *Re*: Yes, I wrote down pattern seeking and that's repeating something over and over again. That's a real key feature of enquiry isn't it, or the process of enquiry?
>
> (Excerpt of video footage case study three: session three 03:50-04:48/49:00)

Materials as passive and inert by nature appears further illustrated in the excerpt above. Here children's actions solely shape the movement of the cardboard boat. That is, the child adapts, decides to blow and consequently makes the boat flow. Neither water nor cardboard are recognised as co-constitutive in the phenomenon.

Significantly, across the three case studies, practitioners' dialogues seemed to reveal a perception that children are agentic knowledge builders who explore their environment and its materials to build knowledge and understanding, in line with constructivist perspectives.

A Vygotskian position on materials appeared evident in practitioners' dialogues in case study two and three. For example, in some instances, materials seemed to be recognised as cultural tools and mediators. The excerpt below, taken from the third video reflective dialogue session in case study two, provides an example. Eight practitioners were present in the session and the group had just watched a clip of a child, her mother and a practitioner in the woods investigating fungi. The practitioner sharing the video footage had described the context for the visit and explained that the footage provided an interesting insight into an interaction between a child and her mother. The excerpt begins with the practitioner describing the child as inquisitive about nature and later books are referred to as a 'bridge' in the child's experience. In the context of the wider video reflective dialogues this seems to be an acknowledgement of the book's contribution to the child, mother and practitioners' processes of meaning making. The book provides access to a phenomenon from a different perspective and encourages interpersonal communication.

> *Jamie*: yeah, she's [*the child*] so inquisitive, the little girl, just asks all these big questions particularly in nature and a lot of why questions.
>
> *Re*: So, had she [*the child*] asked to go investigating mushrooms and she had an interest with the book…?
>
> *Jamie*: Well, she [*the child*] chose it when we went on our first trip, you happened to take that book didn't you?
>
> *Barney*: I think so
>
> *Jamie*: Yeah, you did, and so she [*the child*] saw that book and we had a quick look at it but before we went up a second time, when we were down here, she said 'I want that book' and I remembered what book it was and she made a connection with…and the books are kind of like a bridge aren't they?
>
> *Re*: Yes

Jamie: To the real thing. So, when we went into the woods. It took us ages to get there because all these phenomena, these natural phenomena like pockets of light..do you remember that?

Barney: Yeah, fascinated by it, shards of light

(Excerpt of video footage case study two: session three 32:00-33:20/48:00)

This perspective in which materials were recognised as cultural tools and mediators echoed in the dialogues of practitioners in case study three. For instance, in their third video reflective dialogue session, practitioners seemed to recognise books as a 'mediation of collaborative activity in the negotiation of meaning' (Thompson, 2013, p.259). Mirroring Fleer and March's (2009) suggestion that access to a 'science table' with items from nature provided meaningful ways to support children's enquiries in science, practitioners also identified use of materials as a means through which a phenomenon might be further accessed. The following excerpt provides an illustration. Prior to the dialogue, practitioners had watched a clip of two children mixing water and foam in a large flat tray. Discussion had focused on children's sustained engagement in science enquiry and how children might develop their initial lines of enquiry. Practitioners had commented that modelling, questioning and co-construction of knowledge were strategies that they drew upon. The dialogue then shifted to focus on the role of materials.

Anna: Again, I think it goes back on to that co-construction, doesn't it? When they [the children] give a little bit, you give a little bit, and they give a little bit. And they do feel like they have worked on it with you. So, it's not you completely talking, they've got ownership over it as well.

Re: So, if that's true, and building on what you were saying, as an adult working with children in that way what would you do? Say they [*the children*] became really interested in something like the tyres and then you ask, 'what if, have you thought about this?' and they sustain enquire for a bit longer. What would you do as a third intervention or another intervention or would you leave it?

Anna: It depends on them, we quite often, and it does depend on them, we might add something to it. Thinking about the ice today, we would leave some in a bowl, or leave salt on it. Something that would take it a bit further. Or again depending on the child, quite often we would go over to the school

library to, you know, what else could we find out about this. What else would we do?

(Excerpt of video footage case study three: session three 39:53-41:08/49:00)

Whilst practitioners across the case studies appeared to hold a similar perspective in which children were positioned as agentic knowledge builders and materials passive, it was interesting that practitioners from case study one did not appear to place emphasis on books or other materials as cultural tools. This was perhaps because the children within case study one were under three years. Traditionally greater emphasis is placed on sensorial interaction with materials in this age range, to make meaning of the immediate surrounding world. Indeed, sensory play is emphasised as supporting holistic development in the Early Years Foundation Stage (DfE, 2017) and in texts designed for early childhood practitioners (see for instance, Gascoyne, 2016). However, once children have a 'foundation', books are perceived as a key source or 'bridge' to developing knowledge, as described by case study three. Children's knowledge thus moves from 'common sense' discourses to scientific ones developed through direction to established scientific concepts which are perceived important (Fleer, 2010).

As the study progressed, practitioners' perspectives appeared to broaden within case study one and two to consider children's embodied experience with materials. However, this was not evident in case study three. This may have been due to apparent greater pressure within primary schools to support children's progress towards engagement with the National Curriculum (DfE, 2013), as implied in influential reports such as Bold Beginnings (Ofsted, 2017). Of significance, was recognition by practitioners in case study two for the energy of the elements and the affordances that materials offered when children explored in wider, more expansive environments. Although children seemed to be perceived to hold agency and control over the environment, there appeared to be an emergent understanding that materials also held vitality. For example, in the following video reflective dialogue from the third session for case study two, seven practitioners responded to video footage of children developing their own enquiries from encounters with strips of material and bags on a windy hill. Reference to materials began from the position that they were inert objects which children manipulated according to their own ideas.

Tish: We also talked about how the brambles and stuff stopped it [*the bag*] and thorns made holes in it. And then they [*the children*] made holes, didn't they? Was there more?

Barney: [*Inaudible*]

Tish: There were things about holes in the bag and you [*Barney*] had some questions…You know…saying why isn't the bag working? We [*Barney and Tish*] were talking about the holes that the brambles had made….
Barney: It is like that further on…there is not a lot of dialogue.

Re: Actually, it is quite nice that there isn't it? I mean, you can see the way that the children…I mean what a rich experience that the children have had with a bag.

Tish: They [*the children*] all wanted the bag as well, more than the fabric. I thought it might be because of the strength of it….it changed state more obviously and they were like 'Wow! It's caught the wind', really playful. Barney and I have briefly talked about how it [*the clip of video footage*] looked quite still but when we were there [*on the hill*] it felt really energetic and joyful and frenetic almost at points. It didn't really feel like that just then [*in the clip of video footage*].

(Excerpt of video reflective dialogue case study two: session three 09:30-11:08/48:00)

The discussion developed and interpretations shifted slightly but significantly to a focus on ideas that could be interpreted as children's embodied interactions with materials. Here practitioners' perspectives seemed to move beyond the individual as a meaning maker. That is, the wind had energy and practitioners and children were full of the 'wind energy' of their environment. There was thus what appeared as an acknowledgement for a relationship between humans and the environment; children were not solely acting upon a pre-existing world. It also appeared significant that practitioners perceived this experience to promote complete immersion in the enquiry.

Tish: I guess it was the wind as well, we [*practitioners and children*] were full of wind energy.

Jamie: It's the open space as well. It could be very windy in the garden and it can also create this energy …but I think it adds something to it with this complete expanse of space and big sky.

Tish: Max was just howling "hoooowwl…" for ages, I started doing it as well because it was just like wow! It was really raining as well. Brilliant.

Jamie: Because there was no one about as well, completely unfettered.

Tilly: Yeah, all the children were completely engaged.

(Excerpt of video reflective dialogue case study two: session three 11:10-11:56/48:00)

Practitioners' interpretations of children's engagement with materials as an embodied experience also seemed evident in the video reflective dialogues of practitioners in case study one. This is illustrated in the following excerpt taken from the second video reflective dialogue session. Seven practitioners had responded to video footage of a child playing with water in which there was very little dialogue between practitioner and child. Discussion had focused on the child's on-going interest in water and careful attention was given to how the child had repeatedly twirled around mimicking the action of water in the footage. Although the dialogue was tentative, a connection appeared to be made between child, environment and material which did not mirror Vygotskian or Piagetian perspectives.

Re: And it's almost like he's [*the child*] living that concept that force, like you [*Maddie*] just said, [*imitates Maddie's demonstration of drawing in breath and exhaling 'oooh'*]. That's a really amazing connection that he's demonstrating his understanding of a really complex concept.

Lilian: Being able to feel; there's something about physically feeling force. Because it's not something you can see, is it? So, to have that resistance.

Maddie: It was unfortunate that the video stopped when I think it was Petie was exploring the two [*magnets*] that repelled. He calls it pulling, he went 'puuuull, puuull', and they [the magnets] aren't actually doing it. But it's amazing, his action.

(Excerpt of video reflective dialogue case study one: session two, 25:23-26:06/30:00)

To summarise, mirroring the first finding, practitioners appeared to interpret children's engagement with materials in their creative scientific enquiries through Piagetian and Vygotskian perspectives. Indeed, practitioners' dialogues in all case studies seemed to reflect aspects of Piagetian constructivism in that children appeared to be perceived as agentic beings and materials manipulated to support meaning making. A Vygotskian position whereby materials are understood as cultural tools or mediators seemed to be evident in practitioners' dialogues in case study two and three. For case studies one and two, interpretations included consideration for children's embodied interactions with materials. There was also discussion about the effect that the elements and enquiry within expansive environments might have on children's enquiries. In particular, that they might possess vitality.

Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) agitate and broaden perspectives

Practitioners' reflections on their participation in Video Stimulated Reflective Dialogues (VSRD) (Moyles *et al.*, 2003) mirrored perspectives common within literature which explores teacher professional development and knowledge making practices (see for instance, Appleby, 2010; Creemers *et al.*, 2013). In particular, practitioners appeared to hold the perception that new knowledge could be co-constructed through a community of practice (Spelman and Rohlwing, 2013) where reflection and different perspectives were foregrounded. For example, in the following excerpt from the final video dialogue session in case study one, two practitioners shared their reflections on participating in Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003), drawing attention to 'shared discovery' within a supportive community. The dialogue emerged from a more general discussion with six practitioners about engagement in critical reflection and challenges which had arisen during the study.

> *Lilian*: I feel that part of it [*participating in video reflective dialogues*] is that we [*the group*] are in a supportive community...and I feel that whatever you share is seen in a positive light ...feedback which is genuinely to support you.

Maddie: Well, this [*gestures to the group*] there is not any, there is no judgement there….it is judgement free because we [*the group*] are discovering together.

(Excerpt of video reflective dialogue case study one: session five, 54:30-55:00/01:00/05)

Practitioners in case study two held a similar position. Video reflective dialogues were also perceived to broaden individual perspectives and provoke different ways of seeing. The excerpt below, taken from the fifth video dialogue session, is illustrative. Prior to the excerpt, a group of four practitioners had shared their experience of participating in the study with a particular focus on the engagement in collective video reflective dialogues.

Barney: Well without a doubt, the clip has helped to explore different perspectives.

Re: Do you think, I mean for me, I fundamentally agree that is really important, the more perspectives you have on something, the more you are likely to change practice and develop ideas and transform your thinking. Do you agree with that or does that resonate or not?

Jamie: Yeah, because you are coming from slightly different viewpoints and engaging. Talking about our ethos, which is something which is common to the way we work here, but then within that um if you are actually looking at the video different things occur to you, don't they? As an individual which, you know, the person who is analysing their own piece of video wouldn't have thought of...I think that has been a prominent theme with you know in, from the first session, people come up with things that you hadn't have thought of.

(Excerpt of video reflective dialogue case study two: session five, 35:16-36:31/56:00)

The value given to listening to different viewpoints by practitioners in case study one and two appeared reflective of their setting which emphasised engagement in research and working together as a community of practice. Practitioners within case study three differed in their emphasis and discussed the contribution that different levels of experience in practice made to the development of understandings. This may also have been due to their particular setting in which nursery and reception teachers of differing levels of experience worked together as one foundation stage unit. This is illustrated in the following excerpt which is taken from the final video

dialogue session in which practitioners reflected on the extent to which participation in the study had supported critical reflection.

> *Anna*: And I think it is really interesting getting all of us together and having so many different dynamics because obviously Melissa has been an Early Years practitioner now for a few years, Charly is very new and Olivia has just finished her Early Years degree, and I'm the newest trainee. And having all of those dynamics is really key, I think, and it's also very nice, I think you do feel closer to your team because you're doing something together.
>
> (Excerpt of video footage CS3 session 5: Primary, 21:24-21:25/28:00)

Practitioners across the case studies also identified that standing back and viewing their practice from another perspective was particularly beneficial, mirroring the findings of Brantley Diaz *et al.* (2008), Moyles *et al.* (2003) and Fisher *et al.* (2006) in that the use of digital technologies encourage practitioners to consider pedagogy from different positions. Interestingly, for practitioners in case studies one and three this involved reflection on talk, though these reflections did not appear to be critical in nature. The illustrative excerpts below are taken from the final video dialogue session in which practitioners were invited by me to discuss the benefits and challenges of engaging in collective Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003).

> *Lilian*: It [*the video footage*] made me think about the language that I use and how much I spoke, and when you step back a bit, how you could be different….you know my actual practice.
>
> (Excerpt of video footage case study one, session five, 36:45-37:05/01:05:00)

In this first excerpt, video footage is associated with standing back and considering alternative approaches to practice. However, the comment does not go beyond initial consideration of established approaches or demonstrate new perspectives. Rather, thinking appears agitated.

> *Charly*: I think to watch yourself as a teacher was quite revealing because sometimes you just think ‘shut up’. You know, I think ‘just don’t talk’. From that point of view, it has made me really think about what I am saying to children,

> you know. Sometimes you do give them far too much, verbal. You know, that's how it is sometimes, isn't it? So, from that point of view it has been very interesting.
>
> (Excerpt of video footage case study three, session five, 15:35-15:56/28:00)

The practitioner in this second excerpt begins to unpack the impact of her use of talk when engaging with children in alignment with Schon's (1987) suggestion that 'reflection-on-action' involves exploring alternative modes of framing by reviewing, analysing and evaluating. Though, as with the previous excerpt, although thinking appears agitated, the comment does not appear critical whereby new perspectives might be transformed or considered beyond technical realms (Brookfield, 1995; Mezirow, 1991). This type of reflection in case study one and three was perhaps due to talk being an ongoing and unresolved dilemma, whereas in case study three, reference to talk was more focused on when it might be used most appropriately.

For case study three, standing back and considering another perspective included the involvement of children and manipulating the video footage itself.

> *Charly*: I think what also I find really interesting is I've shared it [*the video footage*] with the children, so they've got involved and looked at that and then you start talking about different things and sometimes there are things you didn't even notice happening, it happened in the background.
>
> (Excerpt of video footage case study three, session five, 20:39-20:53/28:00)

> *Charly*: Well, they were talking about what they were doing and commenting on what other children were doing so that was great for them as well and we did lots of other things like turning things in fast motion and slow motion that they loved. Seeing them doing it all in really, really fast motion and mixing things, yeah that was good.
>
> (Excerpt of video footage case study three, session five, 21:08-21:23/28:00)

In case study two, video footage was also considered by a practitioner to provoke different insight to that which might be recalled 'in the moment' of an enquiry with children. This view appeared to mirror findings by Nolan *et al.* (2018) whereby video

footage is considered complementary and supplementary in the development of understanding.

> *Tish*: There is something about capturing a very fluid moment in time that often, you know, throughout the day happens naturally and then goes and, you know, if you have written down anything at the time or taken photos, it is not the same as when you have actually captured it in real time and you go back to it in a different state of mind so, not on a blustery beach or not, you know, in a group time, that you are going back to it collectively and looking at it. I found it very, very useful and interesting, and it has made me think about, open different ways of looking at things and understanding them and realising that the way I do things and the way other people do things, it is a very reflective tool.
>
> *Barney*: It is very honest.
>
> *Tish*: Very honest, yeah.

(Excerpt of video reflective dialogue case study two: session five, 36:31-37:32/56:00)

Within the framework of the early phase of analysis, practitioners across the three case studies appeared to narrate video footage and engage in cumulative and exploratory talk (Littleton and Mercer, 2013) to make meaning of young children's creativity in science enquiry during video reflective dialogues. Figure four, from phase one analysis, draws attention to such talk. Documented are the first three episodes in the second video dialogue session with eight practitioners in case study

two.

What is happening within the phenomenon of VSRD? (Session 2 R3-4 24.11.15)

Time	Phase	Connected by	Reflection
Episode 1 (1:41)	I – AL – AF -ST -- R - AL -- G – AL - AF --	Comments Perspectives Listening Affirmation Time – long sequence of individual storytelling	Specular Polyphonic/cumulative
Episode 2 (2.24)	I – RX – CR – AL – AF -- EXPLORATORY G - CP -- G - OP -- SU - ALL --	Challenging comments Perspectives Shared understanding Listening Affirmation Reflexive stance Time – long sequence of individual reflexivity/critical r	Specular Exploratory Critical
Episode 3 (5:52)	R – AL – TP - Q -- I – AL - ST -- R – EG - Q -- EXPLORATORY AL – AF – G - OP -- RX – CR – I - AL -- R – S - AL --	Theoretical perspectives Comments Questions Listening Affirmation Reflexive stance Summative Time – longer with shorter intra-actions between participants	Specular Exploratory Critical
Episode 4		Fluidity	Specular

Key
I - individual
AL - active listening
AF - affirmation
ST - storytelling
R - researcher
G - group
RX - reflexive stance
CR - critical reflection
CP - challenges perspectives
OP - opposes perspectives
SU - shared understanding
TP - theoretical position
Q - question
EG - example given
S - summary

Figure four: Phase one analysis of video stimulated reflective dialogues case study two: session two a

The analysis in this figure, underpinned by Rantatalo and Karp's (2016) collective perspective on reflective dialogues, illuminates practitioners' dialogues as, at times, reflexive and critical in nature. In particular, exploratory dialogue which opposed perspectives to build understanding appeared evident. This emerged in response to a practitioner's stance or a question from the researcher. Most frequently though, the dialogue was cumulative, individual storytelling which was largely framed by active

listening and affirmation. Cumulative talk, whereby practitioners shared knowledge and affirmed each other's perspectives, featured across the case studies and appeared to be drawn on to support the establishment of connections between ideas. The excerpt below, from the second video dialogue session for case study two, illustrates such talk. In the session a practitioner had shared video footage of herself and a small group of children exploring lines of enquiry with small animals and figures on a mirror. The practitioner reflected on her experience and, as below, two other practitioners from a group of seven built positively upon the practitioners' contributions, developing a shared interpretation of the children's enquiry.

