

## **Diffraction encounters with empirical and theoretical understandings of children's creativity in science enquiry**

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# DIFFRACTIVE ENCOUNTERS WITH EMPIRICAL AND THEORETICAL UNDERSTANDINGS OF CHILDREN'S CREATIVITY IN SCIENCE ENQUIRY

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**Abstract:** *Diffraction methodology is a recently established alternative to the interpretivist approach commonly used in educational research. Unlike epistemological practices grounded in representation, it recognises knowledge making as performative and emergent from difference.*

*This paper offers new insights into diffractive readings in early childhood science education through experimentation with entangled empirical video data, theoretical perspectives and transdisciplinary space. A methodological contribution is made by showing how critical points of difference are created when video footage of shared understandings held by early childhood practitioners encounters existing research on early childhood science education diffractively. These points of difference are made to matter and illuminated as affecting emergent new connections which can reconfigure dominant ways of understanding creativity in early childhood science education. In doing so, children's creative knowledge making practices in science enquiry are (re)presented as expansive, material knowing which is enacted at once through talk and materials.*

**Keywords:** *new materialism, diffraction, early childhood, science education, creativity, videography, transdisciplinary*

## Introduction

Interest in the materiality of children's science enquiry has grown in the past few years with scholars such as de Freitas and Palmer (2016), Hetherington and Wegerif (2018), Hardman (2017), Hardman, Riordan, and Hetherington (2020), Jeong *et al.*, (2021) and Kayumova *et al.*, (2019) working with relational ontologies to elucidate the complexity of teaching and learning in science education. Building on these works and drawing on the new materialist/posthuman philosophy of Karen Barad (2003, 2007, 2014), this paper offers new insights into methodological experiments with diffraction in the context of early childhood science education and shows how critical points of difference are created when empirical video data encounter theoretical perspectives diffractively. As a result of this encountering methodology, conflicting discourses in early childhood science education are challenged as limiting, and points of difference are illuminated as significant in affecting connections which can reconfigure dominant ways of seeing.

The paper draws on empirical video data from a recent study which explored shared understandings of creativity in science enquiry held by early childhood practitioners gathered using Video Stimulated Reflective Dialogues (Moyle et al., 2003). Initially analysed using an

interpretivist approach (Willis, 2007), the data were found to be largely representative of and limited by existing perspectives on young children's creativity in science enquiry and the analysis restricted by theoretical, ontological and axiological norms within the interpretivist paradigm. By way of contrast, presented here is an exemplification of empirical video data that was 're-turned' in a diffraction together with existing research on early childhood science education, revealing critical points of difference which, in superposition, contributed to possibilities for (re)conceptualising young children's creativity in science enquiry. The paper also discusses the entanglement of transdisciplinary space, the potential of video as more-than-human matter, and the ethics of reading diffractively, to consider how children's creativity in science enquiry is enacted at once through talk and materials. Cutting together and apart the superposition of points of difference reveals children's encounters with materials as emergent through a relational, affective experience. Materials' qualities hold potential to reveal themselves to children as always becoming in moments which are made to matter. Creative knowledge-making practices in science enquiry are thus (re)presented as expansive, as a material knowing which emerges necessarily entangled with 'spaces, sensations, memories' (Robinson and Kutner, 2019, p. 112) and that which is 'not yet known' (Davies, 2020, p.148).

### **Theoretical and methodological orientation**

New materialism's emergence within studies of early childhood education has been relatively recent. Hillevi Lenz Taguchi (2010; 2012; 2013; 2014), Karin Murriss (2015; 2016; 2018) and Bronwyn Davies (2014; 2018) have pioneered research in the field. Following this, new materialist philosophies have received increasing attention (Fairchild, 2020; Giorza and Haynes, 2018; Hackett, Pahl and Pool, 2017; Osgood, 2019; Otterstad, 2018; Penfold, 2019; Somerville and Green, 2015). Studies have foregrounded the role of materials in children's daily lived experiences; a theme defined as 'lifeliness' by Somerville (2019) in her 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 this theme with others including Giugni (2011), Rautio (2013), Somerville and Powell (2018) and Giorza and Haynes (2018) illustrating a decentred child in non-hierarchical relationships between human and more-than-human matter and coming to know as a range of social and material relations.

