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**CREATIVE PEDAGOGY AND ENVIRONMENTAL RESPONSIBILITY: A  
DIFFRACTIVE ANALYSIS OF AN INTRA-ACTIVE SCIENCE|ARTS PRACTICE**

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**ABSTRACT**

This chapter explores the entanglement of research and practice, offering an account of science|arts practice in which research-driven “features of creative pedagogy” were used within an action research project to engage young people with the problem of ocean plastics. Thinking with Barad’s theory of agential realism, we explore the ongoing emergence of new matter and meaning for the young people, teachers and researchers engaged in this transdisciplinary practice-research.

One component of a large H2020-funded project exploring creativity in science/arts transdisciplinary practices across Europe was a study of action research in six UK secondary schools with science/art teacher pairs. This chapter draws on research conducted within one school in which the issue of plastics in the ocean was explored with 52 students aged 14–15 within an “arts-science project”, to develop the young people’s ideas about environmental responsibility understood, explored and expressed together through science and art.

An approach to researching emergent and creative pedagogies which brings agency to the fore within a material-dialogic, intra-active understanding of (post)human creativity was used. Data gathered through mixed methods, including questionnaires, interviews and photographs, and selected via “glow moment” assemblages, were analysed with and through theory using diffractive analysis to iteratively unfold data, theory, research and practice. This stance embodies a material-dialogic approach, with research, theory and “data” in dialogue.

In the chapter, a sequence of diffractions is described, responding to initial questions posed by the book editors: “When/where/how do objects/subjects of inquiry, and embodiment, come to matter in STEAM (re-)configurings in practice?” These diffractions unfold the emergence of matter and meaning through intra-active material dialogue in a science|art practice, raising questions from/for practice about the concept of ethics, trusteeship and responsibility in environmental education.

*Keywords:* action research, agential realism, Barad, creative pedagogy, diffraction, embodied dialogue, environmental responsibility, intra-action, new materialism, transdisciplinarity

**INTRODUCTION**

There are many things in the human body and materials that are works of art, and science is almost like learning about the art. (student, age 14–15)

In this chapter, I offer an account of an iterative unfolding of research and practice in which a science|arts transdisciplinary practice<sup>1</sup> surfaced, for those involved, different ways of thinking about school subjects, about environmental responsibility and about themselves. At the same time, I engage critically with a relational understanding of research and practice to explore the opportunities offered by STEAM transdisciplinarity to think “research practice” differently. I take a diffractive analytical approach (Barad, 2007) to read insights from a specific example of science|arts school practice and theories of creativity through one another. In so doing, I produce “an emergent series of readings as data and theory make themselves intelligible to each other” (Mazzei, 2014: 742). This chapter therefore reflects a living inquiry in which the researcher’s intra-action<sup>2</sup> with data and theory is a creative and emergent process of meaning making about science|arts creative pedagogy. I respond to the questions “How/where/when do objects/subjects of inquiry matter in STEAM (re-)configurings in practice?”, and “How/where/when does embodiment matter in STEAM (re-)configuring practices” in the context of STEAM environmental education practice with a creativity and “future-making” orientation. My response to these questions is informed by our previous theoretical and empirical work exploring science|arts creative pedagogies as part of the CREATIONS project (Chappell et al., 2019). The chapter begins with an explanation of the CREATIONS project. I outline the research-based “features of creative pedagogy” which informed the practice explored in this chapter, and the theorisation of creativity which developed and unfolded through the project and in subsequent work that draws diffractively on ideas from Barad (2007). This enables a strong foundation on which to ground STEAM practices (Colucci-Gray et al., 2017). I then outline the diffractive methodological approach used in analysing data and theory together, before turning to the specific practice-based example at the core of the chapter. Following a short description of the example, I offer a sequence of “diffractions”, in which I explore the science|arts practice in an iterative response to questions emerging from engaging with theory and previous analyses. This is, in itself, a transdisciplinary approach, where transdisciplinarity is understood as drawing on different disciplinary ideas and ways of knowing in order to respond to ongoing questioning. As such, it exemplifies a different way of approaching both research and practice through science|arts creativity. I close the chapter with a deliberately speculative diffraction, opening a space for teachers and researchers to continue to engage diffractively with the ideas shared.