> *Molly*: I loved the idea that you brought the perspective that you brought the horse on, so you could see the horse's tummy, and suddenly, I thought that opened their [*the children's*] minds up. Because you had given them that thread, that way to look at it differently. Because then they brought lots of different things on, didn't they?
>
> *Tish*: Exactly, that's when the technical language came out.
>
> *Jamie*: Lots of experimenting then isn't it?
>
> *Tish*: Yes, I often find that, especially at this time of year, you are presenting something and then they [*the children*] follow their own lines of enquiry at this point. It all comes out from something initially, but it's extended as part of that scaffolding, there's a next sort of perspective on it.
>
> (Excerpt of video footage case study two: session 2a, 03:49-04:39/12:00)

Reflecting aspects of Mercer's (1995) definition of exploratory talk, dialogues in the three case studies were, at varying points, characterised by questioning and active listening. The following excerpt of dialogue from case study one is illustrative. The dialogue occurred in the first session in which seven practitioners had been invited to share their understanding and experiences of science enquiry in response to the abstract of Andersson and Gullberg (2012). The group had discussed the importance of tuning into children's interests and had placed value on an enquiry-based approach to the curriculum.

Marie: And we learn from the child. We may know more about it, but actually when you look at the child, hear what they are saying and doing.

Maddie: Actually, the child inspires your own enquiry because it could be all sorts of things that if you weren't with the child that you would walk past. But the children are inspired, oh yes, I wouldn't have thought of that. So, we are both enquiring together.

Lilian: I often find myself holding back quite a bit to enliven processes. Yes, if that makes sense. I know the answer, I know what they are trying.

Jay: [Interjects] So you won't be concerned about misconceptions then?

Group laugh

Lilian: No, I don't know, but you know, I don't feel that I have to give them [*children*] all the information. I want them to find out for themselves. After trial and error.

Maddie: So they [*children*] will understand, rather that you try to lead them.

(Excerpt of video footage case study one: session one a, 12:00-13:19/20:00)

Instances of exploratory talk which challenged practitioners' interpretations were only evident in case study two and involved reasoning and questioning to constructively oppose others' ideas. It is interesting that practitioners' exploratory dialogues in case study two offered more critical and oppositional perspectives than those in case study one and three which appeared more tentative; drawing on questioning rather than direct challenges. It is difficult to make a direct connection to why this might be as a number of factors may have had interrelated effects on the group. These might have included differing levels of experience; confidence; and the dynamics of the professional relationships.

Exploratory talk within case study two appeared to support the expansion of shared perspectives. For instance, in the following excerpt from the third video dialogue session with eight practitioners, different perspectives are offered in a dialogue exploring the place of creativity in scientific enquiry. Prior to the excerpt, the group had watched video footage of children exploring with bags and strips of material on a

windy hill. The excerpt begins with one practitioner questioning the functionality of the term creativity. Her challenge seemed to prompt the emergence of broader perspectives.

> *Tilly*: Don't you think the word creativity is a redundant word really, because a lot of the scientific...is the same thing. So what is this creativity? People are very hung up on this…
>
> *Jamie*: Could it be asking questions?
>
> *Re*: ...it does seem when I'm asking you for your ideas and reflections on that you're pulling out links and I'm saying where are the links? If they are the same thing, what are they? And so, going back to your clip, one example might be that, discovering something new is the same as part of an enquiry, whenever you engage in enquiry, you're seeking new knowledge and understanding and the same way there that may be, for instance…
>
> *Tilly*: It's the same with nearly every subject, look at maths, one of the things about maths is problem solving as it is with science and that's hugely….is the word creativity really needed?
>
> *Re*: Because it's embedded?
>
> *Tilly*: One of the nurseries I know talks about themselves as being creative, that they are a creative nursery but surely all the nurseries are creative?…Everybody always jumps on the bandwagon of creativity…
>
> *Jamie*: I suppose if you treat creativity in quite a narrow way then you might actually be verging away from creativity, and not just see creativity as something that all human minds are naturally creative. That's what we do, we're creating all the time, creating meaning, creating images… but in the context of an educational system that can sometimes constrain that kind of thinking because it's channelling you to think in a certain way to think about a certain process and discourage you to think like that!
>
> *Barney*: For me a creative question would be one that no one else has thought of and that form of enquiry and is perhaps something very unique.
>
> *Re*: I agree with you that it's embedded but I'm still particularly enquiring as to how we might foster those dispositions in children, so there's a difference between being creative and a creative process or how you might engage with

a creative act? To me there are such strong parallels with the science enquiry process and supporting and nurturing children's creative enquiry.

Tilly: When one talks about creativity ‘oh you’re creative’ or ‘that was really creative’ it's maybe an individual thing of how you see creativity it's…so into individuals…

Jamie: I think the unexpected is quite an important thing, isn’t it, something that is not conforming to a normal perspective…

Barney: It doesn’t have a definite thought process, it can be outside of that, because perhaps that’s where creativity lies…

(Excerpt of video footage case study two: session three, 37:15-41:57/48:00)

The presence of multiple perspectives in this excerpt appeared akin to Wegerif’s (2014) concept of dialogic space whereby practitioners began to move beyond the narrow set of assumptions which framed their interpretations. Indeed, broader insights on the position of creativity followed, as illustrated by one practitioner’s consideration for wider influences which might impact on understanding of creativity.

Further, listening to others’ perspectives within the context of *Video Stimulated* Reflective Dialogues (Moyles *et al.*, 2003) appeared to agitate thinking across the three case studies. This was evident in the surfacing of pedagogical dilemmas for case study one and three, and in the grappling with video footage of children immersed in enquiry with materials for case studies one and two. For example, the following excerpt from case study one illustrates a practitioner’s thinking ‘disrupted’ as she discusses the pedagogical dilemma of whether she should talk during a child’s immersion in enquiry.

Re: Thinking about the language, I noticed that you [*Ally*] did quite a few pauses - there were moments when the first crash of water happened...my immediate reaction would have been - woah! - but you paused - you really waited for her [*the child*] to have her reaction before [*you gave yours*]. Was that purposeful? How important was that, do you think?

[PAUSE]

Ally: I thinking it was more, I knew I was talking a lot and I just wanted to be quiet - it's hard to judge when you shouldn't and when you should talk. There is that big debate on [*referring to the group*], are we part of it? Should we be talking? Should we be using that language? I think part of me wanted to be part of it and then part of me wanted her [*the child*] to talk.

(Excerpt of video footage case study one: session three a, 23:44-24:28/01:04:00)

It is of interest that the video footage itself appeared to play a key role in agitating the perspectives of early childhood practitioners within case study one and two. This appeared evident in the sense of unease in the dialogues of seven practitioners in case study one when they first shared video footage in which the focus was centred on a child's immersion with materials in scientific enquiry. During the video dialogue, talk appeared stilted and slow, as if the video footage had disconcerted practitioners by providing a 'different' perspective. This was also apparent in the dialogues of practitioners in case study two. For instance, in their fourth video dialogue session, video footage was shared which illustrated children engaged in science enquiry within an open, expansive environment. Here practitioners appeared to begin to explore a 'role' for the landscape in a child's enquiry, in relation to what was made visually prominent by the video footage. In the discussion prior to the excerpt below, talk was cumulative but tentative and slow with practitioners frequently asking questions to confirm their interpretations.

Tish: Yes, they [*the children*] are doing the same thing but choosing different ways to do it. Feeling the gusts. Another thing was, you know, he [*the child*] seemed to paw the grass, I don't know if that was the whole time. But he seemed to go back on that spot. I don't know if he was really seeing the difference there because the water is pooling. Whereas it disappears in other areas. So, yes, retesting and comparing.

Jamie: The landscape as well was all about channels and how the water flows, it just was just formed by the water moving. Because behind it was the stream and the river flowing into it. And it had a real bend curving around at a low tide. So all these kind of spaces were created by, obviously by the water coming in.

(Excerpt of video footage case study two: session four, 18:47-20:06/53:00)

Practitioners' reflections on their participation in the study mirrored aspects of the literature on teacher professional development. This included, for practitioners in case study one and two, recognition that meaning making occurs through reflection, different perspectives and shared discovery within communities of practice. For practitioners in case study three, differing levels of experience appeared to be more closely associated with the development of their shared understandings. Practitioners in all three case studies cited standing back and viewing their own practice from another perspective as key to their learning. For practitioners in case study one and three this included reflection on their use of talk, echoing an ongoing dilemma.

Practitioners in all three case studies engaged in cumulative talk to narrate and share knowledge, which was often framed by positive affirmations from the group. Exploratory talk also appeared evident in all three cases though it was employed differently. For practitioners in case study one and three, explorations were characterised by questioning. Whereas in case study two, there was evidence of more oppositional perspectives and direct challenges which drew on questioning and reasoning. Such talk in case study two seemed to resonate with Wegerif's (2014) conceptualisation of dialogic space. Participation in Video Stimulated Reflection Dialogues (Moyles, *et al.*, 2003) appeared to agitate practitioners' thinking across all three case studies. Significantly, the video camera and the focus on video footage which illuminated children's immersion with materials seemed central to this, acting as a key point of difference. However, whilst the camera and video footage appeared important as 'an-other' perspective, it also drew attention to an issue in that the methodology sought generalised perspectives within groups and also agitated for differences. This is resolved in part two where the methodology develops through diffractive readings.

Summary of early insights

Key insights from each of the findings in part one of this chapter are drawn together and presented in the summary below. They are returned to in the discussion chapter.

- Influence of constructivist perspectives and child-centred approaches

Practitioners seemed to interpret young children's science enquiry through common conceptualisations influenced by Piagetian and Vygotskian perspectives and child-centred approaches. In particular, children appeared to be positioned as agentic knowledge builders; language as a mediator of scientific knowledge; and practitioners as facilitators who co-construct children's learning. However, such findings produced little new insight into young children's creativity in science enquiry.

- Pedagogical dilemmas in practice

Findings relating to practitioners' pedagogical dilemmas appeared to reflect an age-old tension between Piagetian and Vygotskian approaches. That is, whether to intervene or stand back from practice and whether to talk or not talk during children's scientific enquiries. Whilst practitioners navigated some dilemmas, the issue of when and how to talk appeared irreconcilable. Moreover, it was perceived as compounded by the influence of policy, accountability and early childhood education literature.

- Creativity as embedded within science enquiry

Mirroring other findings, practitioners' perceptions of creativity in science enquiry reflected common conceptualisations and thus produced little new insight. An anthropocentric perspective was foregrounded, with creativity largely perceived as a thinking skill which is embedded in science enquiry. However, an interesting finding emerged from a challenge to the usefulness of the term creativity. That is, creativity was perceived as potentially located outside of the space of human thinking.

- Materials and the environment as inert stimuli, and supporting an embodied experience

There appeared to be a lack of focus on materials in practitioners' dialogues. Indeed, materials seemed separate, inert and flattened against the emphasis which was placed on children as agentic thought builders. In some cases, materials appeared to be recognised as cultural tools and attention was drawn to children's embodied interactions with materials. However, the telos of materials appeared to be to support cognitive development. It was of interest that there was commentary on the importance and vitality of the elements and expansive environments in supporting scientific enquiry.

- Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) agitate and broaden perspectives

Practitioners' commentary on their engagement in Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) largely echoed existing literature on professional development. Similarly, practitioners' use of dialogue to develop shared understandings reflected established perspectives in the literature. As such, these findings did not produce new insights. The role that the video camera and footage of children immersed in enquiry seemed to play in agitating thinking was, however, of significance.

Findings Part Two

Diffractive Readings

Research question three informed the findings that are presented in this second part of the chapter:

- What insights are gained from a diffractive analysis of current understandings in literature and of empirical research of young children's creativity in science enquiry?

Findings are firstly orientated through a discussion focused on the visible apparatus which inform and determine the outcome of the diffractive reading. This is followed by commentary related to the process of experimenting with a new approach to diffractive analysis. Here, emphasis is placed on 'getting to the points of critical difference' which are considered crucial in this approach to diffractive analysis. Critical points of difference are then offered through the juxtaposition of narrated fragments of data. Finally, superpositions are presented and related to 'cutting together and apart' to make visible new ways of seeing.

Orientating

Although limited, the findings from an interpretivist reading of early childhood practitioners' shared understandings yielded some insights into the materiality of young children's creative knowledge practices in science enquiry. In particular, that

practitioners appear to draw on a narrow range of theoretical frames of reference to make meaning, and that video footage which illustrates children's immersion in material encounters agitates dominant thinking, creating a potential space for *different* perspectives. Differing, a diffractive analysis led to the creation of *new* perspectives and subsequently new knowledge to that which could be interpreted from empirical data or gleaned from engagement with literature. In particular, the reading of differences through transdisciplinary positions proved transformative. In the space of diffraction, making meaning from different literatures and empirical data became uncertain and fluid as opposed to isolated, contextually bound and inevitably reproductive of established disciplinary thinking.

Nonetheless, prevailing literature in early childhood (science) education and creativity in education, and empirical data which was analysed through an interpretivist frame are not dismissed. Indeed, the diffractive reading presented in this part of the chapter builds on early meaning making and insights. As reflected in research question three, empirical data from this study and current understandings in literature are 're-turned' and opened up to 'breathe in new life' into conceptualisations of young children's creativity in science enquiry (Barad, 2014, p.168).

The starting point was an ethico-onto-epistemic position. Therefore, emphasis was placed on the phenomena of 'shared understandings' and close attention was paid to its material-discursive, intra-acting entanglements (Barad, 2007). From an ethical perspective, I was keen to ensure that I took responsibility for my entanglement in what was made visible in the findings. Thus, the apparatus influencing agentic cuts within and through the relationships in the phenomena are made explicit as: the research questions and myself as researcher and participant in the study; empirical data and interpretations of shared understandings held by early childhood practitioners; existing research on early childhood science education; and conceptualisations of creativity. Crucially, it is recognised that these apparatuses affect the outcome of the diffractive reading. In acknowledgement of the 'unseen' apparatus in an ever diffracting, ever becoming material-discursive phenomenon of shared understandings, the findings from the diffractive reading are claimed as

representative of one moment of mattering. Unseen apparatus made visible could, of course, be productive of different agentic cuts and insights.

The findings in this diffractive reading are also affected by attention given to the emergence of ‘critical points of difference’ within a diffractive encounter of the apparatus i) empirical research data of shared understanding held by early childhood practitioners; ii) existing research on early childhood science education; iii) conceptualisations of creativity; and iv) myself as participant and researcher. That is, in enacting the diffraction, I was attuned to which points the apparatus collided and made visible difference. The subsequent superpositions - the merging ‘waves’ in the diffractive encounter - were also considered carefully, as indeterminate spaces from which new understandings have the potential to emerge. As illustrated in the Research Design chapter, figure six (please see p.101) takes the analogy of pebbles rippling in a pond and illustrates where the apparatus collides with each other. It also shows critical points of difference made visible through the enactment of transient boundaries, differential cuts resulting from collisions between the relationships between and within the data. Superpositions are also presented in the figure.

Getting to the points where difference is made visible

A great deal of time was spent with the apparatus of i) empirical research data of shared understanding held by early childhood practitioners; ii) existing research on early childhood science education; and iii) conceptualisations of creativity. This meant immersion within a transdisciplinary space in which multiple perspectives reside to read and re-read existing research, and watch and re-watch the video footage that I had collected during the study. As a process, I likened it to Barad's (2014) concept of 're-turning' which is described using the analogy of an earthworm who turns soil over and over again. I was not constrained to logical steps and, as such, was conscious not to look over data from an analytical position or treat it as raw material. Instead, I foregrounded experimentation and established a slow rhythm as I moved from text to transcript to text, paying careful attention to differences in perspectives that I was drawn towards. Caton's (2019) affective experience with video material and Holmes' (2016) description of how she endlessly returned to a piece of video footage and how it 'called her' back to new thought resonated with me. I could understand MacLure's (2017, p.53) need to be 'attentive to data's invitation and capacity to force thought'; that data might 'reach out and grasp' me. Inspired by Bennett (2010) and MacLure (2013), I felt secure in acknowledging the data as lively and vibrant and glowing. Within this space, some perspectives appeared to mirror each other whilst others not so. For example, as illustrated in the first part of this chapter, empirical data on early childhood practitioners' perspectives seemed to reflect those existing within established literature on creativity in education. Yet perspectives on creativity held by Ingold (2014) and Malafouris *et al.* (2014) appeared different. I focused on these different perspectives and placed them alongside the empirical data, identifying them as *critical points of difference* as they indicated a point at which there was potential to come to know young children's creativity in science enquiry differently. Though it is acknowledged that difference will always emerge within a diffraction, these particular points *mattered* to this study (Thiel, 2020). In effect, the act of placing different perspectives alongside each other was a differential cut which enabled spaces for becoming (Kember and Zylinska, 2012). That is, the critical point of difference signified a boundary from which meanings could be made.

Pondering what makes a point of difference critical, it occurred to me later, as I revisited my own entanglement in the diffractive reading, that both the selection of apparatus and the identification of critical points of difference had been a much more deliberate act than I had at first acknowledged. Entangled within and of the apparatus, I had inevitably determined outcomes. For instance, the study aims and research questions fundamentally influenced what I was attentive to and looked for in terms of difference. I aimed to challenge dominant perspectives on young children's creativity in scientific enquiry and this was entangled with my own interest in the relationship between art and science. Also enmeshed was my experience as a maker who sought sense of the creative process beyond the dominant terms in which I had come to know it. Thus, critical points of difference emerged as cuts from entangled material-discursive apparatus within a *particular* phenomenon not solely from the materiality of vibrant or glowing data. Whilst, agreeing with MacLure (2017, p.53) that 'as long as we remain intelligible to ourselves as the orchestrators of data's adventures, it will be difficult to escape the fetters of representation, humanism and anthropocentrism', care needed to be taken acknowledge my 'being and becoming' within the phenomenon. Such acknowledgement took the form of recognising myself as both inhabiting and becoming with both the video camera and footage, and text (Murris and Bozalek, 2019). This was made possible by using the concentric circles in figure six as a visual aid to keep sight of the non-linear and fluxional material-discursive state of the phenomenon of shared understandings. Albeit a partial illustration of the phenomenon, figure six also provided a frame from which to consider what came to matter and what was excluded from mattering in this study, supporting my desire to take ethical responsibility. Significantly, through my pondering figure six, I could *see* that it was only at the point of agential cut that boundaries temporarily fixed and made visible new understandings. Although cuts were not enacted directly by me but rather simultaneously together and apart, inside and outside of the phenomena, I was still accountable for any created. Thus, in the act of cutting, firstly making visible critical points of difference and then in attempts to 'measure' the superposition, I 'become' a particular maker and researcher, as do the co-constitutive apparatus of science literature, creativity literature and video material. And from this, new knowledge and new understanding from the larger material arrangements in which we are entangled (Adema, 2014).

What follows below is a detailed exploration of the critical points of difference which were made to matter within the diffractive encounter of i) empirical research data of shared understanding held by early childhood practitioners; ii) existing research on early childhood science education; iii) conceptualisations of creativity; and iv) myself as participant and researcher. Consideration is also given to the contribution of superpositions and agential cuts in the creation of new understandings of young children's creativity in science enquiry.