Within this field, research focusing on early science education is growing (Areljung, 2019; de Freitas and Palmer, 2016; Gunther-Hanssen *et al.*, 2020; Haus, 2018; Haus and Siry, 2019 and Taylor and Pacini-Ketchabaw, 2015). Areljung (2019), has reworked her previous research underpinned by socio-cultural theory to illustrate child-object explorations as agentic, emergent and as being in relational intra-action, which leads to new knowledge articulated through the existing scientific concept of force. Similarly, Haus and Siry (2019) defined experience of the concepts of sound and condensation as the new understanding which emerges from within intra-acting children and bottles of liquid. However, an overarching focus on outcomes defined through concept formation of established scientific knowledge may impose onto children an adult apparatus of interpretation, restricting opportunities for new and 'not yet made' visible (Davies, 2020) knowledges to come to matter. My study has, therefore, moved from articulating children's knowledge outcomes to a focus on gaining deeper insight into *the tools*, or *the apparatus*, which

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*determine particular outcomes.* Thereby, children's creative knowledge making practices in science enquiry are positioned as emergent through critical points of difference, where apparatuses collide and differentially cut, within diffractive encounters.

### *Diffractive methodology*

Before considering insights into children's creative knowledge making practices, this paper first discusses key elements of diffractive methodology which include: *phenomena; material-discursive entanglement; intra-action; apparatus; agential cuts; difference; ethics* and *superposition*.

Situated within the broader interdisciplinary paradigm of new materialisms, at times described as posthuman and post-qualitative (MacLure, 2015; Ulmer, 2017), Karen Barad's Agential Realism recognises 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 young children's creativity in scientific enquiry could make visible the entanglement of and spaces in-between myself, existing literature on early childhood science education and empirical data illustrating early childhood practitioners' perspectives. There are infinite other entanglements within this phenomenon which may remain unseen. Thus, meaning that is made about young children's creativity in science enquiry is recognised as one moment of 'mattering' as it is inevitably created in this paper by what is made visible: myself; space, existing theoretical positions and empirical video data. Knowledge making practices are therefore influenced and shaped by particular tools. The tools are co-constitutive of one another and agentic in both their 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, for which we hold responsibility.

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 creativity in early childhood science education using the relational material-discursive apparatus of

‘sociocultural perspectives on science education’, ‘early childhood practitioners’ perspectives’, or ‘transdisciplinary spaces in-between’, making this a moment which defines what matters. As material-discursive practices, apparatuses are performative and consist of innumerate social, cultural, political, physical and other enactments. Thus, cutting together and apart with ‘sociocultural perspectives’ offers insight into creativity in early childhood science education as defined by the particular material-discursive practices through which it is understood. In another moment, an agential cut may be enacted with ‘cognitive conceptualisations of creativity’ making something different matter. How we come to know then, is defined by agential cuts using relational material-discursive apparatuses which are co-constituted within an entangled intra-acting phenomenon.

Diffraction apparatus does something different. 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) 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). Lamenting reflexivity and reflection as only able to displace the same elsewhere in distorted form, Haraway (1997, p.26) argues that as a critical practice it invites the illusion of essential, fixed positioning which holds the world at a distance and traps the researcher in a ‘search for the authentic and really real’. Drawing from Haraway (1997), Barad (2007) claims that diffractive methodology is respectful of the entanglement of ideas and other materials in ways that reflexive methodologies are not by calling attention to apparatuses of production, how boundaries are produced and small but consequential differences. Whilst reflexivity is founded on representationalism which appears to have no effect on the objects of investigation and invites reification, simplification and separation, diffraction recognises that the subject and object do not preexist but emerge through intra-actions we are involved in and producing and, for this, we must take responsibility (Barad, 2007). As a knowledge making practice, diffraction can thus 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 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 was 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. Of equal importance is 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 were used in this study to both understand and articulate a 'space' in which new knowledge/ways of seeing might reside, albeit indeterminately. Related, is Barad's claim that apparatuses enact agential cuts in an attempt to 'measure' and produce boundaries, making 'manifest the extraordinary liveliness of the world' (Barad, 2007, p.91). Murriss 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 simultaneous differential being and becoming. This is an ethico-onto-epistemic position articulated by Barad (2007) as the inseparability of ethics, ontology and epistemology in knowledge production; a perspective further discussed below through the exemplification of a diffractive reading enacted in this study.