## CREATIVITY AND CREATIVE PEDAGOGIES

The data I draw on in this chapter was captured in the context of the CREATIONS project, a large H2020-EU funded program aiming to develop arts-based creative approaches for science education. Working across eleven countries, the project was situated in the context of the growing STE(A)M education movement with the aim of engaging more students with science. Research conducted as part of this project included: 1) an exploration of the role of dialogue and materiality/embodiment in science|arts pedagogy across four cases in three participant countries (Chappell et al., 2019); 2) European educators’ perspectives on creativity in science (Hetherington et al., 2019b); and 3) monitoring students’ creativity in science|arts contexts (Conradty & Bogner, 2018; Thuneberg, Salmi & Bogner, 2018). Underpinning this work was an extensive literature review and workshopping process in

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<sup>1</sup> The practice explored in this chapter was part of an action research study conducted as part of the CREATIONS project, funded by the EU under the H2020 scheme.

<sup>2</sup> The term intra-action within Barad’s (2007) agential realism, rather than the more familiar interaction, is used to highlight that bounded entities do not pre-exist any intra-action, but are continuously made and remade through entangled material-discursive relationships.

which a set of eight features of creative pedagogy were developed (Chappell et al., 2015) and used to design teaching and learning activities for approximately 100 different science|arts activities across Europe, including the one explored in this chapter. The eight features are: dialogue; empowerment and agency; interdisciplinarity (which became transdisciplinarity during the life of the project); possibilities; risk, immersion and play; ethics and trusteeship; balance and navigation; and individual, collaborative and communal activities for change. Throughout this project, we expanded and developed our theoretical understanding of creativity in STE(A)M education. A brief diversion to outline our theoretical stance is therefore necessary before connecting it to practice in this chapter.

Influential in defining creativity and creative pedagogy in STEAM studies is a “democratic” approach to educational research and practice, that recognises the everyday creativity of all children, whilst acknowledging that novelty may apply only to the creator/s (Banaji, Burn & Buckingham, 2006; Craft, 2001, 2013; Kaufman & Beghetto, 2009). Teaching creatively is distinct from teaching for creativity (fostering creativity in students), and in combination these two processes enable co-participative approaches where students’ perspectives guide learning (Jeffrey & Craft, 2004). Creative teaching is not oppositional to the teaching of knowledge, skills and understanding (Cremin & Barnes, 2014), but the role of the teacher is shifted from the “sage on the stage” (with the teacher transmitting knowledge to the learner) to a “meddler in the middle” (McWilliam, 2008), with the teacher engaging in the dynamic of learning with the learners, as part of an improvisational educational relationship (Sawyer, 2011). This argues for the importance of relationality in creative pedagogy: a key theoretical notion in interpreting the features of creative pedagogy used within and developed through the research.

Informing the CREATIONS project research was a definition of creativity in science education, developed by building on and refining an earlier definition within EU-funded science education projects<sup>3</sup> via literature reviews of creative pedagogy research and co-creation via international workshops (Chappell et al., 2015). Creativity in science education was defined as:

Purposive and imaginative activity generating outcomes that are original and valuable in relation to the learner. This occurs through critical reasoning using the available evidence to generate ideas, explanations and strategies as an individual or community, whilst acknowledging the role of risk and emotions in interdisciplinary contexts. (Chappell et al., 2015: 61)

Both the CREATIONS definition and the features of creative pedagogies developed through the project and its antecedents were founded in respect for professional wisdom, recognising practitioners’ wealth of expertise both in their teaching and in their disciplinary knowledge and skills. Derived against a background of inter- and transdisciplinary work in creative pedagogies, their ongoing materialisation within the research is part of an emergent phenomenon through meaningful engagement in a responsible, professional educational relation (Biesta, 2004).