Critical point of difference: Talk is fundamental to scientific understanding, talk interrupts children's immersion with materials in science enquiry

A critical point of difference emerged in the diffractive encounter between i) video footage illuminating practitioners' concern over the role of talk - provoked by footage of children deeply immersed with materials - and ii) existing research on early childhood science pedagogy. The positions are outlined below to draw attention to how they created disturbance in established and normative approaches to supporting young children's knowledge making in science enquiry and, thus, how they were subsequently made to matter.

Fragments of video footage from empirical data are used to illustrate practitioners' concern over the role of talk in children's creative scientific enquiries. The first fragment, from the second video dialogue session with practitioners from case study one, draws attention to talk as a pedagogical dilemma. The dilemma emerged after watching footage of a child deeply immersed in enquiry with materials. There were few utterances from the child and very little dialogue between the child and practitioner. A second fragment is taken from the same group of practitioners engaged in their third video dialogue session. It illustrates the continuation of the dilemma of practitioner talk whilst children are immersed in creative scientific enquiry. In this fragment, a practitioner is troubled by her role and her engagement with a child who is also enquiring with water. Together, the fragments draw attention to a moment where practitioners became 'stuck' and repetitive in their dialogue in reaction to video footage.

Woven throughout the fragments is my narrative as researcher, which acts to contextualise the video footage. The narration is not constitutively separate, representative or interpretive of the voices of the early childhood practitioners. Instead, it is recognised as part of the phenomenon of this study exploring shared understandings of young children's creativity in science enquiry. It is entangled within the empirical perspective and illustrates the interpretivist approach which has partially informed the study. As such, it is acknowledged as data, apparatus and an ethical cut through the data which makes visible the researcher's perspective and enables it to matter (Barad, 2007; Davies; 2014; Ivinson and Renold, 2016; Mazzei, 2014).

Water swirling

> The group of seven have gathered for the second time. It is the afternoon meeting slot in the children's centre. Time to engage with the study has been agreed by the head of the centre and by practitioners, and we will come together on five occasions. There is a sense of nervous anticipation as this is the first session in which practitioners have shared video footage with both me and each other. Jay, an experienced practitioner shows the first clip in which a child plays with water. The child is positioned beside a large transparent tank on legs. A smaller blue plastic trug is on the floor in front of him. The child has a small cup which he fills with water from the tank on the table. He then turns and pours this into the trug on the floor. There is the hum of life in the children's centre in the background and a practitioner and child walk to and from the child as he enquires with the water. He is momentarily distracted but then returns to collecting water from the tank and pouring it into the trug. The action is repeated a number of times with the child moving in a circular motion from tank to trug and back again. The child increases his speed until it appears that the water moves from one tank to the other as if swirling through the air. Then the child slows down and pours water into the trug with careful attention. A small plastic toy pig, and later a disc, are placed in the trug and water is repeatedly poured onto them. Finally, the video footage shows the child holding a small plastic figure under a fast-running tap. There is very little dialogue in the clip and the practitioner filming has placed himself behind a small handheld camera which is shaking slightly. In the subsequent reflective dialogues, practitioners focus on the child's immersion in enquiry and the absence of talk.
>
> *Lilian*: [*Talking to Jay*]. You know you said that you were quiet in that [*clip*]. I quite liked it.
>
> *Bella*: Yeah, I liked it.

Lilian: I liked it and I was saying that because I was saying...I filmed myself with the magnets and I was on the other side of the room for that session and I was talking to her [*an early years consultant*] about it and she was saying that I used a lot of language didn't you and anticipated their [*the children's*] thinking instead of giving it to them and I whenever watched the video back, as you know because you were there with me, I hated it because I was spoke the whole time and it wasn't natural to me, though I do talk a lot [*laughs*] but it was different and I had missed so much of that immersed stuff that I really really stopped it. Stopped them [*the children*] being immersed.

Bella: I don't think that child needed you to...You know he had ideas, he knew what he was doing, and his ideas were changing. He didn't need you to give him that support, he was actually working out his own ideas. Anything you would have been adding would have been what you thought he was thinking not what he actually wanted to do…

(Excerpt of video footage case study one: session two, 16:55-18:00/30:00)

Water pouring

A sense of momentum and commitment to shared video reflective dialogues has built in this third session and a number of practitioners have shared video footage in previous sessions. Choice of footage of children engaged in enquiries has subtly evolved following the previous video reflective dialogue session. It has become more responsive to focal points from discussion in previous sessions. In this third session, a less experienced practitioner offers a short clip of video footage to the group. It depicts her recent encounter with a child. The seven practitioners present quieten, and the clip of video footage plays. Immediately visible is a child playing with water in a small room within the children's centre. She is pouring water from a large jug into a larger transparent tank which has a plank of wood propped up in it, acting as a ramp or a slope. Not visible but audible is the practitioner filming the child immersed in an enquiry which now involves filling the jug with water from the tank and pouring it back into the tank. She repeats this motion many times. The water splashes and ripples and sways in the tank. The jug wobbles in the child's hand when full of water and moves ever so slightly, as if springing back, when emptied. For a while there appears to be silence but on closer listening, beyond the child, the tank, the water, the jug and practitioner, there are the faint sounds of other children, of the scrapes of furniture moving and of doors opening and closing. The practitioner remains 'off scene'. She is holding an ipad and her presence is felt through the slightly shaking image as she shifts about capturing the child's encounter with the water. Within a minute of the enquiry, the practitioner talks, and the child responds. The talk is focused on commentary about the water and at one point the practitioner 'wonders' what

might happen to the water. This is followed by a short dialogue between the practitioner and the child.

Ally: Are you having a drink? [*Laughs*]

Kerys: I'm washing my face

Ally: You are cleaning your face! Okay

Kerys: [*Rubs water on plank*] I did the washing!

Ally: You were doing the washing!

Kerys: [Rubs water on plank again] I got all dirty now

Ally: Oh dear!

Kerys: [*Puts hand back in jug*] Let's wash it again

(Excerpt of video footage case study one: session three, Water Pouring, 00:01:46-00:02:24/07:30)

The clips finishes and the practitioner turns to the group to give context. She explains that the child had gone straight to the water on arrival at the children's centre that morning and that she was immersed in this playful encounter for a much longer period than was usual for her. This stimulates discussion and group turn to the subject of talk:

Re: Thinking about the language, I noticed that you [*Ally*] did quite a few pauses - there were moments when the first crash of water happened...my immediate reaction would have been - woah! - but you paused - you really waited for her [*the child*] to have her reaction before you gave yours. Was that purposeful? How important was that do you think?

[PAUSE]

Ally: I thinking it was more, I knew I was talking a lot and I just wanted to be quiet - it's hard to judge when you shouldn't and when you should talk. There is that big debate on [*referring to the group*], are we part of it? Should we be talking? Should we be using that language? I think part of me wanted to be part of it and then part of me wanted to let her [*the child*] talk.

(Excerpt of video footage case study one: session three a, 23:44-24:28/01:04:00)

Diffracted with existing literature on early childhood science pedagogy, these fragments of empirical data emerge as critical points which illustrate something different to established thinking about early childhood science. For example, within early science pedagogy, talk is recognised as a crucial tool for the development of scientific understanding (Driver *et al.*, 1994; Harlen, 2013). Informed by sociocultural theory, the established belief is that talk should occur in 'concrete' sustained social experiences and shared investigation (Johnston, 2008; Siraj-Blatchford, 2001). Additionally, talk in the form of dialogue, discussion and argument is advocated as an effective pedagogical strategy for the co-construction of meaning (Alexander, 2008; Eccles and Taylor, 2011; Harlen, 2014). The following fragment, from the popular text for early childhood practitioners 'Emergent Science: Teaching science from birth to eight' (Johnston, 2014, pp.40-41), illuminates these points by drawing attention to the importance of social experiences and language for the development of thinking:

> *"Dialogic teaching (Alexander, 2008) is an approach that can utilise social and language development to assist thinking (Johnston, 2011). Dialogic teaching is collective - children and teachers address learning together and reciprocally, so that each participant in the dialogue listens to others and there is a sharing of ideas and viewpoints....At this stage of development, children should be beginning to link their ideas with those of others, on an equal footing (Mercer, 2000) and in a coherent way, and beginning to develop simple arguments (Toulmin, 1958) more characteristic of older children (Erduran, 2012; Osborne et al., 2004)....The effectiveness of talk in developing scientific understanding is a common theme in many early years research findings (Johnston, 2011; Kallery et al., 2009; Tunnicliffe, 2007). Kallery et al. (2009)...found that, in teaching floating and sinking...children needed to make cognitive and verbal links between their exploratory findings and scientific phenomena. Tunnicliffe's (2007) research...identified that children's understanding of keeping healthy was enhanced by interaction and talk...This seems to require professionals who are not only aware of the importance of the complex balance between adult, peer and contextual support, but who will facilitate oral and social interaction, building on rich and varied language opportunities found in the home and ensuring that formal settings do not restrict language development (Wells, 1987)."*

Superposition

The fragments of empirical data and text, entangled and co-constitutive of the phenomenon of practitioners' shared understandings of young children's science

enquiry, contribute to the conditions which enable the emergence of a critical point of difference. That is, during the video reflective dialogues, early childhood practitioners across the case studies found themselves encountering pedagogical dilemmas in relation to the positionality of talk within early childhood science literature. As these dialogues collide with existing research on early science enquiry, there emerges a point of difference which is made to matter in this study. Difference manifests in the relationship between talk and not talking within the context of children's creativity in science enquiry, and in its process of becoming a 'differential cut' is enacted (Kember and Zylinska, 2012). As these points of difference superpose in a performative act, young children's creativity in early childhood science enquiry is at once supported by talk for the development of scientific understanding and by the children's immersion in material encounters. Here new configurations of science education are made possible. Insight into children's knowledge making practices goes beyond a simple illumination of the tensions that talk can create for practitioners as they seek to make sense of pedagogy and practice. It also moves beyond the perspective that manipulation of passive materials supports individual cognitive development. To see this, there is a shift from a focus on dialogue and the practitioners' subsequent pedagogical dilemmas and viewing the child as a knowing subject who uses materials for understanding. Instead, there is focus on a measurement within and outside of the superposition; a cutting together and apart of creativity in science enquiry as material intra-actions between a young child and water. Focusing on the 'more-than-human' of video footage, the child is decentred as a knowledge maker and instead emergent in relation to phenomena and its material-discursive apparatus. Indeed, both child and material are entangled matter, being and becoming through difference within the phenomenon of apparatus which includes but is not exclusive to water, child, cup, tap, plastic pig, disc, plastic figure, video camera and footage and practitioner. Child-material is made to matter.

If positioned as complementary, talk is not made visible in the act of cutting child-material. However, talk has potential to be foregrounded in knowledge making practices in another moment of 'cutting'. Significantly, an appreciation for both talk and the materiality of material in superposition connects to Murris and Bozalek's (2019) point, drawn from Olkowsky (2009, p. 55) and Barad (2012, p.77), that differentiating is not 'othering or separating' but rather about making connections in

relationships. Indeed, the critical points of difference here are relational. Making the materiality of children's knowledge visible is not an act of dichotomy but rather a cutting together and apart which reconfigures the world and makes one indefinite moment matter.

Critical point of difference: creativity in science as a cognitive concept, creativity in art as process enacted with materials

A second point of difference was created between i) existing research on creativity in early science education, which situates children's knowledge making within the confines of humans and the cognitive domain, and ii) broader conceptualisations of creativity, outside of the discipline of education. In particular, those within the domain of art which articulate creativity as enacted through engagement with materials (Malafouris *et al.*, 2014).

For example, existing research on early childhood science education is underpinned by a plethora of interpretivist studies which assume that young children's learning in science enquiry exists within a constructivist/sociocultural framework (see for example, Harlen and Qualter, 2018; Johnston, 2013; Kallery, 2015; Tunnicliffe, 2015). Whilst acknowledging oversimplification, there exists a consensus that practitioners, and peers, should share the cultural tools of science to enable the construction of ideas through discourse (Driver *et al.*, 1994). Hence, learning in science is perceived as a process of enculturation over discovery. This position is reflected in the literature focusing on creativity in science education. Here, there is consensus amongst scholars that critical thinking, problem-solving and exploratory and investigative approaches are evident in both science and creativity (see for instance, Barrow, 2010; CLS, 2012; Davies and McGregor, 2016). Cremin *et al.* (2015) draw synergies between early childhood science education and creativity which expound this position. These are presented as: play and exploration; motivation and affect; dialogue and collaboration; questioning and curiosity; problem solving and agency; reflection and reasoning and teacher scaffolding and involvement. The fragment below, from Cremin *et al.* (2015, p.12) illustrates the point:

Creative Little Scientists

> *"As the illustrative extracts evidence, teachers planned motivating contexts for learning often linked to children's interests and everyday events, some capitalised upon familiar stories as framing context. Teachers provided rich physical environments for inquiry in their classrooms, making good use of everyday and household materials and natural resources. Episodes drawn from the outdoor environment, whilst relatively few overall, highlighted the potential of sustained engagement with the outdoors and with living things to generate children's interest and questions, expressed both verbally and behaviourally. Group work was commonly observed as a feature of teachers' practice and often prompted dialogue and collaboration….core to this work was the opportunity for children to engage agentically in exploring diverse materials and resources. They frequently did so with curiosity and with what the project came to describe as 'hands-on, minds-on exploratory engagement' leading to problem-solving, problem-finding, dialogue and learner creativity"*

When diffracted with conceptualisations of creativity which sit outside of the domain of education, in the context of art, there emerges a critical point of difference between cognitive perspectives on creativity in science enquiry and those which include the material. For instance, a number of studies from cognitive science, which draw on artists' relationship with materials in the creative process, challenge conceptualisations of creativity that focus solely on human intelligence and the cognitive domain. These include Glăveanu *et al.*'s (2013) extensive study of creativity across five domains in which there is evidence of artists' referring to how the material that they engage with seems to take over and lead to the completion of an artefact. Others such as Ingold (2014, p.124) claim that creativity lies not in humans but rather in their 'attending to the world in formation'. That is, creativity is becoming which is realised in the forming and making of things. Describing the creative process, Ingold argues that both the 'thing' and the idea of it emerge together from the performance of making. Similarly, Chappell (2018) describes how humans and materials can 'enmesh' in the creative process. Materials, in these instances, are recognised as acted upon but also as acting on the creator to enable the production of something new. The critical point of difference between creativity as a cognitive and a material process draws attention to an assumption within the domain of art that materials are not fixed and inert in a pre-existing world.

The following extract from Ingold (2014, p. 138) which draws on commentary by lace maker Hana Majerova provides insight:

Objects are performative

> *"....Such undergoing [the process of creating] does not translate from an image in the mind to an object in the world. Rather, as we have seen in the case of Hana Majerova's account of her lace-making, both the thing and the idea of it emerge together to form the performance itself. This performance, moreover, is an act to which you submit: you do not initiate it; rather it behooves to you."*

And Malafouris (2014, p.150), drawing on claywork:

Creative material engagement

> *"I propose that Creative thinking happens at the point of intersection between the mentioned kinds of incorporation. Creativity can then be seen as a transactional relational achievement that emerges out of an effort to create and align understandings of people and things. What I call the feeling of and for clay refers precisely to this dynamic process of creative material engagement, wherein material and human agency are coupled to each other and allow action to gain a 'life of its own."*
>
> *"...the creativity process emerges as a temporally stretched but unified experiential assembly comprised of living moments that differ in duration, intensity or location, but it nonetheless remains a material process that is open to empirical investigation."*

Superposition

Creativity as a knowledge making practice in early childhood science education is informed by the dominant discourses of constructivist and socio-cultural theory which situate knowledge within the cognitive domain. Collaboration, dialogue, exploratory problem-solving, analytical and critical thinking, and human agency are all perceived as mediators through which learning and development occurs. Within the domain of art, creativity as a knowledge making practice is informed by psychology and cognitive science. This has given rise to perspectives which draw on embodiment rooted in sociocultural theory. Materials are also recognised as connected to the creative making process within this domain. In particular, creativity is understood as a 'dynamic process of creative material engagement' in which things and ideas emerge together (Malafouris, 2014, p.150). In a diffractive encounter, creativity in

science as enacted within the cognitive domain and creativity in art as a process involving materials emerge as critical points of difference. A differential cut makes them matter, revealing the potential to come to know creativity in science enquiry differently, further challenging the regulatory discourses of developmental psychology which shape early childhood education. This is particularly important because both the perspectives in science and art are present in superposition; the cognitive and the material. One is not pitted against the other. Indeed, both are necessary. Together young children's creativity in science enquiry becomes a knowledge making practice which is informed by perceptions of a pre-existing world and an embodied experience of materials. Materials are not solely fixed and inert, they are also dynamic and relational.

The enactment of an agential cut here makes visible creative knowledge making practices in science enquiry as material. The relational, cognitive perspective is positioned as a potential complement within the superposition, and as such is necessarily not made visible. Though it is not dismissed. Indeed, one dominant perspective is not replaced by another. Significantly, science as a cognitive process and science as material encounter are of and within this particular phenomenon. Creative knowledge making practices in science enquiry would of course be determined differently with other apparatus.

Summary of diffractive readings

Significant findings which emerged from the diffractive reading in part two of this chapter are summarised below and returned to in the discussion chapter.

- Reading diffractively

Getting to the points where difference was made visible revealed how immersion in a transdisciplinary space supported experimentation with 're-turning' theoretical and empirical data. The transdisciplinary space also drew attention to the affective associations that the apparatus of data made in co-constitutive relationship with the apparatus of my own ethical entanglement. Figure six proved important in visually refocusing attention to what determined the outcome in this study; the points of difference which mattered; and the non-linear, fluxional state of shared understandings of young children's creativity in science enquiry.

- Critical points of difference

Two critical points of difference emerged with and through the colliding apparatus within the phenomenon of shared understandings of young children's creativity in science enquiry:

talk as fundamental to scientific understanding and talk as interrupting children's immersion with materials in science enquiry

creativity in science as a cognitive concept and creativity in art as process enacted with materials

- Superposition

As points of difference superposed, they emerged to reveal potential new ways of seeing. The enactment of cutting together and apart child-material through the superposed space, illuminated children as decentred and becoming through potential differences between themselves and materials - within the wider phenomenon of creativity in scientific enquiry. In complementary relationship, and thus not visible, was the potential to come to know through talk. Additionally, in superposition, creativity as a knowledge making practice in science enquiry was shown as at once a cognitive and a material process. In cutting together and apart, creativity-material, the materiality of young children's knowledge making is made visible whilst creativity as a cognitive process is in complementary relationship and necessarily invisible.

Significant here is the acknowledgement that children are not at the centre of knowledge-making. Rather, children's creativity in science enquiry is a material phenomenon in which there are entangled intra-actions that are ever diffracting in the world's 'differential becoming' (Barad, 2007, p. 89). Apparatus emerge as open-ended material-discursive practices within and through these intra-actions. They produce knowledge and configure the world in particular ways. Thus, experimenting with a diffractive apparatus can illuminate material configurations that participate in the world's becoming (Hill, 2017). Made visible in this diffractive reading is one moment of mattering: the materiality of children's creative knowledge making practices in science enquiry.