Consideration is given by scholars to the entangled role of researcher when enacting new materialist approaches to inquiry (Asberg *et al.*, 2015, p.150; Davies, 2018, p.122; and Frigerio *et al.*, 2018, p.392). Of particular interest are accounts of entanglement in experiments with diffractive methodologies in studies of early childhood education (Davies, 2014; Hultman and Lenz Taguchi, 2010; Lenz Taguchi and Palmer, 2013; Osgood and Giugni, 2015; Otterstad, 2018), and in education research more widely (Bozalek and Zembylas, 2017; Chappell *et al.*, 2019; Mazzei, 2014 and Taylor and Gannon, 2018). Insightful discussion on the application of a diffractive approach in research has affected my experimentation with reading diffractively. 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 'within' interview data. Also acting on this diffraction, are readings with the material of theory by Taylor and Gannon (2018) who discuss 'two passes' through data and Mazzei (2014) who considers the entanglement of bodies, texts, relationships, data and language. Considering the entangled relationality of transdisciplinary creative pedagogy, Chappell *et al.* (2019)'s description of methodological cuts as creative of new knowledge *and* new research questions in their diffractive process and Burnard *et al.*'s (2021) exploration of the relationship between diffractive methodology and transdisciplinarity have brought attention, more recently, to multiple cartographies of knowing. This is also visible in experimentation with the materiality of video and visual material in diffractive readings (Caton, 2019; Holmes, 2016; Magnusson, 2021; and Mengis and Nicolini 2021) which illustrate how re-encounter with video data agitate the emergence of ideas and connections in-between video data.

## Context

This paper now moves to a diffractive reading of empirical video data from a wider study which deployed Video Stimulated Reflective Dialogues (VSRD) (Moyles *et al.* 2003) to explore young

children's creativity in science enquiry. The study took place across two early childhood education settings: a nursery school with a children's centre; and a primary school across one academic year. Participants included 25 teachers, learning support assistants and early childhood practitioners, and 50 children aged from two to five years. A deconstruction of empirical data bound as case studies using a traditional interpretivist analysis yielded some insight into young children's creativity in science enquiry. However, these insights did little more than reflect existing disciplinary bound literature within the domain of education. For example, 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, this was perceived as compounded by the influence of accountability and policy. 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 (Harlen and Qualter, 2018; Kallery, 2015; Johnston, 2014; Tunnicliffe, 2015). Thus, (re)presented was a position which realises science as a material world separate from human interpretations of it. Children were positioned as agentic and at the centre of scientific and creative knowledge making practices enacted through thought and language within the cognitive domain. Normative approaches to early childhood science pedagogy were subsequently reinforced, and children fixed as 'becoming' (Moss, 2017), in need of enculturation into the established practices of science. These findings are not new. They represent a repeating cycle of understanding which, when considered through a new materialist framework, perform an agential cut which makes visible one way of 'seeing'. That is, the apparatus of: literature reflecting dominant perspectives on early childhood science education and creativity; the early childhood education system as primarily shaped by developmental psychology, and 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.

### **Diffraction reading: re-turning the data**

To illustrate my engagement with diffractive methodology, this section re-turns empirical video data within the entangled phenomenon of practitioners' shared understandings of young children's science enquiry. The process of getting to the points where difference was made visible is discussed and new perspectives emerging in the data are offered.

Initially, time was spent with the apparatus of: empirical video data of shared understanding held by early childhood practitioners; existing research on early childhood science education, and conceptualisations of creativity. This meant immersion within a transdisciplinary space in which entangled multiple perspectives reside to read and re-read existing research, and watch and re-watch the video footage collected during the study. As a process, I likened it to Barad's (2014) analogy of an earthworm who turns soil over and over again. In rhizomatic (Deleuze and Guattari, 1987), non-linear movements I was, over time, 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, understood in this context as embracing the unknown (Hickey-

Moody *et al.*, 2016), and established a slow rhythm as I moved from text to transcript to video 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. 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. Within this space, some perspectives appeared to mirror each other whilst others not so. For example, empirical video data of children's engagement in enquiry seemed different to perspectives on talk held within established literature on science education. I placed these perspectives together, 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.

### 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 and were made to matter within the diffractive encounter:

*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*

What follows is a detailed exploration of one point of difference, an encounter with talk. 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.

A critical point of difference in which talk was recognised as fundamental to scientific understanding and as interrupting children's immersion with materials in enquiry emerged in the diffractive encounter between video footage illuminating practitioners' concern over the role of talk - provoked by footage of children deeply immersed with materials - and existing research on early childhood science pedagogy. These 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 which 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 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 over and over 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, blurred and swirling through the air.