In the broader literature on creative pedagogies described above and, indeed, in the CREATIONS definition itself, there is a dominantly humanist conception of creativity in research and practice. Our recent research is moving away from this (whilst acknowledging its influence) as we are increasingly engaged with new materialist theorising (Chappell, 2018; Hetherington et al., 2019c). Therefore, the articulation of the relevant features in this chapter is rooted in a new materialist stance. Broadly, this is in response to the synergies we find

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<sup>3</sup> Creative Little Scientists (Cremin et al., 2015) and CREAT-IT (Craft et al., 2016).

between the embodied, relational dialogic stance at the heart of Chappell and Craft's (2011) earlier articulation of creativity and our theorising of creativity, which acknowledges the enmeshed (from Braidotti, 2013) or entangled (from Barad, 2007) nature of human–other-than-human relationships<sup>4</sup> in order to be able to creatively respond to the educational challenges of rapid and unpredictable change. Chappell's (2018) (post-humanising) creativity situates embodied dialogue at its heart, with objects, environments and humans intra-acting as embodied, agentic and entangled actants. Creativity is dispersed through the intra-action rather than humanly centred. As such, the “becomings” that emerge through creative, material-dialogic intra-actions are also dispersed through the emerging phenomena. Ethics is re-configured as emergent and relational.

However, in re-configuring creative pedagogies through relational new materialist or post-humanist lenses, we need to go further and consider also the temporality of creative intra-action: in Barad's (2007) terms, spacetime-mattering. As (2018) points out, learning theories often associate learning with either “building on” earlier foundational knowledge or “breaking with” previous naïve understandings, and therefore do not exist in temporal isolation. Neither does creativity: as highlighted earlier, creative pedagogy is not oppositional to the teaching of knowledge and skills and, indeed, creativity cannot be separated from the disciplinary context(s) in which it is enacted. However, creativity in education, albeit activity creating outcomes that are original *to the learner*, is often associated with novelty and therefore with learning that breaks with previous ideas and understandings – the “aha!” moments. Barad (in conversation with Juelskjær and Schwennesen, 2012) explains that the notion of dis/continuity is helpful here. Using the both/and logic typically found in post-humanist and new materialist theorising, Barad sees creativity as a “dis/continuity”: *both continuous and discontinuous with past and future as part of an ongoing entangled material-discursive intra-action with spacetime.*

[C]reativity is not about crafting the new through a radical break with the past. It's a matter of dis/continuity, neither continuous nor discontinuous in *the usual sense*. *It seems to me that it's important to have some kind of way of thinking about change that doesn't presume there's either more of the same or a radical break. Dis/continuity is a cutting together-apart (one move) that doesn't deny creativity and innovation but understands its indebtedness and entanglements to the past and the future.* (Barad, in conversation with Juelskjær & Schwennesen, 2012: 16, emphasis added)

STEAM transdisciplinarity is one way of (re)configuring educational practices that engage with this dis/continuous understanding of creativity to teach *for* creativity (Jeffery & Craft, 2004). In our previous work, we have described our perspective on transdisciplinarity that draws dynamically and openly on ideas and processes from any discipline to respond to questions asked (Chappell et al., 2019, drawing on Morgan, 2000). We shifted to the term transdisciplinarity rather than interdisciplinarity, or the integration of disciplines, because for us it implies a sense of disciplinary equality that is not necessarily the case in interdisciplinary practices where one discipline supports the learning in the other. In transdisciplinary practice, then, creativity and innovation lie in the generation of and response

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<sup>4</sup> Although they are distinct theoretical notions, Braidotti's (2013) concept of enmeshing and Barad's (2007) notion of entanglement sit within a similar position in the arguments made throughout this chapter. For simplicity, and because Barad's agential realism is the dominant new materialist theorisation drawn into this diffractive analysis, entanglement is used throughout the remainder of the chapter.

to new questions whilst maintaining a connection to the ideas and processes embodied in existing, and ongoing, disciplinary knowledges, practices and creativities – acknowledging that creativity emerges and materialises differently in different disciplinary contexts (Colucci-Gray et al., 2017; Hetherington et al., 2019b). This leads to a question-driven approach to teaching for creativity through STEAM.