Chapter Five: Discussion

Following the two distinct parts of the findings chapter, the discussion begins with broad consideration of the findings from part one; early insights. This is underpinned by an ethical position which foregrounds empathic questioning. Each of the key themes from early insights; constructivist/sociocultural interpretations; pedagogical dilemmas including talk; creativity in science enquiry; and children's engagement with materials, are discussed. The contribution of Video Stimulated Reflective Dialogues' is also considered. Here, emphasis is placed on the role of video footage in the development of practitioners' shared understandings. The findings from the diffractive reading are discussed in the second part of the chapter. This discussion is presented through three new ways of seeing; i) reading diffractively using the new approach developed in this study; ii) understanding of knowledge making practices; and iii) creativity in science enquiry as coming to know through material encounters. The chapter concludes with discussion of the limitations of the study.

The three research questions guiding the study are addressed holistically throughout the body of the discussion.

- R1: What representations of creativity exist within and beyond the field of (early childhood science) education?

- R2: What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

- R3: What insights are gained from a diffractive analysis of current understandings in literature and of empirical research on young children's creativity in science enquiry?

Research question one focusing on representations of creativity and research question two which considers the potential of Video Stimulated Reflective Dialogues inform the discussion of early insights. Research question one is also considered in

the discussion of the diffractive readings as is research question three, which specifically focuses on insights gained from a diffractive analysis of shared understandings in literature and empirical research.

Early Insights

Mirroring through interpretation

A traditional interpretivist analysis and deconstruction of empirical data yields some insight into young children's creativity in science enquiry. In summary, dominant constructivist and sociocultural conceptualisations appeared to inform practitioners' interpretations of children's scientific enquiries. Such frames of reference also seemed to be linked to practitioners' pedagogical dilemmas about whether to intervene or stand back from practice, and whether to and how to talk when supporting children's scientific endeavours. The role of materials within science enquiry also appeared to be interpreted through the presiding constructivist position. Though practitioners in case studies one and two also made references to what appeared to be related to the concept of embodiment in their descriptions of children's engagement with materials.

Practitioners' initial interpretations of young children's creativity in science enquiry reflected conceptualisations common to the field of cognitive science, in which creativity is perceived as a human centric process which is enacted within the cognitive domain. It was also understood as democratic and ubiquitous (see, Banaji *et al.*, 2010; Beghetto and Plucker, 2006; Rinaldi, 2006) in that practitioners considered all children to have the capacity to engage in a creative process. In addition, case study two recognised a relationship between creativity and science enquiry which echoed Craft's (2000) concept of possibility thinking. The three case studies also identified common connections between the process of scientific enquiry and creativity. That is, both were agreed as involving curiosity, making links, experimentation, problem solving and taking risks. These perceptions reflected synergies between science and creativity identified by Cremin *et al.* (2015). In particular, play and exploration; problem solving and agency; and questioning and curiosity.

However, such insights do little more than reflect existing literature within the domain of education. Rather than creating new knowledge about young children's creativity in science enquiry, the interpretivist framework appeared to restrict production to conventional findings, common in research and in materials that support the development of practitioner's pedagogy and practice. Indeed, they mirrored the theoretical, ontological and axiological norms within the paradigm. Thus, (re)presented in the early insights is a position which realises science as a material world separate from human interpretations of it. Children are positioned as agentic and at the centre of scientific and creative knowledge making practices which are enacted through thought and language within the cognitive domain. Normative approaches to early childhood science pedagogy are subsequently reinforced, and children are fixed as 'becoming' (Moss, 2017), in need of enculturation into the established practices of science. These findings are not new. Rather, they represent a repeating cycle of understanding which draws on a narrow reference of literature.

Considered through the new materialist framework which has been used to develop the later phase of this study, these interpretative insights perform an agential cut which makes visible one way of 'seeing'. That is, the apparatus of i) literature reflecting dominant perspectives on early childhood science education and creativity; ii) the early childhood education system as primarily shaped by developmental psychology and iii) an interpretivist framework for meaning making, make visible and determine an outcome which illustrates what is already perceived to be in existence about children's creativity in science enquiry.

From an onto-ethico-epistemic position, attention is drawn to Deleuzian ethical questions such as 'what is it to be this?' (Davies, 2014, p.738) and 'who is advantaged or disadvantaged through such agential cuts?'. Findings which identify early childhood practitioners' pedagogical dilemmas about whether to intervene or stand back, and whether to and how to talk when children are engaged in scientific enquiries certainly draw attention to a position in which practitioners are disadvantaged. For example, in case study one practitioners navigated concern over whether allowing children to 'find out for themselves' would lead to misconceptions about scientific concepts; that too much talk might prevent immersion in enquiry; and

how ‘scientific’ language might be used. Practitioners in case study two agreed a tension existed in their practice between supporting the development of scientific knowledge through explanation and encouraging children to develop their own theories. Andch practitioners in case study three gave ‘vague’ answers to children to negotiate a line between genuine shared enquiry and curriculum outcomes. Given such a mix of positions, practitioners need to be skilful at traversing muddled pedagogical waters at the same time as seeming to have little autonomy over their own practice. For case study one, dilemmas appeared manifest in a practitioners’ tentative talk during a child’s enquiry with water (see, appendix six excerpt of video footage case study one: session three a, 23:44-24:28/01:04:00). Viewed through the dominant sociocultural perspective, such talk has been perceived as impoverished and lacking sufficient scaffolding (see for instance, Johnston, 2009; Siraj-Blatchford *et al.*, 2002; Litson, 2002), resulting in ‘the practitioner’ portrayed as deficit in their practice. Further, traditional constructivist and sociocultural perspectives position children themselves as the subjects of predetermined frameworks for learning which privilege language and the cognitive domain as a central site for knowledge making. Such structures which fix boundaries on processes of meaning making are arguably limiting. They give rise to further questions such as; what is not made visible or known about children’s creative knowledge making practices in science enquiry? What else is possible? Which apparatus might inform and determine different insights?

Thinking with new materialism and creating space for such questions to arise means that the first phase of this study becomes something more than a reflection of existing perceptions. The emergent questions are the starting points for further insights; the diffractive insights are discussed in the second part of this chapter. Firstly, as implicit in this first part of the chapter, both the practitioners and I gained new understandings from the interpretive journey. I was challenged to reassess long established ideas about children’s creativity in science and began to make desired links between my professional practice as an early childhood educator and my existence as a maker, reconsidering relationships between science and art in the process. Practitioners gained deeper understanding of their own practice by both engaging as a community to explore different perspectives and standing back from practice. The medium of video footage agitated our normative thinking and

contributed to the emergence of different perspectives on children's creativity in science enquiry. Without the distraction of talk on the video footage, we noticed children's immersive experience with materials. We began to consider the environment and its elements as contributing to children's scientific processes and practitioners in case study two touched on the idea that creativity might reside outside of 'human thinking'. The role that the video footage played in agitating thinking appeared significant. I considered it as contributing to and expanding dialogic space (Wegerif, 2014). Specifically, that the video footage acted as a point of difference, an 'other' perspective which, together with multiple dialogues, unsettled established ways of seeing.

Thus, there is something to be gained from careful consideration of the early insights phase of the study. What follows is a detailed discussion of the key themes which form the findings for this phase.

What is made visible in the early insights?

Constructivist/sociocultural interpretations

Given that the theoretical frameworks which support early childhood practitioners' training materials are largely underpinned by constructivist and sociocultural perspectives, and a plethora of research studies assume that young children's learning in science enquiry also exists within these frameworks (see for example, Harlen and Qualter, 2018; Kallery, 2015; Johnston, 2014; Tunnicliffe, 2015), it is not surprising that both my own and early childhood practitioners' interpretations appeared to be influenced by these positions. Indeed, descriptions within case study one of children's sensory exploration of different materials and related cognition which seemed to draw on the dominant Piagetian metaphor of the little scientist (O'Loughlin, 1992), and Vygotskian perspective that scientific knowledge is developed through co-construction and language as appeared visible across the case studies, are long established and prevalent in the literature (see for example, Adams, 2006; Bruce, 2015; Keaton and Bodie, 2011; Kim and Darling, 2009; Nutbrown et al, 2008; Harlen and Qualter, 2018; Tunnicliffe, 2015). Alongside this, as an accepted truth within child-centred perspectives, it seems inevitable that children were positioned at the centre of their enquiries by practitioners. Indeed,

such placement of children ‘has come to epitomise’ pedagogy within early childhood education (Campbell-Barr, 2017).

Unexpectedly, when interpreting video footage there appeared a high emphasis placed on children’s engagement in the initial phases of scientific enquiry. In particular, children’s initiation of lines of enquiry and their emergent skills in observation, asking questions and collecting data. A focus on ‘later’ stages of science enquiry were not visible in practitioners’ discussions during the video reflective dialogues across the case studies. This is perhaps due to the focus on creativity in this study which was more readily linked to the generating ideas as necessary in the early phases of science enquiry, rather than the later stages which require rigorous testing of ideas, abstractions and logical steps (Shavelson and Towne, 2002).

Pedagogical dilemmas

Mirroring well-established literature within early childhood education, the combination of constructivist, sociocultural and child-centred practices appeared to contribute to practitioners’ pedagogical dilemmas, across the three communities. For instance, Cherrington (2016), highlights the difficulty early childhood practitioners face in repositioning themselves from a passive role as advocated in child-centred pedagogies to the more active position required within sociocultural approaches. Fisher (2016) has unpacked the issue of intervention versus interference in young children’s learning experiences through consideration of the ‘quality’ of interactions, and Langford (2010) draws attention to ethical dilemmas which emerge from the unequal status created between practitioners and children in child-centred approaches. Such conflicts between pedagogical approaches in early childhood education are age old. We have been round and round in circles with them, over many years (see for instance, Lewis *et al.*, 2019; Mellou, 1994; Murray, 2015; Wood and Hedges, 2016). Although points raised about dilemmas arguably go some way to explaining practitioners’ unsureness about whether to intervene or stand back from young children’s scientific enquiries in this study, the mix of epistemologies manifested in pedagogy appeared, to some extent, to be able to coexist in practice. Though it should be acknowledged that this was at the expense of practitioners who were required to navigate potentially conflicting approaches. Viewed from this

perspective, practitioners' dialogues revealed complexity within their role which implicitly supported decision making about which theoretical perspectives to draw on in any one moment. For instance, as well as theory, interpretations of young children's scientific endeavours were informed by practitioners' attunement and deep, resonant relationships with children in their care. More specifically, their practical wisdom or 'phronesis', based on experience and everyday knowledge shaped practitioners' pedagogical approach (Campbell-Barr, 2019).

Talk

While intervening or standing back from children's enquiries could be negotiated through skill and experience, the closely related pedagogical dilemma of when and how to talk remained persistent and unresolved for practitioners in the study. Indeed, it developed into a running theme during the video dialogue sessions of case study one. Literature within the domains of early childhood and science education place high value on talk, advocating it as crucial in supporting children's development and learning (see for instance, Alexander, 2018; Deason, 2009; Mercer, 2009; van der Veen *et al.*, 2017). Within early childhood education, the 'quality' of talking interactions is emphasised (see for example, Siraji-Blatchford and Manni, 2008; Davis and Torr, 2015; Fisher, 2016). Indeed, although a contested concept, quality heralds global interest in the context of early childhood education (see OECD, 2011; European Commission, 2014). The seminal reports entitled Researching Effective Pedagogy in the Early Years (REPEY) (Siraji-Blatchford *et al.*, 2002) and The Effective Provision of Pre-School Education (EPPE) (Sylva *et al.*, 2004), drew attention to the notion of quality in practice, highlighting what was perceived as lacking in child-adult interactions within early childhood settings. Underpinned by constructivist theory and carried out within mixed positivist and interpretivist frameworks, the reports introduced the term 'Sustained Shared Thinking' as an effective pedagogical strategy to support children's development. Sustained interactions are underpinned by a range of sociocultural pedagogies including listening, thinking and/or talk within a Zone of Proximal Development to scaffold and co-construct meaning (Siraji-Blatchford, 2009), and are promoted throughout the areas of learning within the Early Years Foundation Stage (DfE, 2017). They are also valued within child-centred approaches where practitioners might engage pedagogies of listening and talk to invite and guide participation (Bogatic *et al.*,

2018). Given such credence, it is understandable that early childhood practitioners describe pressure to use talk and promote language development continually throughout children's experiences in settings. As noted by one early childhood practitioner in the study; not talking with children is considered a 'non-interaction' by some settings. Related to this, practitioners recognised that the dilemma of when and how to talk could be exacerbated by a tension between the predetermined outcomes within the Early Years Foundation Stage (DfE, 2017) and the National Curriculum (DfE, 2013), and the direction in which children might wish to develop their own enquiries. Echoing well-versed critique about the influence of policy and accountability on early childhood education (see for instance, Arndt *et al.*, 2018; Moss, 2018; TACTYC, 2017), practitioners in case study two discussed talk as an increasingly valued tool to support knowledge construction, no matter the context.

Focusing on the position of talk within literature on science education provides further insight and possibility for persistent pedagogical dilemmas. For example, a seemingly irreconcilable difference between Piagetian perspectives which focus on the individual 'agentic being' and talk for elicitation (Ollerenshaw and Ritchie, 1997), and Vygotskian theory which advocates the 'social being' who co-constructs meaning through language (Mercer and Littleton, 2007), has been highlighted as an issue many times to no avail. It seems that debates remain fixed on the same issue without coming to a point of resolution (see for example, Driver *et al.*, 1994; DeVries, 2000; Semmar *et al.*, 2015; Siraj-Blatchford, 2009; Wood and Bennett, 1998). Consequently, how we 'see' young children's meaning making in early science education has been limited to debates within constructivist and sociocultural theory. This leads to outcomes whereby practitioners rely on narrow frames of reference to come to know children's scientific enquiries, as illustrated below.

One of the key outcomes of participating in the study, as cited by practitioners, was an opportunity to stand back from practice and view it from another perspective. Creating such distance led to an awareness of the extent to which talk was drawn on as a pedagogical strategy and, crucially, how talk interrupted children's engagement with materials in scientific enquiry. Indeed, when children explored lines of enquiry in expansive and elemental environments or when they were clearly in relationship with materials, it appeared that there was little space for talk. It did not fit; it interrupted

and hindered children's immersive experiences. Within such contexts, where talk hindered immersion, practitioners across the three case studies considered being present as an 'interested adult' part of their role; an approach which stems from sustained shared thinking (Brodie, 2014; DfE, 2015). Thus, although not talking was considered superfluous at times, the space that it created for practitioners and children appeared to be interpreted through the normative sociocultural frame of reference; as another form of human interaction. Conceptualising 'being present' within the frame of sociocultural theory reveals little new understanding about children's scientific enquiries and, to some extent, perpetuates the pedagogical dilemma of whether or not to talk as it morphs to whether or not to think to co-construct meaning.

Considered from an onto-ethico-epistemic position, the focus on one discourse necessarily excludes other ways of 'seeing'. However, in the context of the empirical data and in existing research on early childhood science education, little attention is given to what is excluded, at the expense of talking or sustained shared thinking. Instead, variations of a dominant discourse pervade, creating a fixed image of children.

Creativity in science enquiry

As with interpretations of young children's scientific enquiries, it was not unexpected that early childhood practitioners drew on dominant perspectives to conceptualise the position of creativity in science enquiry. Nor was it surprising that alongside perceptions of creativity as curiosity; making links; experimentation; problem solving and; taking risks, which closely aligned with aspects of Cremin *et al.*'s (2015) synergies between science and creativity, the concept itself was argued as a redundant term by practitioners in case study two. Ultimately, creativity and science do little more than mirror each other in their close alignment with education's aim to improve the mind of the individual (Biesta, 2010). Indeed, they have been positioned as key to the development of higher order thinking skills necessary for global competitiveness (Havu-Nuutien *et al.*, 2017).

Practitioner's exploratory dialogues within case study two which reflected awareness of the positioning of creativity in education were taken for granted given their context

within a nursery and children's centre which presents itself a site for research and pedagogical innovation. Although uncommon in many early childhood settings, practitioners' engagement with research and awareness of the ways in which the education system is productive of particular individuals reflects a niche of centres which adopt the social and democratic ideals of sites such as Reggio Emilia. Entirely unexpected though was the dialogue which began to look beyond the established norms of constructivism and humanism, which situate creativity within the cognitive domain as a process of human intelligence. That is, creativity was considered to reside outside of a definite thought process. Such a perspective resonated with Wegerif's (2014) dialogic space whereby the possibility of creativity is enacted within the spaces between dialogues, dependent on a mix of 'other' and different perspectives. Indeed, at times, practitioners' multiple perspectives appeared to support the expansion of space and the creation of *new* perspectives in this study. It is of interest that such new perspectives emerged in response to video footage of children's immersive experience with materials and, consequently, they are of significance to this study.

Thinking with perspectives and difference in the context of new materialism, this study accounts for material-discursive apparatus co-constituting a phenomenon of shared understandings of young children's scientific enquiries. From this position, both the video camera and footage become 'an-other' perspective; an object of matter. Rather than knowledge making practices being born solely of dialogic interaction - which Hetherington and Wegerif (2018) reframe as material-dialogic, acknowledging Barad's (2007) argument for dialogues as composed of matter - knowledge making includes both video camera and footage as more-than-human, emergent, intra-acting and *of* the process of meaning making. This positioning of video camera and footage disrupts the idea that knowledge is produced within humans or directed by their intervention. Indeed, it acknowledges the more-than-human as part of meaning making processes. Thus, within the phenomenon of shared understandings about young children's creativity in science enquiry, video camera and footage, and dialogues intra-act not as separate individual units but as being and becoming differentials, creatively enacting to make meaning. For this study, they become the starting point for a different perspective on meaning making. It is of note that videography literature informing the early phase of the research

design was well matched to the interpretivist paradigm and thus underpinned by an assumption that video footage might ‘represent the real world as it is’ (Murris and Menning, 2019, p. 4). Findings also revealed practitioners' perceptions that video footage might enable unique insights such as capturing ‘real time’ as discussed in case study two, and children’s perspectives on differing speeds and playbacks of the footage, as shared by practitioners in case study three. The shift in this study, prompted by the findings, to an acknowledgment of both video camera and footage as performative apparatus in knowledge making, repositions it from a passive observing instrument (Mengis *et al.*, 2018) to *matter* in knowledge production. Thus, rather than an attempt to find meaning in how children in the video footage creatively enact scientific enquiry, fragments of empirical video footage are diffracted as a doing which ‘interrupt habitual processes of seeing and understanding’ (Murris and Menning, 2019, p. 5).