Figure 1. Video still *Water Swirling*, case study one: session two

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 *Water Swirling*, case study one: session two)

*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 this and the second session. 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 this third session, a less experienced practitioner offers a short clip of video footage to the group depicting her recent encounter with a child. The seven practitioners present quietly, and the clip of video footage plays. Immediately visible is a child playing with water in a small room within the children's centre. The water moves 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 enquiry which involves jug filling with water and water pouring back to the tank. This motion is repeated 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.



*Figure 2. Video Still Water Pouring, case study one: session three*

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 Water Pouring, case study one: session three)

The clip 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 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 splash 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 Water Pouring, case study one: session three)

Diffraction 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 video 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 found themselves encountering pedagogical dilemmas in relation to the positionality of talk within early childhood science literature provoked by video footage. As these dialogues collide with video footage and 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 talking 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 understood through talk for the development of scientific understanding and by the *children's immersion with material encounters*. Here new configurations of science education are made possible. My insight into children's knowledge making practices moves beyond a perspective that advocates talk and manipulation of passive materials for individual cognitive development. To see this, there is a shift from a focus on dialogue and the practitioners' subsequent pedagogical dilemmas and foregrounding the child as a knowing subject who uses materials for understanding. Instead, there is focus on a measurement within and outside of the superposition of difference; 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 apparatuses. Here, both child and material are entangled matter, being and becoming through difference within the phenomenon of apparatuses

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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.

### Creating differences that matter

Pondering what makes a point of difference critical, I revisited my entanglement in the diffractive reading, recognising both the selection of apparatus and the identification of critical points of difference as deliberate acts. Entangled within and of the apparatus, I inevitably determine outcomes. For instance, the study focus fundamentally influenced what I was attentive to and looked for in terms of difference in this diffraction. I was concerned with dominant perspectives on young children's creativity in scientific enquiry and a relationship between art and science; enmeshed with my experience as a maker who sought understanding of creative processes. 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 was taken to acknowledge my 'being and becoming' within the phenomenon. Such acknowledgement took the form of recognising myself as both inhabiting and becoming within the space in-between both the video camera and footage, and text (Murriss and Bozalek, 2019). This was made possible by using the concentric circles in figure three below as a visual 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, the figure also provided a frame from which to consider what came to matter and what was excluded from mattering in this study, supporting a desire to take ethical responsibility. Significantly, through the figure, 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).

The process of visualising patterns intra-acting and emergent within the phenomenon of shared understandings is illuminated in the figure below as concentric circles overlapping to reveal spaces 'in-between'. 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* (Ma (Ferguson and Kuby, 2015); dialogic space (Wegerif, 2014); and conceptualisations of creativity (Malafouris *et al.*, 2014)). They later evolved as spaces of superposition; emergent new waves which are composed of aspects of prior intersecting waves. The concentric circles themselves illustrate material-discursive apparatus (an inner circle) and associated constructs of the apparatus (an outer circle). Here the apparatuses are shown as conceptualisations of creativity; research on early childhood education; and video reflective dialogue. The figure 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).

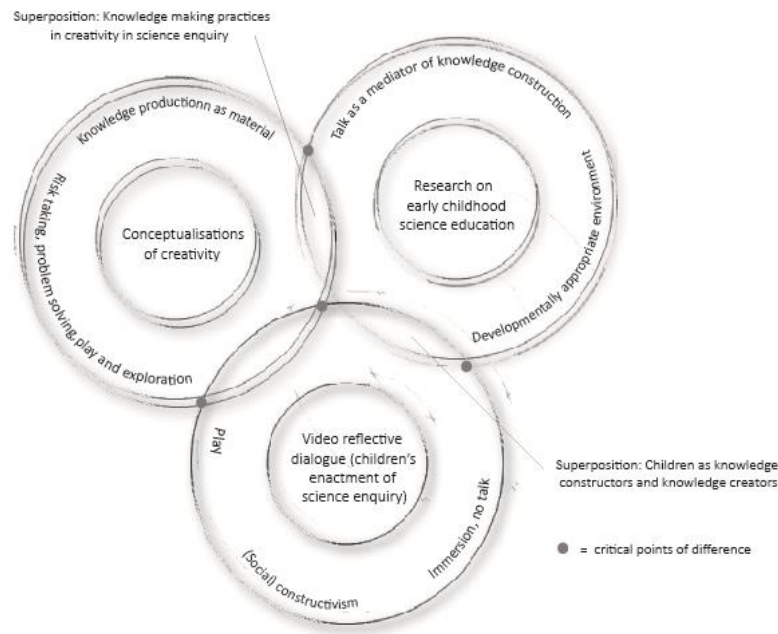


Figure 3. Critical points of difference and superpositions within the phenomenon of practitioners’ shared understandings of young children’s science enquiry