Children’s engagement with materials

Maintaining focus on practitioners in case study two, a catalyst for the shifting perspectives on creativity was children’s engagement with materials as presented in video footage (see for instance, children enquiring with bags on a Windy Hill, session three). For these practitioners, the theme of embodiment appeared to emerge as a point of reference through which to make meaning of children’s engagement with materials. The concept of embodiment and research on children’s embodied enactments in their daily lived experiences are well established within the context of early childhood education (see for example, Danish *et al.*, 2020; Dunn and Wright, 2015; Frith *et al.*, 2019). Indeed, embodiment has been theorised through multiple discourses, such as naturalist, semiotic, poststructuralist, feminist, Foucauldian and posthumanist perspectives (Ellingson, 2017; Jones and Woglom, 2015). However, although a sensorial relationship was acknowledged between mind and body by practitioners in case study one and two, indicating that bodies could be productive of knowledge, their frames of reference seemed deeply rooted within constructivist, sociocultural and child-centred perspectives. Thus, explorations of embodiment ultimately reinforced a position whereby children are at the very centre of knowledge making practices. For instance, referring to science enquiry with materials on a windy hill, practitioners in case study two described children as ‘howling’ like the

wind. Similarly, practitioners in case study one inferred that children 'lived the concept of force'.

Towards the end of the video reflective dialogues, practitioners in case study two explored what could be described as the 'agency' of materials. That is, they acknowledged that children were influenced *by* the expanse of environment and the wind in their science enquiries, as illuminated by video footage. Although the environment was perceived as separate and pre-existing, as within constructivist and sociocultural frames, there appeared room for the environment and materials to offer something to the child. Considering the place of agency for materials, Ingold (2007) invites thinking *with* the environment. To do so means to understand the environment as a world that continually unfolds in relation to children and materials who participate in its ongoing generation and regeneration. Thus, children grow with the 'current' of materials, participating and transforming from within. Humans are subsequently not conceived as solid matter with mentality and agency, as perpetuated by the current perspective on early childhood science education, but as materiality itself. Children, from such a position, investigate relational and processual qualities of materials over fixed and predetermined properties. Thinking with Ingold (2007) goes some way to acknowledge children's relationship with materials. However, both appear trapped in a world which ultimately separates humans and materials. Additionally, by adopting such established insights there is a risk of simply reproducing another's interpretation. This seems to limit the possibility of a *meaningful* challenge to current, dominant practices within early childhood science education as well as any deepening understanding of young children's knowledge making practices within science enquiry. As such, a traditional approach of deconstructing and coding data, and later reconstructing it in relation to literature is restrictive.

Drawing on those who have experimented with diffractive approaches (see for instance, Hultman and Lenz Taguchi, 2010; Lenz Taguchi and Palmer, 2013; Osgood and Giugni, 2015; Otterstad, 2018) and Baradian new materialist philosophy, the next section of the chapter discusses the findings from a diffractive reading which emerged from the new approach to diffractive analysis introduced in the research design chapter.

Diffractive Readings

Whilst the findings from early insights drew attention to how the interpretivist paradigm and constructivist traditions reproduce and reflect what is already perceived to be known, a diffractive reading makes visible new knowledge and ways of seeing young children's creativity in science enquiry. Foregrounding research question three and the findings from a diffractive reading of the material-discursive apparatus i) empirical research data of shared understandings held by early childhood practitioners, along with ii) existing research on early childhood science education; iii) conceptualisations of creativity; and iv) myself as participant and researcher, this second part of the chapter discusses defining features of the approach to diffractive reading and the affects of early insights 're-turned' as within and of the phenomenon shared understandings of young children's creativity in science enquiry. The affects are introduced below as three new ways of seeing. It is acknowledged that they are determined by the diffracted material-discursive apparatus and made visible by agential cuts which are not fixed but rather performative of a particular moment of knowledge. It is claimed that such cuts reveal perspectives which have previously been overshadowed by dominant discourses.

The three understandings are presented thus:

i) reading diffractively

Attention is drawn to the finding that adopting a transdisciplinary position was necessary to challenge contextually bound, established disciplinary thinking. Additionally, consideration is given to how a transdisciplinary position and a re-turning of empirical research data made possible a search for *critical points of difference*; differential cuts which *mattered to this study*. The enactment of agential cuts through superposed critical points of difference is also explored and subsequently positioned as significant in making visible relational, complementary understandings about young children's creativity in science enquiry.

ii) knowledge making practices

Knowledge making practices are initially discussed through the finding that, in the space of diffraction, traditional interpretivist processes of meaning making which

reflect back empirical research data and literature are limiting. The finding that knowledge making manifested in differential cuts enacted by critical points of difference through and within the phenomenon of shared understandings of young children's creativity in science enquiry is also examined. Additionally, entangled empathic affects within knowledge production are explored and noted as significant in making visible the ethics of what was made to matter and consequently what was necessarily excluded in material encounters.

iii) creativity in science enquiry includes coming to 'know' through material encounters

The findings which revealed young children's creative knowledge making practices in science enquiry to be enacted through a cognitive process which includes talk *and* encounters with the materiality of materials are referenced here. That is, the two positions of talk and material which were recognised as critical points of difference and potentially complementary in superposition. The subsequent enactment of cutting together and apart 'child-material' which necessarily excluded talk as a knowledge making practice but did not dismiss it as an established position is explored. Consideration is also given to the finding that in one moment of indeterminate meaning children are recognised as de-centred, emergent and becoming with material within and of the phenomenon of shared understandings of young children's creativity in science enquiry.

What follows is a detailed discussion of these understandings.

Reading diffractively

New materialist perspectives on 'difference' offer an alternative understanding of knowledge making practices. When conceptualised as rich in potential, of the world in its becoming (Barad, 2007) and thus the condition of our existence (Hultman and Lenz Taguchi 2010; Rautio, 2013), difference is positioned as a means through which we come to know in relationship rather than as a challenge to be overcome for internal development, as in Vygotskian dialectics or Piagetian constructivism. From this perspective, in search of insights from shared understandings on young children's creativity in science enquiry, the diffractive reading in this study focused attention towards 'patterns of difference which make a difference' (Barad, 2007, p.

72) and the ‘in-between’ as a space which ceaselessly proliferates material-discursive realities (Barad, 2007, p. 140). In doing so, a new approach to reading diffractively was developed which foregrounded critical points of difference.

The findings illustrated a transdisciplinary position and the re-turning of video footage as integral to the emergence of *critical points of difference* and subsequent differential cuts from which there was potential to see new understandings of young children’s creativity in science enquiry. Acknowledging that within a diffractive encounter there will always be superposition from colliding differences and thus something new created, the search for differences revealed knowledge which *mattered to this study*. As described by Thiel (2020), Barad’s (2007) use of the verb to ‘matter’ denotes something as materialised and something that is of significance. Points of difference were thus identified ‘critical’ as, although they emerged from an experimental, performative approach in which the affective nature of matter was acknowledged, they were determined as mattering by intra-active, entangled apparatus such as myself as researcher, research questions, conceptualisations of creativity and early childhood science education. Thus, in a relational and entangled sense, the search for critical points of difference has been a deliberate act of measurement through which I take conscious responsibility for creating particular knowledge. In doing so, there are necessary exclusions to what matters rather than a hierarchy of ‘points of difference’.

Findings also revealed that as critical points of difference superposed, apparatus overlapped to reveal young children’s creative knowledge making practices in science enquiry as enacted by both talk and material encounters. Conceptualising these knowledge making practices as co-constitutive complements, drawing on Barad’s inspiration from Bohr’s complementarity theory whereby if light is seen as a particle, it necessarily cannot be seen as a wave, enabled the study to offer new ways of ‘thinking-doing out research which do not run against [other] philosophies...but at the same time bring new emphases and new priorities’ (Davies, 2018, p. 125).

Knowledge making practices as emergent from phenomena and determined through diffraction/difference

Paying attention to what is not normally seen and to what is excluded (Taylor, 2013, p.692), shared understandings, as gathered through empirical research, were repositioned from a central focus on the researcher, practitioner or child as individual or collaborative knowledge constructor, to phenomena of *particular* entangled material-discursive apparatus through which *particular* agential cuts make visible new knowledge. This is seen through the finding that, in the enactment of differential cuts as apparatus collided, critical points of difference superposed to reveal children's creative knowledge making practices as at once enacted through talk and material encounters. Thereby, the *performative act of cutting together apart particular critical points of difference is knowledge making practice*. Thus, in this study, there were no subjects with inherent boundaries and properties such as those presented within Cartesian dualism. There are instead intra-acting and emerging apparatus co-constitutive of particular materials, environment, social practices, video camera and footage, research, theory. Indeed, as Barad (2003, p.815) states 'relata does not proceed relating' and therefore there is no prior separation between the world and the subject.

What is made visible through the enactment of the diffractive reading is an 'exteriority within phenomena' (Barad, 2007, p.140) through which practitioner, researcher, child, materials, environment, video camera and footage, and theoretical perspectives are emergent and becoming, in relation to the emergent understanding that children's creative knowledge making practices as enacted through talk and material encounters. Hence for this study focused on how shared understandings can inform perspectives on creativity in science enquiry, *the agency of knowledge making* concurrently exists and emerges through relationships within the phenomenon of shared understandings.

From this position, dichotomous relationships existent in constructivist and sociocultural theory become stark and unsettling. That is, centring on practitioners' dialogue and reflection as the source of knowledge making over the material of both video camera and footage for instance, or conceptualising science education as discursive practice in which practitioners enculturate children to predetermined

knowledge over other possible configurations, restricts the potential for understanding processes of how we come to know. Indeed, when considered alongside practitioners' pedagogical dilemmas which result from the atomisation of knowledge making practices and privileging of the human perspective, such theoretical frames appear constrictive and counterproductive. Moreover, in finding shared understandings performative, relational and emergent, a tension is created with science education which is commonly understood to seek to create shared understandings through discursive practices (Driver *et al.*, 1994). Presenting a convincing challenge to these conceptualisations, the findings from the diffractive reading show innumerate possibilities as to how shared understandings might be enacted. Indeed, the enactment is related to apparatus which define outcomes, the collision of critical points of difference, and the agential cuts which make visible 'exteriorities within' (Barad, 2007, p.140). It is thus claimed that current conceptualisations of early childhood science education limit children's knowledge making practices to a predetermined route from which little *new* scientific knowledge might be acknowledged or made visible.

Coming to know through material encounters

Within the diffraction of shared understandings of young children's creativity in science enquiry, the findings revealed a critical point of difference emergent between conceptualisations of creativity within art (a relational process entwined with materials) and theoretical positions on science enquiry within education (a cognitive process).

As these two points collide and superpose creativity in science enquiry is performed as both a material and a cognitive encounter. This is different to established positions such as that within Piagetian constructivist theory. Although Piaget emphasised a role for materials in supporting scientific understanding within the cognitive domain (Mercer and Littleton, 2007), material encounters are limited to aiding the development of representational perceptions of an assumed reality. That is, in popular constructivism material and child are separate from one another and grounded in a dualist philosophy whereby there is separation between the human mind and external world (Hua Liu and Matthews, 2005). The critical point of difference in this study shows material encounters as more than rudimentary tools

which support intellectual development. Crucially, a relational ontology underpins material encounters in conceptualisations within art. Thus, child and material emerge in relationship; one does not precede the other. In the diffractive reading, coming to know through materials is affective and co-constitutive within relational spaces. To symbolise this, a dash in cutting together and apart child-material might act as a signifier for ‘a difference between’, whereas a slash in a child/material Piagetian cut signifies ‘a separation between’.

Reinforcing the argument for a relational ontological positioning of materials in early science education, another critical point of difference identified young children’s creativity in science enquiry as more than a discursive process.

Talk as fundamental to scientific understanding and talk as interrupting children’s immersion with materials in science enquiry.

That is, in the diffractive encounter between theory espousing talk as fundamental to meaning making in early childhood science and video footage illustrating talk as interrupting children’s immersion in science enquiry, materials are again visible as relational in knowledge making. While video footage of children’s connection with materials appeared to agitate practitioners’ thinking in the early phase of the study, in a diffractive reading, understanding of materials shifts. Materials do not simply support individual cognitive development. Indeed, critical points of difference within the framework of new materialism are more than a simple Cartesian division between a sociocultural perspective which privileges talk and individual constructivism in which a child might manipulate materials for concept formation. Importantly, cutting together and apart child-material in this diffractive reading purposefully determines a boundary within the phenomenon of shared understandings of creativity in science enquiry (Arlander, 2017), making matter a *different* relationship between materials and children in coming to know scientifically. Thus, acknowledging complementary relationships, made visible through the critical points of difference is young children’s creativity in science enquiry as enacted through the materiality of materials *and* language/individual cognition.

Considering pedagogy and practice in early childhood science education, this suggests that it is necessary to attune to children's material encounters in science enquiry beyond perspectives informed by Piaget's 'individual epistemological idiosyncrasy' (Hua-Lui and Matthew, 2005, p.388) or Vygotsky's 'historical-dialectical-monism' (ibid, p. 387). Indeed, attunement needs to include a focus on differences emergent between children and their encounters with the materiality of materials. That is, an acknowledgement for the more-than-human as entangled in creative knowledge making practices in science enquiry *and* emergent differences between child and material as holding potential for new ways of knowing. Crucially, investigating which differences matter, and to whom, is ethically entangled in the relational and affective experience.

Considered more broadly, children are 'becoming' in relation to intra-acting apparatus which determine what knowledge is made visible. Therefore, pedagogic focus needs to keep in mind that relational differences within a child-material encounter emerge and become in relation to all the material-discursive apparatus visible within particular phenomenon. For instance, in video footage from case study two of children playing with strips of material and bags on a windy hill (see appendix six case study two, session three: Windy Hill), material wraps around a child, and both child and materials emerge through a phenomenon which includes but is not exclusive to differences between child, material, hill, wind, practitioners, video footage. This is further exemplified in the video footage from case study one of a child swirling water from tank to trug (see appendix six case study one, session two: Water Swirling). Here, the child is decentred as a knowledge maker and emergent as differential in relation to the phenomena and its material-discursive apparatus: water, child, bucket, tap, plastic pig, counter and spiderman, video camera and footage, and practitioner.

Such apparatus, as illustrated in Water Swirling, along with that which is less visible, determines outcomes of how child-material is known within this study. I do not presume to know what this might be for the child. However, to acknowledge my entanglement as apparatus within the phenomenon of shared understandings and the cuts to which I hold some responsibility for enacting, in cutting together and apart child-material, the water reveals to me qualities of swirling, gushing, and slowing as

differences in relation to a young child throwing, pouring and splashing. Resisting a space determined through talk, sustained shared thinking or materials as inert and passive, I wonder what understanding of science and scientific knowledge could emerge.

However, such a perspective is problematic within the current realities of early childhood science education, influenced by the Early Years Foundation Stage framework (DfE, 2017), constructivist, sociocultural and child-centred theory. By relinquishing predetermined insight into what 'knowledge' might be gained by an individual child from science enquiry and instead valuing the child-material intra-action as a cut through a phenomenon, knowledge is not easily measured in terms of established scientific understanding. Arguably, by predetermining knowledge outcomes as within the Early Years Foundation Stage (DfE, 2017) and dictated within the National Curriculum (DfE, 2013), children's potential to come to know their world through rich spontaneous and differential relationships is bound and limited. Certainly, the aim to produce human capital which will lead the future knowledge economy positions children as 'progressing' and reproductive of established norms of science education which view the world as static and fixed.

Despite such arguments, powerful governing regimes are difficult to challenge or change (Moss, 2017). Further, there is a risk that in adopting new materialist perspectives, early childhood practitioners will face variations on existing pedagogical dilemmas: to focus on material encounters or to talk? To predetermine knowledge as an outcome or leave spaces for uncertainty? In the context of prescriptive frameworks such as the Early Years Foundation Stage (DfE, 2017) and in attempting to reconcile pedagogical dilemmas, care needs to be taken to avoid falling into an in-between space. One in which children and materials are acknowledged as intra-active and co-constitutive but fixed concepts are still applied as the knowledge outcomes of encounters. What seems crucial is that the two positions of talk and material are not pitted in opposition but rather that both are acknowledged. Such a position is akin to Barad's claim that seeing something new is not performed as a radical break with the past. Instead, it is a 'dis/continuity' which doesn't presume that there is more of the same or a disconnection from what has been before. It is a cutting together-apart as one move. This, Barad states, doesn't

deny ‘creativity and innovation but understands its indebtedness and entanglements to the past and the future’ (Barad, cited in Juelskjær and Schwennesen, 2012, p.16).

In light of this, it seems imperative that early childhood practitioners both listen and respond to that which is framed through discursive practices and that which emerges through children’s affective, relational encounters with the materiality of materials. Particularly important is that practitioners allow their gaze to decentre and shift from the agentic knowing child to materials as more-than-human matter in relationship with children. In such decentring, practitioners need to acknowledge their ethical entanglement in determining that which is made known as children and materials become through relationships which emerge within wider phenomena. Moreover, attention needs to be focused on the spaces in-between child and material, through which differences that matter might emerge.

Video footage can play a significant role in supporting this shift in ways of seeing. As the findings from early insights showed, video footage agitated practitioners’ thinking. It provided a point of difference. Indeed, footage of children’s immersion with materials appeared to unsettle normative ways of seeing and stilt practitioners’ discussion. Positioned as more-than-human in a diffractive reading, video footage emerged as a critical point of difference to established perspectives on early childhood scientific enquiry. It decentred my human gaze and promoted in-depth exploration of the significance that the materiality of materials plays in young children’s creative knowledge making practices. For both practitioners’ and children, both the video camera and footage positioned as a more-than-human point of difference could support greater focus on the quality and affective nature of materials in scientific enquiry. Due to its visual nature, it provides a space to consider potential differences between children and materials, as well as relationships with wider apparatus which determine what is known within a particular phenomenon. Crucially, use of video footage in this way could encourage greater awareness and ethical responsibility for the cuts that are made by practitioners in ‘assessing’ what children know. As illustrated in this study, this could be, but is not exclusive to, cutting together and apart the complementary relationship of ‘knowing as mediated through talk’ or ‘knowing as becoming in relationship with materials’.

Summary of chapter

The first part of the chapter discussed early insights gained within an interpretivist paradigm, with acknowledgement that they were largely representative of what is already known about young children's creativity in science enquiry. The discussion drew attention to complexity within practitioners' pedagogical approach, particularly when navigating what appeared to be conflicting constructivist and child-centred influences. Discussion also focused on practitioners' unresolved issue of whether to talk when supporting children's creativity in science enquiry, and the role of both video camera and footage as more-than-human matter in agitating practitioners' established and normative perspectives. Part two of this chapter, diffractive readings, considered different ways of knowing young children's creativity in science enquiry. Repositioned but not dismissed were the perspectives of popular constructivism. For example, those stemming from Piaget's material/child which illustrates a dichotomous relationship between passive material and agentic child, and Vygotsky's talk/child which privileges language and difference to be overcome in children's knowledge making practices. Indeed, the diffractive reading was described as making visible constructivist/sociocultural perspectives in potential complementary relationship to children's encounters with the materiality of materials. Discussion which focused on a child-material cut through the phenomenon of shared understandings of young children's creativity in science enquiry, foregrounded children's encounters with materiality. It also suggested critical points of difference as potentially emergent in the spaces in-between such encounters. Further research might explore such points of difference in relation to children's ways of knowing in science enquiry.

This diffractive reading illuminates the narrow frames of reference drawn on to understand knowledge and processes of knowing in current, popular conceptualisations of children's knowledge making practices in early childhood (science) education (see for instance, Johnston, 2014; Brunton and Thornton, 2010; Tunnicliffe, 2020). Indeed, it adds to the body of literature which draws on new materialism in early childhood education to challenge the limitations of dominant anthropocentric perspectives on young children's lived experiences. In particular, the reading contributes to research focused on 'lifefulness' (Somerville, 2019), in that it

foregrounds children's relational experiences with materials. The findings which indicate critical points of difference as illuminating spaces in-between which matter, furthers Lenz Taguchi's (2012) argument that learning events occur simultaneously between hands *and* material things. Indeed, the focus on superpositions as spaces in-between and the cutting together and apart through these spaces to reveal potential complementary relationships adds a new perspective to established literature. Potential complementary relationships, such as the materiality of children's creative knowledge making practices *and* the use of talk to construct knowledge, shows something of that which is necessarily excluded in cutting together and apart. This offers insight into the under researched area of what is excluded or invisible in diffractive readings (Hollin *et al.*, 2017). The diffractive reading also broadens the scope of recent research informed by new materialism in early childhood science education (see for instance, Areljung, 2019; Haus and Siry, 2019). In particular, new insight is offered through the wider consideration given to what it means to know and become through intra-actions with materials. That is, what might emerge from the spaces in-between children's encounters with the materiality of materials, and the potential emergent points of difference which direct thinking towards relational and affective ways of knowing in scientific enquiry. That creativity in early childhood science education emerges as a more-than-human process in the diffractive reading, beyond current conceptualisations which position it as a thinking skill enacted within the cognitive domain (Havu-Nuutien *et al.*, 2017), contributes to a growing field of thought which argues that humans and materials enmesh in the creative process. That is, humans, environments and objects are both embodied and agentic, emerging through intra-actions (see for instance, Chappell, 2018).

The new approach to diffractive analysis offered in this thesis adds to a growing body of experimentation with diffractive methodologies in educational research (see, for instance, Chappell *et al.*, 2019; Davies, 2014; Hultman and Lenz Taguchi, 2010, Osgood and Giugni, 2015 and Taylor and Gannon, 2018). Adding further perspective to the significance of transdisciplinary spaces and how intra-action with 'others' produces emergent outcomes (Chappell *et al.*, 2019), this reading emphasises the transdisciplinary space as supporting the possibility for finding *critical points of difference* which matter. The search for critical points of difference in this diffraction is a new approach to both reading with theory and mapping patterns of difference.

Indeed, in a move away from identifying, for example, passes between the data (Taylor and Gannon, 2018) or differences across the data (Mazzei, 2014), I present points of difference as in potentially complementary relationships. Here, Barad's (2007) concept of in-determinacy is drawn on, emphasising relational understandings of difference. As such, the entanglement of what has been and what is not yet known, or, what is made visible and necessarily invisible is acknowledged in ways that are different to other experiments with diffractive methodology (see for instance, Bozalek and Zembylas, 2016; Hoel and van der Tuin, 2012; Osgood and Giugni, 2015; Otterstad, 2018). Here, a contribution is also made to literature which examines how researchers are entangled in meaning making (Davies, 2018, p.122). This is most evident in the consideration given to ethical responsibility for that which is excluded in the diffractive analysis.

Finally, less visible in other diffractive readings is the emphasis this study placed on wider frames when exploring what is made known. Specifically, the focus on the phenomenon of shared understandings and the intra-active material-discursive apparatus which affect and determine understandings of young children's creativity in science enquiry. This appears particularly significant in relation to the limitations of the findings yielded within the interpretivist paradigm underpinning the early part of the study. This point is taken up in the conclusion.

The concluding chapter opens with discussion of the limitations of the study. Outcomes are then explored in relation to both the study aims and research questions. This is followed with a focus on implications for pedagogy and practice in early childhood science education. Final thoughts are given to my own learning from the study.

Chapter Six: Conclusion

The final chapter begins with consideration for the limitations of the study. Following this, each of the three research questions is revisited through the study aims which sought to:

- illustrate existing discourses of creativity within and beyond the field of (early childhood) education to demonstrate elusive and wide-ranging conceptualisations;
- challenge conflicting and dominant discourses on creativity in science enquiry in early childhood education as limiting;
- illuminate the potential for alternative conceptualisations of young children's creativity in science enquiry, adopting diffractive methodology as a knowledge making practice; and
- present a new approach to diffractive analysis by showing critical points of difference as crucial in affecting connections which can convincingly reconfigure dominant ways of seeing.

Findings from research question one are briefly summarised and reference is made to key outcomes from the literature review. These are related to research practice. For research questions two and three, focus is placed on findings which have provoked further questions. The value that the diffractive analysis contributes to educational research is discussed through research question three. Subsequently, implications for research and practice are considered. Emergent recommendations for early childhood pedagogy and practice and my own learning from the study form the conclusion of the chapter.

Limitations of the study

Whilst it is important to acknowledge the limitations of the research design, data collection and the early meaning making phase of the study with reference to established evaluative frameworks such as Lincoln and Guba (1985), there lies an inherent tension in this created by the experimental approach which was adopted in the later diffractive reading underpinned by new materialist philosophy. That is, in an

interpretivist evaluation I might identify limitations in the trustworthiness of what is claimed in the first part of the study. Whereas my later diffractive reading foregrounds knowledge making practices as differential and indeterminate and thus challenges the representationalist epistemological framework which informs such evaluative tools. As such, key determining factors which indicate an interpretivist study reliable including credibility, transferability, dependability and confirmability are rendered somewhat obsolete. To navigate this tension, Barad's (2007) conceptualisation of 'dis/continuity', which doesn't presume disconnection but rather creative entanglements, is acknowledged, and what is discussed draws from both interpretivist and new materialist perspectives to illustrate the limitations of the study and how these might be addressed.

Early childhood practitioners participating in the study were representative of particular groups. Although balanced in that they mirrored the typical features of the early childhood education workforce (see, Bonetti, 2018) and held some contrasting geographic features, they were all located within the South-West region of England. Other contexts from further afield would have offered broader scope and further 'different' perspectives to the shared understandings of young children's creativity in science enquiry, and the subsequent theoretical outcomes. Perhaps this would have contributed to and strengthened 'transferability' within the study. However, through a new materialist perspective, broadening the demographic field would have made visible different apparatus and thus determined a different outcome, affecting different shared understandings and becomings. More relevant, therefore, seems further consideration for the *purpose* of increasing transferability. For instance, who benefits from strengthening transferability to another context given the claim that emergent new knowledge is not fixed? As such, positioning the outcomes of this study as apparatus to 're-turn' in a diffractive encounter with different demographics might determine more expansive insights on shared understandings of creativity in science enquiry.

The use of videography as a research tool during both the data collection and early phase of analysis revealed the limitations of my own interpretations in terms of credibility. For instance, measures were put in place during early meaning making to ensure confirmability. These included seeking practitioners' agreement with

generalised perspectives based on initial coding. However, generalised perspectives together with the identification of broad themes during later analysis meant that nuances in practitioners' voice enmeshed within a large volume of video footage and were necessarily fragmented and lost within a reductive analytical process. Additionally, my own perspective will inevitably have led to some researcher influence. For example, although a range of pre-selected statements on creativity and an abstract relating to early childhood science was used in the first session to stimulate discussion with practitioners, they are likely to have been drawn on with some unconscious bias. Considered in relation to both interpretivism and the diffractive reading, transparency seems essential. That is, acknowledging my bias as a limitation which to some extent is mitigated by transparency, as within the interpretivist position, and ensuring responsibility is taken for my own entanglement as apparatus determining what will be made known, as influenced by new materialist philosophy.

Further limitations of the study are manifest in my positionality as researcher and participant during the data collection phase of the study. Despite an initial desire to engage reflexively with awareness of the influence and impact of my presence, maintaining this position whilst immersed in video stimulated reflective dialogues with practitioners proved challenging. My background as an educator in early childhood, primary education, and early childhood studies, inevitably influenced my participation in dialogues and the balance with my relationships with participants. From the perspective of an interpretivist study, this could be considered to limit both the credibility and reliability of the study (Yin, 2009). Particularly in that participants' contributions may have been biased by my contributions. However, from a new materialist position, my role is acknowledged as necessarily entangled as apparatus and always implicated in determining the outcome of the study. Transparency seems again imperative here for future research positioned within a new materialist frame. Particularly, with recognition that within new materialism focus is placed on phenomena as opposed to individual agentic entities. Thus, individuals are acknowledged as becoming in relationship and taking ethical responsibility through this relationship is entangled with transparency.

Further points to draw attention to are practical issues that I encountered. For example, some participants needed time to familiarise themselves with using the video camera and the quality of the sound on video footage was an issue at times. On using both video cameras and footage in research again, I would factor in more time for playing and experimenting with equipment for both me and participants.

Revisiting the research questions

What representations of creativity exist within and beyond the field of (early childhood science) education?

Research question one was a key focus in the literature review. Exploration of a wide range of literature provided an opportunity to address the study's aim to illustrate existing discourses and elusive conceptualisations of creativity within and beyond the field of early childhood education. Indeed, it was found that although creativity within education mirrors dominant discourse shaped by an anthropocentric frame within the domain of psychology, a myriad of conceptualisations and definitions have led to creativity within education being deemed a slippery concept (Davies *et al.*, 2014; Kampylis *et al.*, 2009; Sawyer, 2006; *Sefton-Green et al*., 2000). Creativity was predominantly understood to be enacted within the cognitive domain supporting the development of higher order thinking skills necessary for engagement in the global knowledge economy (Havu-Nuutien *et al.*, 2017). This perspective was mirrored in (early childhood) science education, underpinned by humanist and instrumentalist epistemological positions and sociocultural/constructivist theoretical perspectives. Such perspectives informed normalised understandings and identified synergies between creativity and science enquiry (Cremin *et al.*, 2015). Wegerif's (2008) claim that the spaces 'in-between' dialogues hold potential for the enactment of creativity provided a different perspective to one which privileged the cognitive domain. Though an anthropocentric perspective on creativity was still evident in this conceptualisation, Hethington and Wegerif (2018) provided a point of departure from dominant discourse through their consideration for matter as expanding dialogic spaces. Thereby, matter was implicitly acknowledged within the enactment of creativity. However, despite this and numerous conceptualisations, creativity within education is shaped by very narrow epistemological and theoretical perspectives.

Similar theoretical perspectives and conceptualisations were found in the literature directed towards the domain of art. That is, creativity was informed by the field of cognitive psychology and sociocultural theoretical perspectives. However, strikingly different was creativity recognised as a material process. For example, Ingold (2014), drawing on art, found creativity as realised in the process of forming and making things. Hylonoetic spaces ‘in-between’ maker and material were recognised by Malafouris (2014) as significant in that they demonstrated a mental and physical inseparability in the creative process. Such inseparability was echoed in Chappell’s (2018) posthumanist framing of the creative process as emergent from the enmeshing of humans and materials. A number of artists also illuminated the posthuman/new materialist perspective as influential in their understanding of the creative process (see for instance, Garber, 2019; Lehmann, 2017). It was found thus that whilst sociocultural perspectives were influential in the domain of art, conceptualisations of the creative process placed significance on the role of materiality.

Creativity, as it appeared across education and art, was represented by human centric perspectives; educations’ aim to improve the mind of the individual and the artist's necessary relationship with the material. However, the conceptualisation of spaces ‘in-between’ within both domains foregrounded a relational ontology and decentred subject in creative processes. Of significance to the study and related to this research question, was the finding that a transdisciplinary space opens new possibilities for finding difference as opposed to reproducing disciplinary thinking through domain bound conceptualisations and theoretical frames. From this space in-between, there emerged possibilities for creating new knowledge which mattered, and subsequently, a convincing challenge to conflicting and dominant discourses on creativity in science enquiry in early childhood education. As such, this research question has been pivotal to the study by revealing the limitations of centring research practice within one domain.

Bringing together perspectives from art and science in research is not new. Indeed, transdisciplinary collaborations between the fields are increasingly visible and have been used to inform and develop practice within both domains (see for instance,

Braund and Reiss, 2019; Clark *et al.*, 2020; Roughley *et al.*, 2019). However, a focus on identifying *critical points of difference* between conceptualisations across these domains is new and provides a different perspective on approaches to research within the fields of early childhood and science education. That is, by foregrounding the search for critical points of difference in complementary relationships across domains, there is the potential for *new knowledge* to emerge. This is different to the transfer of knowledge in which there is learning from practices which are traditionally considered domain specific. Here dichotomous relationships are prevalent. As illustrated in figure six, the enactment of diffraction reveals superpositions which 'ceaselessly proliferate material-discursive realities' (Barad, 2007, p. 140). In this study, this included a relational transdisciplinary space *'in-between'.*

What potential does Video Stimulated Reflective Dialogue (VSRD) (Moyles *et al.* 2003), within communities of early childhood practitioners, hold in contributing to understanding of young children's creativity in science enquiry?

The study aimed to challenge conflicting and dominant discourses on creativity in science enquiry in early childhood education as limiting. To do this, findings related to research question two were drawn on. Firstly, early childhood practitioners' reflective dialogues and shared understandings were identified as largely reproductive of existing knowledge. Secondly, attention was focused on the conflicts between dominant theoretical constructs within early childhood (science) education evident in practitioners' pedagogical dilemmas. Although to some extent discussion of dilemmas reproduced established perspectives on pedagogy and practice in early childhood education (see for instance, Cherrington 2016; Fisher, 2016), and drew attention to a persistent and seemingly irreconcilable conflict between constructivist and sociocultural perspectives which is age old in the literature (see, Driver *et al.*, 1994), practitioners' dialogues did reveal complexity in their practice through their levels of attunement to children, phronesis (Campbell-Barr, 2019), and skill in navigating potentially conflicting theoretical positions alongside wider educational influences such as accountability.

The finding that Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) held potential to agitate normative thinking and broaden perspectives was most significant

to the aim to challenge current discourses on creativity in science enquiry in early childhood education. In particular, video footage played a role in agitating a *different* perspective. This occurred both through the video footage of children immersed in encounters with material in scientific enquiries, and through the finding that the video footage positioned as more-than-human held potential to expand practitioners' perspectives. However, this was limited to disrupting thinking and normalised perspectives gathered within an interpretivist framework.

The use of Video Stimulated Reflective Dialogues (Moyles *et al.*, 2003) within communities of early childhood practitioners in this study offers insight into the ways in which practitioners understand young children's creativity in science enquiry to the field of science education. That is, it illuminated the reproduction of established understanding in practice, and the broad ranging adaptive skills that early childhood practitioners employ in order to navigate conflicts between such understandings. The use of both video camera and footage was particularly important in offering insight into how new understandings might emerge through difference, to challenge conflicting and dominant discourses on creativity in science enquiry in early childhood education as limiting. Indeed, re-turned in a diffractive reading, video footage emerged as a critical point of difference from which new knowledge could be made visible. In relation to emergent research on videography from a new materialist perspective (see for instance the special issue on video and decolonising early childhood in Video Journal of Education and Pedagogy, 2019) and questions such as; How might video research be implicated in the phenomenon of knowledge-production? (de Freitas, 2016) and; How can videography challenge the ontologies of humanism? (Murris and Menning, 2019), I am keen to pursue the 'agency' of technology. In light of findings summarised below, I question, how is that which is not necessarily 'seen' in video footage implicated in knowledge production?

What insights are gained from a diffractive analysis of current understandings in literature and of empirical research on young children's creativity in science enquiry?

Research question three illuminated the potential of diffractive methodology to make visible alternative conceptualisations of young children's creativity in science enquiry. In particular, the new approach to diffractive analysis presented in this study showed

critical points of difference as crucial in affecting connections which can convincingly reconfigure dominant ways of seeing creativity in science enquiry.

As a knowledge making practice in terms of research, a transdisciplinary position and the diffractive 're-turning' of apparatus i) empirical research data and ii) existing research on early childhood science education and iii) conceptualisations of creativity, were considered pivotal to the emergence of critical points of difference. Such points were recognised as enacting differential cuts premised by a search for difference which *mattered to this study*. Consequently, ethics was acknowledged as openness to the affective nature of data and taking responsibility for my own entanglement as apparatus determining what was made visible within the phenomenon of shared understandings of young children's creativity in science enquiry.

Speaking to young children's creativity in science enquiry, the superposition of critical points of difference revealed knowledge making practice as enacted at once through talk and material encounters, within and of the phenomenon of shared understandings of creativity in science enquiry. The acknowledgement of both configurations of knowledge making was key to 'dis/continuity' in that there was no assumption of more of the same or a disconnection from what has been before (Barad, 2007). This is particularly important as making visible new ways of seeing young children's creativity in science enquiry involved cutting together and apart, not cutting in two. Thus, a measurement was enacted through the phenomenon of shared understandings to reveal child encounters with the materiality of materials and, in doing so, knowledge making as mediated through talk was necessarily not visible. It was not, however, dismissed. Talk and material were subsequently positioned as complementary, acknowledging their relationship to what matters in creative knowledge making practices in science enquiry.

As material encounters are brought to the fore through cutting together and apart child-material, materials are seen as emergent and relational to the phenomenon of shared understandings, rather than inert and passive of a pre-existing environment. Their purpose in a child-material cut is not to support the telos of concept formation within the cognitive domain, as within constructivist theory or a child/talk cut. Indeed,

in the child-material cut children as agentic knowledge builders manipulating their environment is necessarily excluded. Rather, the child and the material emerge and become together, in a different way. The agency of creativity in scientific enquiry making is emergent within this encounter, in the 'in-between' space of child and material. Consequently, children within science education are centred and de-centred, repositioned to knowledge builders and knowledge creators who are entangled and becoming within the wider phenomenon of the world in its ongoing, differential becoming (Barad, 2007).

Coming to know scientifically from this position reveals the potential for new scientific knowledge - that is what is not yet known - to become visible. For instance, critical points of difference emergent in the space in-between child and material hold the possibility of new configurations of scientific knowledge, dependent on which apparatus is made visible within phenomenon and the enactment of cutting together and apart. In this act there will of course always also be necessary exclusions. The implications for practice that this raises are considered below, as recommendations.

Drawing on this approach to reading diffractively and on the insights that it has yielded about how we come to know practices of knowledge making, there is scope for further research in education. In particular, the focus on how that which is necessarily excluded contributes to knowing. This is claimed by Hollin *et al.* (2017) as significantly under researched in Barad's agential realism. The finding that complementary critical points of difference in superposition made visible something of what is necessarily excluded is thus an area for further exploration.

Contribution to knowledge

This study contributes new knowledge about approaches to diffractive methodology and enriches current understandings of how children come to know in early childhood science education.