### Methodological Implications

A diffractive reading led to the creation of *new* perspectives and subsequently new knowledge to that interpreted from empirical data or gleaned from engagement with literature. The reading of differences through transdisciplinary positions and the use of video with awareness of the ethics of entanglement proved particularly significant. Within the space of diffraction, making meaning from different fields of literature and empirical video 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 video data which was analysed through an interpretivist frame were not dismissed. Drawing on an ethico-onto-epistemic position, emphasis was instead 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, this included taking 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 were made explicit as: research focus; 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 was recognised that these apparatuses affect the outcome of the diffractive reading and, so in acknowledgement of the 'unseen' apparatus in an ever diffracting, ever becoming material-discursive phenomenon of shared understandings, findings from reading diffractively are understood as representative of one moment of mattering. Unseen apparatus made visible hold new potential to 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: empirical video data of shared understanding held by early childhood practitioners; existing research on early childhood science education; conceptualisations of creativity, and me as participant and researcher. That is, in enacting the diffraction, I was attuned to which points the apparatus collided with 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.

The enactment of the diffractive reading here is an 'exteriority within phenomena' (Barad, 2007, p.140) through which researcher, practitioner, child, materials, environment, video camera and footage, and transdisciplinary space holding differing 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 which 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 the dominant constructivist and sociocultural theory, and child-centred approaches which shape early science education 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 about talk 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 in transdisciplinary space, 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. Transdisciplinary space, where entangled relationships emerge through intra-action, made visible both artificial boundaries which served to restrict understanding and framed the space where differences collide and intra-act in differential becoming. Difference was to be embraced, not overcome; as within a Vygotskian dialectal position. 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).



Video footage is shown to play a significant role in supporting this shift in ways of seeing. The illustration of the emergence of video footage as a critical point of difference to established perspectives on early childhood scientific enquiry offers a unique methodological contribution to diffractive readings in science education. Positioned as more-than-human, footage of children's immersion with materials appeared to unsettle normative ways of seeing and stilt practitioners' discussion. It decentred my human gaze and invited a dense encounter and attendance to the materiality of materials and spaces in-between play in young children's creative knowledge making practices, supporting greater focus on the quality and affective nature of materials in scientific enquiry. Due to its omnidirectional play with parameters of time, space and embodiment (Thomas and Bellingham, 2021), it invoked consideration for potential differences between children and materials, as well as relationships with wider apparatuses which determine what is known within a particular phenomenon. Crucially, use of video footage in this way encouraged greater awareness and ethical responsibility for the cuts that both I and practitioners made in determining what children know.

In reading the phenomenon of shared understandings of young children's science enquiry diffractively, ethics 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 the critical point of difference which emerged through the diffracting apparatus: existing research on early science education and creativity, which situates children's knowledge making within the confines of the individual, and 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 evident in its disempowerment and discipline. From an ethico-onto-epistemic position, ethical dilemmas cannot be fully anticipated. Ethics is co-constitutive of phenomena in its differential becoming (Barad, 2007). Ethical responsibility, as illuminated through video's demand to shift ways of seeing, requires being alert to the resonances of affects always already materialising across and within multiple more-than-human times and spaces. This is a key methodological shift from the pre-existing hierarchical binaries between subject and object, and the subsequent gaze evident in the critical self-positioning of reflexivity. Responsibility instead invites ongoing relational and embodied tending to which stories get told as differences within phenomena are made to matter, and openness to the stories that may not yet be made visible when agential cuts reconfigure the world in particular ways.

### **Coming to know in science enquiry through material encounters**

Reinforcing the argument for a relational ontological positioning of materials in early science education, the critical point of difference illustrated in this paper identified young children's

creativity in science enquiry as more than a discursive process. Critical points of difference within the framework of new materialism are more than a simple Cartesian division between the thinking mind and the mechanical world: 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.

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).

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 encountered in this study and, emergent through entanglement in creative knowledge making practices, it is made to matter. 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.

Crucially, the two positions of talk and material are not pitted in opposition but rather both are acknowledged. This 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, does not 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, rather than seek to represent through the established practice of reflection, 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.

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