The new approach to diffractive analysis presented in this study contributes to and broadens the current range of experiments with diffraction and reading diffractively. This is offered through the discovery of critical points of difference as emergent

within data as they collide across transdisciplinary spaces, and through exploration of superposition as space 'in-between', which holds the potential for new knowledge to be made visible. Additionally, the focus on critical points of difference as in potential complementary relationship offers a new perspective on diffractive reading which draws on Barad's concept of 'in-determinacy'.

Critical points of difference in this study also offer new knowledge to the field of early childhood (science) education. This draws attention to and challenges current, narrow conceptualisations of creativity in science enquiry. For instance, those in dominant science education literature which assume knowledge as constructed through a separate subject/object relationship, and early childhood science literature which explores intra-active and relational child-object encounters through new materialist philosophy but appear to funnel the emergence of new knowledge towards a fixed outcome of pre-determined scientific concepts (see, for example, Arlejung, 2019).

As this study shows, new materialism can offer different insights into children's creative knowledge making processes in science enquiry. What is *different* is the emphasis on coming to know that which is 'not yet known' (Davies, 2020, p.148) or made visible, as critical points of difference collide within the intra-active, entangled matter of material-child.

Cutting together and apart the superposition of points of difference revealed children's encounters with materials as emergent through a relational, affective experience. Here, children and material(s) are in continual states of becoming through emergent differences in the world in *its* becoming. Drawing on Ingold (2007, p. 14; 2014), the materials' qualities hold potential to reveal themselves to the child in a moment which is made to matter. Such qualities are not constant or fixed nor universal properties that are discovered through sensorial exploration by an agentic, separate subject. Rather, materials are endlessly changing in relation to encounters with, for example, light, shade, wetness, dryness. The material thus emerges in relation to its involvement in its surroundings, which includes the materiality of the child; her skin is not a container for experience, but instead porous and 'leaky', feeling with and sensing with the world (Manning, 2009, p.33). Subjectivity is thus

dispersed (Robinson and Kutner, 2019) and events occur not in the child or the material but rather in the spaces ‘in-between’; in relationship itself. Both child and material in their becoming are *affected* through each other and in this affective experience children create knowledge. Here, creativity is a material knowing which emerges as necessarily entangled with ‘spaces, sensations, memories’ (Robinson and Kutner, 2019, p. 112) *and* that which is ‘not yet known’ (Davies, 2020, p.148).

Science education neglects such ‘other’ ways of knowing in favour of that which is constructed by humans within the cognitive domain. The rational, analytical and linguistic are privileged over other available knowledges. As Robinson and Kutner (2019, P.117) articulate, the affective experience is ‘an attempt to give voice to a crucial something, a haunting that is traceable but always slipping’. Although not easily grasped, affect is *registered* in this study and, emergent through entanglement in creative knowledge making practices, it is made to matter.

In light of this new understanding, implications for pedagogy and practice in early childhood science education are outlined below.

Implications for pedagogy and practice

New materialism draws us to the necessity of maintaining sight of education as relation (Biesta, 2004), and crucially that human participation in practices of knowing occur as part of the ‘larger material configuration of the world and its ongoing open-ended articulation’ Barad (2007, p. 379). Within this framing, this study has

- signified apparatus within and of the phenomenon of shared understandings of children’s creativity in science enquiry as determining the outcome of what is known
- illuminated young children’s creative knowledge making practices in science enquiry as enacted through both a cognitive and material way of knowing
- acknowledged what is seen and necessarily excluded in cutting together and apart child-material

For pedagogy and practice, these findings imply that practitioners' attunement should be directed towards children's emergent knowing and becoming in encounters with the materiality of materials as well as to talk as mediator of knowledge construction. As such, there needs to be acknowledgement in practice that children come to know in ways that lie beyond the cognitive domain. This means that a shift from dominant ways of 'seeing'. Rather than the normative and familiar (constructivist/sociocultural lens) which leads to a narrow interpretation of the 'purpose' of materials, attention needs to be focused towards emergent points of differences in the spaces 'in-between' child and material encounters. For example, difference might manifest in the experience of a child pouring water and material revealing its qualities of flow and stickiness. Instead of articulating this as an agentic child manipulating water to gain insight of stickiness as a concept, emergent differences between a child pouring and water's stickiness need to come to the fore. That is, consideration for what is made visible about children's affective, relational knowing and becoming.

Understanding young children's creative knowledge making practices in science enquiry from this perspective requires practitioners to acknowledge children as decentred and materials as energetic matter. In addition, practitioners need to recognise their entanglement in children's material encounters and their role in determining what is made known. Indeed, to circumnavigate pedagogical dilemmas, focus should shift from grappling with conflicts between theoretical perspectives to taking responsibility for the cuts that are enacted through phenomena within practice, and their affect. As discussed, both the video camera and footage can play a significant role in supporting greater focus on the quality and affective nature of encounters with materials in scientific enquiry. Significantly, it could encourage greater awareness and ethical responsibility for the cuts that are made by practitioners in 'assessing' what children know. However, in order to foster its use in practice, practitioners need exposure to theoretical perspectives beyond the dominant discourse and the opportunity to engage in their own playful enquiries. The foundations of this could begin in Early Childhood Studies at undergraduate and postgraduate level, and in initial teaching training programmes. Here, students might explore their own 'knowing' through experiential enquiries as well as theoretically

through an ethico-onto-epistemic framing, using both video camera and footage as a ‘critical point of difference’.

New lines of enquiry

Engagement with new materialist philosophy and working within a transdisciplinary space in this study has been both inspiring and challenging. Moving from a reductive and restrictive approach to data analysis within the interpretivist paradigm to playful experimentation with data as fluid, affective matter has been liberating and, at times, joyful. Moreover, my understanding of creative processes and what it means to know have been transformed. As I have neared the end of this study, new questions and possible lines of enquiry have emerged.

Potential further research could include investigation of the agency of technology and both video camera and footage as a more-than-human point of difference in knowledge making practices. In particular, the question how is that which is not necessarily ‘seen’ in video footage implicated in knowledge production? Additionally, a focus on the significance of critical points of difference potentially emergent in the spaces in-between children’s encounters with materials in science enquiry would provide the opportunity to deepen understanding of how children come to know and become in early childhood science education.

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Appendix one: Agreement scale seeking generalised perspectives

Case study two: generalising perspectives on session 1

Below is a summary of key perspectives which arose from the discussion on the nature of scientific enquiry in the nursery. The discussion was stimulated by a clip of video footage 1 and an abstract from: Andersson and Gullberg (2012) What is science in pre-school and what do teachers have to know to empower children? *Cultural Studies of Science Education*, 9:275–296.

Please indicate whether you agree/disagree or maybe agree with the perspectives and add additional comments where relevant to elaborate on any perspective.

- When co-research is promoted, science becomes more powerful as it involves discovery and making meaning

Agree Disagree Maybe
Comments:

- When there is a sense of the unknown in the enquiry or in scientific knowledge, meaning and knowledge creation is deeper for children

Agree Disagree Maybe
Comments:

- Scientific enquiry is playful and involves making links

Agree Disagree Maybe
Comments:

- There is a tension between supporting the development of knowledge and concepts through explanation and encouraging children develop their own theories through experience

Agree Disagree Maybe
Comments:

- Modelling being a scientist is key to facilitating children's engagement in the scientific process

Agree Disagree Maybe
Comments:

- There needs to be equality in the relationship between adult and child whilst engaging in enquiry

Agree Disagree Maybe
Comments:

- Subject knowledge plays an important part. It is necessary to have a foundation of knowledge of key concepts

Agree Disagree Maybe
Comments:

- Everyone has some knowledge. Knowledge is not fixed.

Agree Disagree Maybe
Comments:

- Children use resources to make meaning, i.e. in the video clip, buttons were used to experiment with and to illustrate theories in surprising ways

Agree Disagree Maybe
Comments:

- Children use space to illustrate meaning and understanding, e.g. by moving across and lying over the book to emphasise the trajectory of a meteorite

Agree Disagree Maybe
Comments:

- There is a relationship between schemas (Athey 1990) and scientific concept development – this is closely linked to the process of enquiry, e.g. repetition and experimenting with a dropping schema can be related to an early enquiry about physics/gravity

Agree Disagree Maybe
Comments:

- Any other comments:

Appendix two: Final interview questions and PowerPoint presentation updating on analysis

Final Focus Group Interview: impact of the study

1. Do you think Video Stimulated Reflective Dialogue is a useful tool? Please explain why/why not?

2. Please explain the ways in which Video Stimulated Reflective Dialogue has benefited your practice/the children with whom you work

3. What have been the key challenges of engaging with Video Stimulated Reflective Dialogue for yourself? For the team?

4. Has engaging in this project facilitated critical reflection? If so, in what ways?

5. Has your understanding of creativity in science enquiry developed over the course of the study? If so, in what ways?

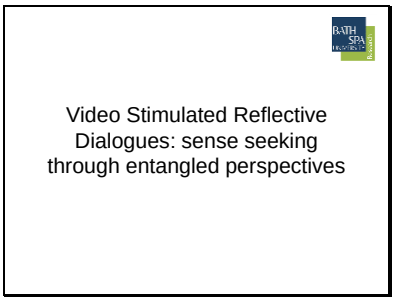
6. Has Video Stimulated Reflective Dialogue supported your understanding of pedagogical approaches which foster children's creativity in science enquiry? If so, in what ways?

7. Do you think that you will continue to use Video Stimulated Reflective Dialogue in your professional practice? Can you give an example of what this might look like?

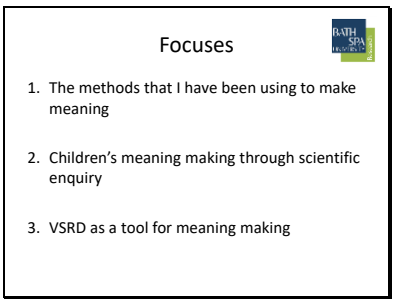
8. Any other comments?

PowerPoint presentation analysis update

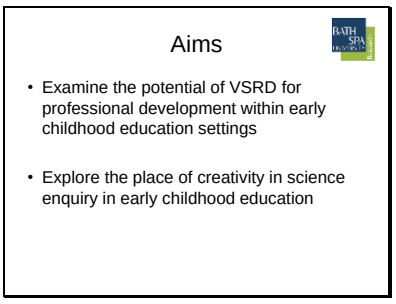
Slide 1



Slide 2



Slide 3



Slide 4

Guiding Questions

- What are the potentials of Video Stimulated Reflective Dialogues (VSRD) in facilitating *critical reflection* within communities of practice in the Early Years?
- Can VSRD contribute to practitioners' understanding of creativity in science enquiry? And if so, in what ways?
- Can VSRD support the development of practitioners' understanding of pedagogical approaches which support creativity in science enquiry? And if so, in what ways?

Slide 5

Context

- Challenging competency-based approaches to Professional Development, e.g. EYITT, Standard for PD
- Drawing on VSRD (Moyles et al. 2003) found to support understanding of pedagogical practices
- Exploring multiple perspectives generated within learning communities (Wegerif, 2014)
- Scientific thinking and creative capacities for citizenship (Cremin et al., 2015; Harlen, 2008; Worth, 2010)

Slide 6

Methodology

- Video Stimulated Reflective Dialogue (Moyles et al., 2003)

Communities of meaning makers

- Interpretivist, dialogic and coding (Sullivan, 2012)

Objects as a unit of analysis

- Diffractive (Barad, 2003; Lenz Taguchi, 2012)

Phenomena of entanglements as unit of analysis

Slide 7

How we made sense of children making meaning

M: I felt **she was trying to discover and know about it (the water) through the touching it, through sensory** - putting it in her mouth. It seemed to be quite experimental, I thought.

All: agree

S: I think that she was talking for a while and when she stopped, she wasn't doing anything for a while but you could see that she was thinking about something.

T: I think she was thinking. What made it quite different was that **she actually linked something with something else**. So even just **putting her hands in that water because that water was like bath water at home - and she said 'oh, I am washing'.** But before that, she wasn't washing but she was able to relate that to something else she does with water.

(Excerpt of VSRD: Session 3 CS1 U3)

Slide 8

Finding Difference

A: I thinking it was more, **I knew I was talking a lot and I just wanted to be quiet – it's hard to judge when you shouldn't and when you should talk.** There is that big debate on (referring to the group), **Are we part of it? Should we be talking? Should we be using that language?** I think part of me wanted to be part of it and then part of me wanted to let her (the child) talk.

(Excerpt of VSRD: Session 3 CS1 U3)

Slide 9

Intra-active pedagogies

- An intra-active relationship between child; space and material
- Agency distributed across child, material and space

"Learning events are taking place just as much and simultaneously between your hands and material things as they do in your thinking body/mind, handling concepts, notions and emotions."

(Lenz Taguchi, 2010:40)

Slide 10

Shared Pedagogy

Pedagogical Framing

- Attention to expansive spaces
- Time and open-ended resources to revisit and develop lines of enquiry

Pedagogical Interaction

- 'Being present' without talk when immersed
- Using commentary and questioning when highly attuned

Slide 11

Meaning Making through VSRD

What are the conditions across the phenomena of VSRD sessions?

- Collective Reflection
  - storytelling and dialogic (establishing shared meanings)
  - exploratory and critical (provoked by questions/stances)
- Video as a disruptor
- Rhythmic relations contribute to meaning making
- Organisational structures

Slide 12

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Appendix three: Information letter; informed consent form; parental permission form

Information Letter

Precis of study: What? How? Why?

Researcher: Rebecca Digby

Director of Studies: Dr Janet Rose

BSU Institute for Education Head of Research: Dr Kate Reynolds

Principle research question:

To what extent can Video Stimulated Reflective Dialogue facilitate the development of critical reflection and understanding/enactment of creativity in scientific enquiry in the Early Years?

Guiding Research Questions:

R1. What are the affordances of videography within communities of practice in the process of critical reflection?

R2. What are the affordances of reflective dialogue within communities of practice in the process of critical reflection?

R3. What evidence is there that VSRD can contribute to practitioners' understanding of the role of creativity in scientific enquiry?

R4. What evidence is there that VSRD can facilitate practitioners' understanding of pedagogical approaches which foster children's creativity in scientific enquiry?

What?

The research will focus on the potential of Video Stimulated Reflective Dialogue (VSRD) (Moyles et al. 2003) as a tool to promote practitioner critical reflection within a community of practice. It will also examine its effectiveness in facilitating practitioner understanding of the role of creativity in scientific enquiry in the Early Years, and pedagogical approaches which foster children's creative endeavour in scientific enquiry.

Why?

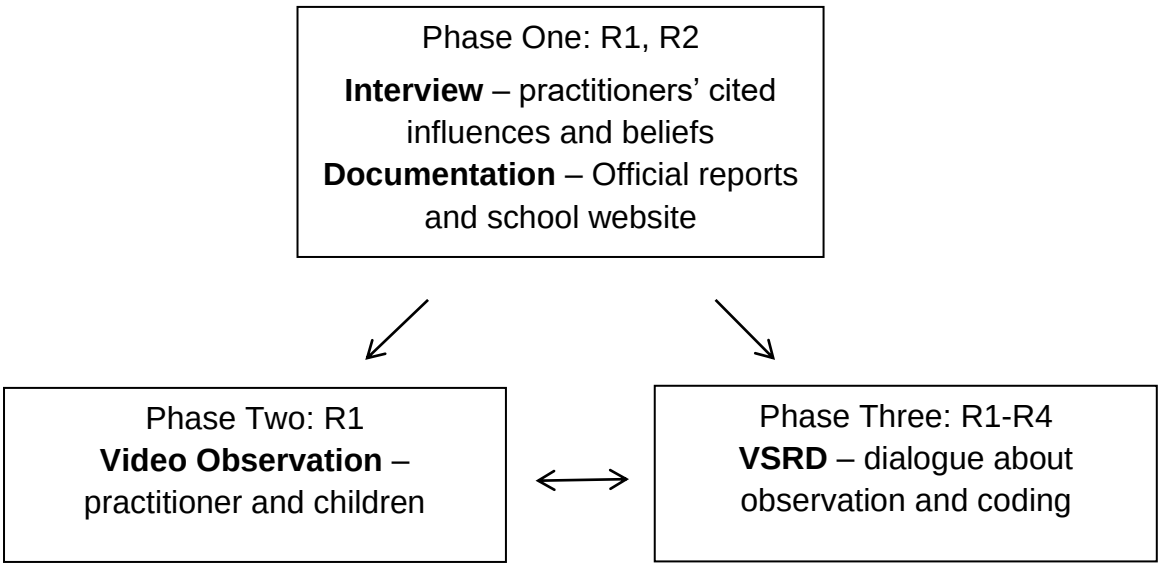
Scientific literacy and creativity are widely recognised as important in children's development and citizenship (Craft 2002, Gibson 2005, Harlen 2008, Heap 2006).

Recent research (Creative Little Scientists 2014) identifies synergies between science, mathematics and creativity and argues that practitioners should develop pedagogical content knowledge to foster inquiry and creativity in Early Years Science.

But…science is not recognised as a discrete subject in the Early Years, and notions of creativity and approaches which foster children's creativity are manifold (Davies et al. 2004, Gibson 2005, Kampylis et al. 2009, Sawyer 2006). This potentially leaves practitioners conceptions of the role of creativity in scientific enquiry open to multiple interpretations and confusion.

The research aims to make recommendations for pedagogy which emerge from practitioner engagement in critical reflection, agreed by academics as crucial to professional growth and learning (e.g. Lay and McGuire 2010, Moon 2006, Schon 1987), within a community of practice asserted as the location in which new knowledge and learning are properly conceived (Wenger 1998).

How?



Over academic year 2015-16:

Group Interview (x1)
Video observation(s) (x5)
Video Stimulated Reflected Dialogue (x5)
(Before VSRD, pairs? review relevant video footage to identify critical incidents)
Coding (within VSRD session) (number will be agreed in relation to video observations – min 2?)
Group Interview and member checking (x1)

Possible structures:

Group interviews

Beginning and end of study

Video Observations

A series of sessions filmed over the course of a week or number of weeks in order to capture children's as they are engaged in developing lines of enquiry.

A series of sessions filmed over the course of a term/year with some sequences and some one-off sessions.

A series of sessions filmed over the course of a year either capturing extracts of children's engagement in long term lines of enquiry or a series of one-off sessions.

VSRD/Coding sessions

A series of VSRD meetings over the course of two or three terms

VSRD meetings once a term

A model of your own?

n.b. [redacted] and [redacted]Terms 2015-16: T1 - 8 weeks/T2 - 7 weeks/T3 - 5 weeks/T4 - 6 weeks/T5 - 7 weeks/T6 - 7 weeks)

Informed Consent Form

Informed Consent Form 280915

Researcher: Rebecca Digby

Director of Studies: Dr Janet Rose

BSU Institute for Education Head of Research: Dr Kate Reynolds

Ethical Protocol

The following ethical considerations are framed from The British Educational Research Association Guidelines for Educational Research, 2011:

- All participants will be informed about the aims, the processes and the outcomes of the research.

  In addition to an initial meeting, information will be shared regarding the aims, processes and outcomes of the research during session 1.
- All participants will be informed about how the research will be used, reported and disseminated.

The findings will be reported to the Director of Studies and Second Supervisor at Bath Spa University and will be disseminated through conferences and journal publications. Additionally, findings may be shared with Bath Spa Teachers on the Primary and Early Years PGCE.

- All participants will be invited to be involved in the research and given the right of non-participation or withdrawal at any time.
- Permission will be sought from parents/guardians to observe children participating in the research. This will include explicit reference to the use of video footage and assurance that the strictest attention will be given to safeguarding children. *Participants will seek this via a letter sent prior to phase two of the research.*
- The names of the schools, practitioners and children will be completely anonymised.
- The confidentiality of all participants will be respected through the assurance that they 'will not be identified or presented in an identifiable form' (Sapsford and Abbott, 1996 cited in Bell, 2005:48).
- Video footage and tape recordings, and field notes made during phase two of the research will be destroyed after the research.
- All participants will have the opportunity to clarify, check meaning and verify a true record of events while the research is in draft form.

	Please initial here
I confirm that I have read and understand the aims, processes and outcomes of the research. I have had the opportunity to consider the information, ask questions and have these answered satisfactorily.	
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	
I understand that any information given by me may be used in future reports, articles or presentations by the research team.	
I understand that my name will not appear in any reports, articles or presentations.	
I agree to take part in the above study.	
I wish to be informed about publications that result from this research.	

Name of participant	
Signature of participant	
Date	
Email address (if you wish to be informed of publications)	

Name of researcher	Rebecca Digby
Signature of researcher	[redacted]
Date	280915

Parental Permission Form

Rebecca Digby: Senior Lecturer in Education
Bath Spa University
Newton Park
Newton St. Loe
Bath
BA2 9BN

Telephone: [redacted]

Dear Parent/Carer,

I am currently carrying out research for a doctoral study at Bath Spa University. The study is focused on learning about children's creative ideas and thinking about science.

For the study, I will be asking key people if they could show me video clips that they take for their learning diary observations which involve interesting examples of children engaging with science in any way. The clips will then be discussed and reflected on by both myself and staff within the setting, before gathering relevant information that will help towards the study. None of this material will be used as part of any presentation outside of the setting and I will delete any video material that I may use for the project.

In writing up the report of the study, neither the setting nor any child involved in the study will be named or shown in any identifiable form. As I draw up my findings, I will share them with my Director of Studies and Second Supervisor, as well as present them at conferences and in academic journals. They may also be shared on the Primary and Early Years PGCE at Bath Spa University.

If you have any further questions, please talk to your child's keyperson. I would also be very happy to answer any queries personally.
Please sign below if you are happy to give your consent for your child to be included in this study.

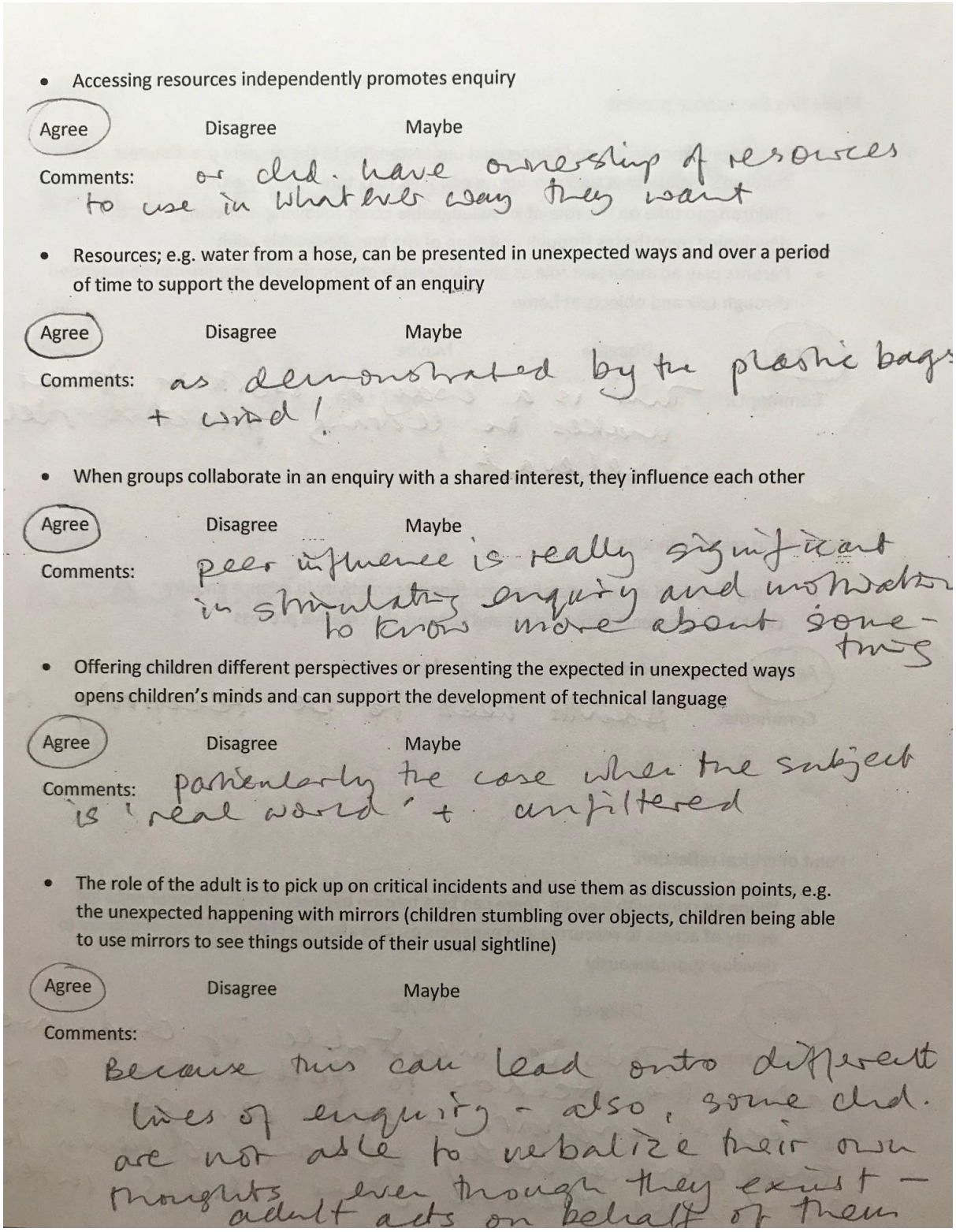
With kind regards,

Rebecca Digby
……

I give permission for my child to collaborate in the creativity and science enquiry research project outlined above.

Signed …….
Date……..

Appendix four: Qualitative comments of generalised perspectives



- Accessing resources independently promotes enquiry

Agree Disagree Maybe

Comments: or chd. have ownership of resources to use in whatever way they want

- Resources; e.g. water from a hose, can be presented in unexpected ways and over a period of time to support the development of an enquiry

Agree Disagree Maybe

Comments: as demonstrated by the plastic bags + wind!

- When groups collaborate in an enquiry with a shared interest, they influence each other

Agree Disagree Maybe

Comments: peer influence is really significant in stimulating enquiry and motivation to know more about something

- Offering children different perspectives or presenting the expected in unexpected ways opens children's minds and can support the development of technical language

Agree Disagree Maybe

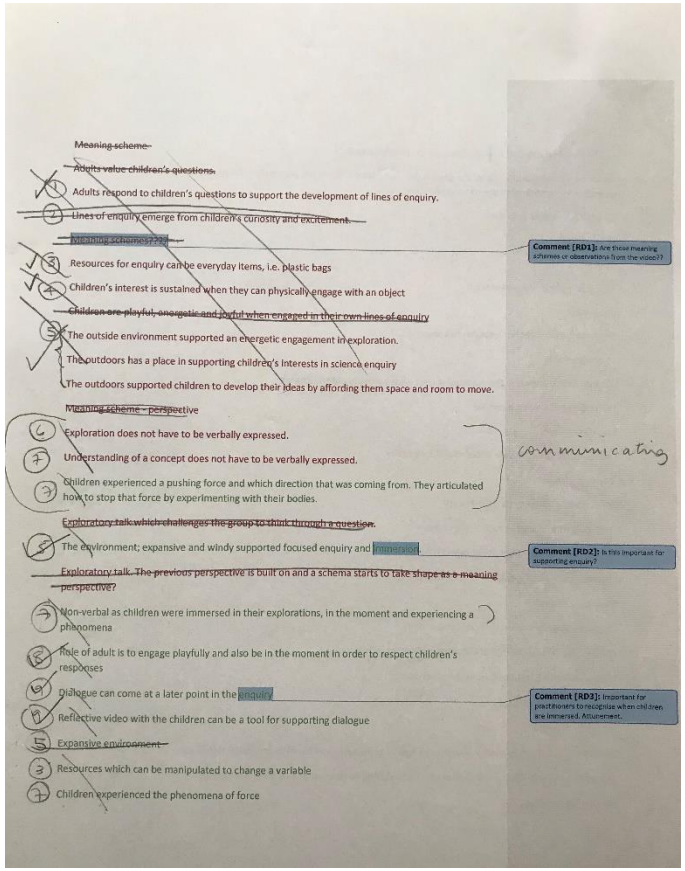
Comments: particularly the case when the subject is 'real world' + unfiltered

- The role of the adult is to pick up on critical incidents and use them as discussion points, e.g. the unexpected happening with mirrors (children stumbling over objects, children being able to use mirrors to see things outside of their usual sightline)

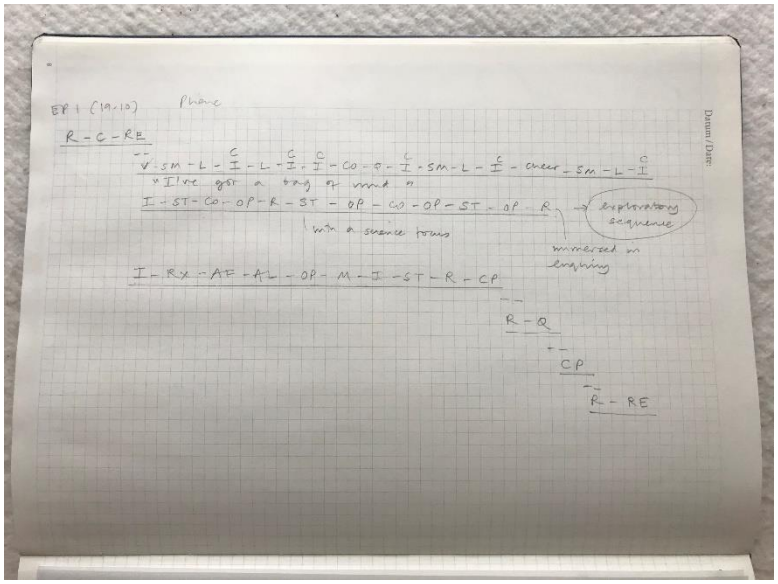
Agree Disagree Maybe

Comments:
Because this can lead onto different lines of enquiry - also, some chd. are not able to verbalize their own thoughts even though they exist - adult acts on behalf of them

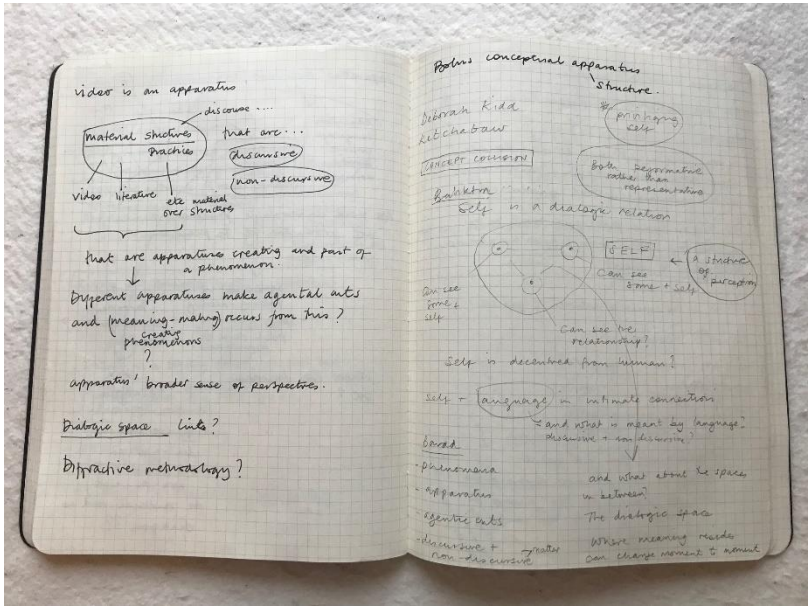
Appendix five: Notebooks; examples of early meaning making; blue book of tracings



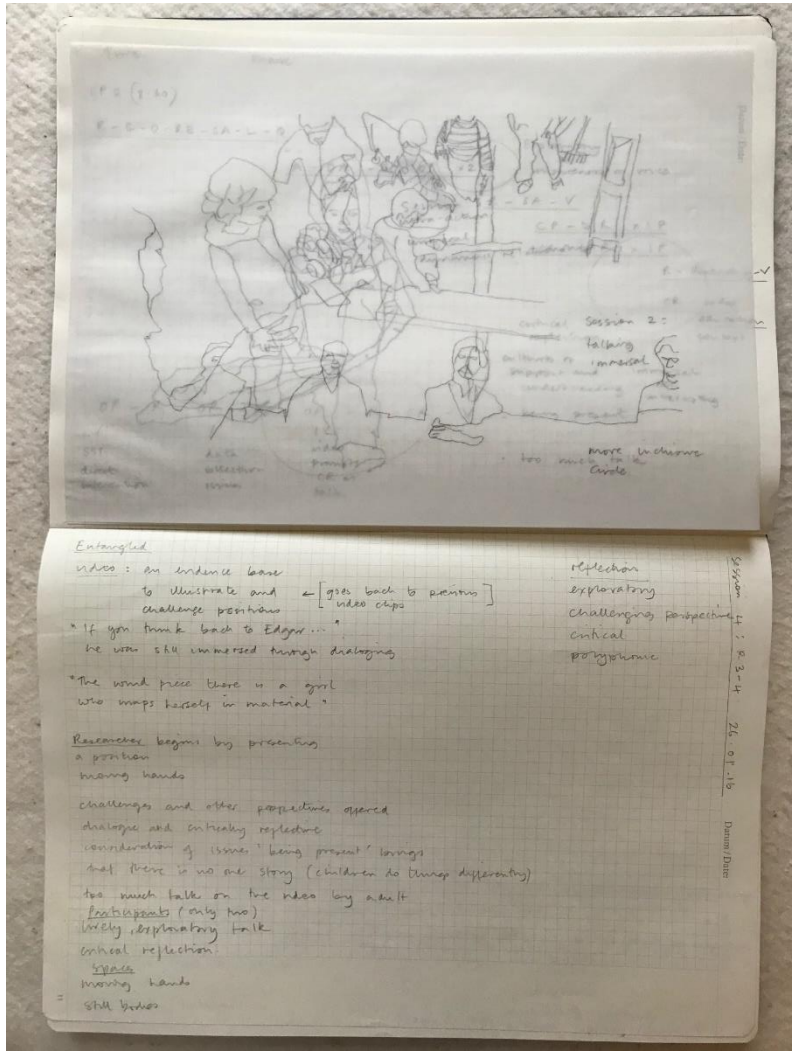
Early meaning making: developing themes



A focus on early childhood practitioners' dialogues

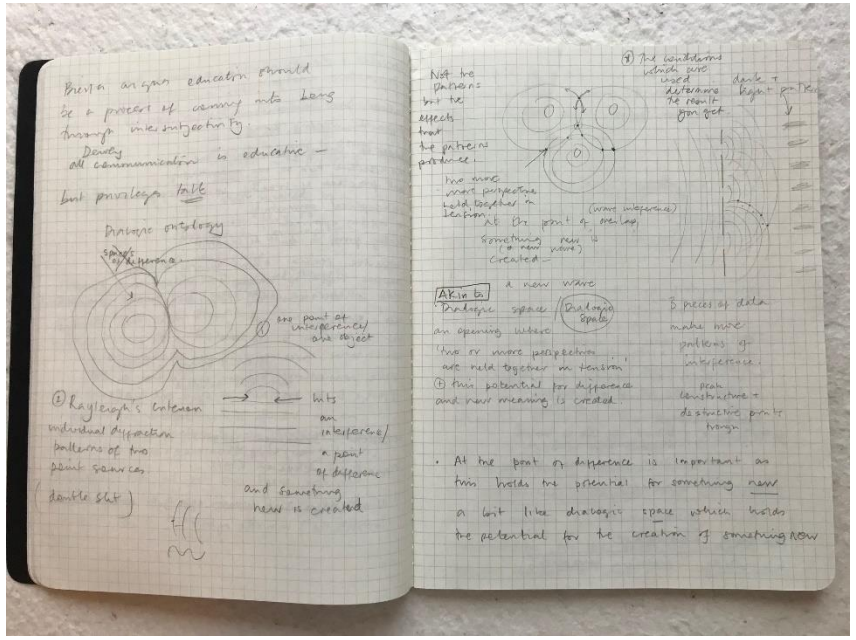


Grappling with new materialism



Exploring entangled apparatus: video footage, space, dialogue, researcher and practitioners

Early experiments with diffractive analysis



Developing an approach to diffractive analysis

Appendix six: Electronic links to video data

Case study one

Session 1a
https://figshare.com/s/7ef130b4ad384193e7ec

Session 1b
https://figshare.com/s/8cb5d64b9e2487255a87

Session 2
https://figshare.com/s/8eba655dd6ee5e4c0e3e

Session 2 Water Swirling
https://figshare.com/s/57b3991af7ea0a895185

Session 3a
https://figshare.com/s/06f2cee8fd46bc039681

Session 3b
https://figshare.com/s/06b00224fb8eabbd4cc8

Session 3 Water Pouring
https://figshare.com/s/3013b536b22e90b45ecd

Session 4a
https://figshare.com/s/7605ced30509c31dc3dc

Session 4b
https://figshare.com/s/de8ae5fc63cff3080630

Session 5
https://figshare.com/s/553f8f4d96e17e49a357

Case study two

Session 1a
https://figshare.com/s/7d6502a0d8bf7a7ec8ce

Session 1b

https://figshare.com/s/bb52daa5e13d990c3f57

Session 2a
https://figshare.com/s/1011d01780dc5fdbe0df

Session 3
https://figshare.com/s/fb6df0119f158744c759

Session 3 Windy Hill
https://figshare.com/s/82a676977fd511d5841a

Session 4
https://figshare.com/s/fef59419e465b4b3f9ba

Session 5
https://figshare.com/s/ee896e26e78f32d50b23

Case study three

Session 1
https://figshare.com/s/e655578fccbfbd7e406b

Session 2
https://figshare.com/s/61d20b57afe2d3d264b9

Session 3
https://figshare.com/s/c31392f6025c670548e8

Session 4
https://figshare.com/s/87a954dde5293ca76878

Session 5
https://figshare.com/s/7128c9e89f9edabccf27