Resulting from our ongoing theorisation of creative pedagogies using new materialist ideas, we are also engaged in an iterative and emergent reconfiguring of the practice-oriented CREATIONS features, seeing creativity as a more-than-human, entangled and intra-active material dialogue within space and time. An emergent outcome from previous work (Chappell et al., 2019) that is relevant to the analysis in this chapter is that question-driven STEAM transdisciplinary practice is grounded in the idea that matter and meaning are mutually constituted in a material-dialogic space (Hetherington et al., 2019c). This has wider implications for the question-driven practice described above, because if what is emerging through intra-actions in the dialogic “gap” between temporarily bounded, entangled and intra-acting objects/subjects is *subjectivities* – rather than unique human subjects/minds – then practice is continually (re-)configured through unique *assemblages* of teachers, students, ideas and materials as they respond to emergent inquiry questions by drawing on intra-acting disciplinary practices. This approach to STEAM transdisciplinary inquiry in practice is an embodied/material process.

Our starting point for the diffractions through which we explore these questions in this chapter is therefore that *entangled matter/meaning/subjectivities emerge and are dynamically (re-)configured through embodied material-dialogic intra-actions in STEAM transdisciplinary inquiry*.

The chapter does not follow the familiar format for reporting empirical research, but instead exemplifies a process that Barad (2014) calls “cutting together-apart”, as the entangled phenomena within the research assemblage (the researchers, the theories, the participants [through their words/creations/survey responses], and the methodology) intra-act. This diffractive approach is appropriate in researching creativity and future making in education, given its complementarity with the emergent and open-ended theoretical stance of the work. It is chosen in anticipation of opening a space for teachers, students and researchers to explore seeing, doing, feeling, talking, thinking and materialising responsible, anticipatory science|arts creative pedagogy in environmental education.

I now turn to the diffractive methodology, followed by a short description of the specific practice-based context from which the data in this chapter is drawn. I then engage with the diffractive process by exploring and intra-acting with strands of theory and data within the research assemblage, uniquely cutting them together-apart in a process that is itself emergent and creative.

## DIFFRACTIVE METHODOLOGY

The relational theoretical stance we developed through the life of the CREATIONS project led us to a diffractive methodology, to enable a creative response to the dynamic settings of arts|science practices we were engaging with (Chappell et al., 2019). The concept of diffraction, as a methodology developed by Barad (2007, building on Haraway, 1997), highlights how different methodological “cuts” are performed (Van Der Tuin, 2011), which interrupt and dissect the object of study in co-productive ways such that methods, data, the object/s of study and the researchers are cut together-apart in a single move to materialise new meanings (Barad, 2014). In our approach to diffractive methodology, we draw on the concept of assemblages, made up of intra-acting elements that are productive of new matter/meaning (Fox & Alldred, 2015). The primary unit of analysis, the assemblage, is

composed of data selected through the agentic intra-action of data and researcher/s together. MacLure (2013), drawing on Deleuze and Guattari, refers to “moments that glow” to describe data/theory that pushes itself forward into the assemblages, provoking a response. Assemblages are formed and re-formed as the analysis proceeds, questioning and responding and questioning as new methodological cuts are made, new knowledge created, and new questions generated. In this way, theory and data are read through one another in a challenging process that does not seek closure but acknowledges the complexity of the study (Mazzei, 2014; Uprichard & Dawney, 2016).

Typically, this analytical approach draws on qualitative data but avoids “coding” it, resisting the reduction and representation that a more typical analytical stance offers (St Pierre, 2011). However, following Uprichard and Dawney (2016), we suggest that the entanglement of mixed methods and mixed analytical techniques offers another form of intra-activity and the materialisation of meaning, and therefore the findings of quantitative analysis of survey data and thematic coding of large numbers of qualitative survey responses can be drawn into a diffractive research assemblage, as we do here (Hetherington, 2019). Diffractive analysis shifts our attention away from the human “subject” of the research and towards the agentic role of both theory and materiality in research (Lenz Taguchi, 2009). We assert that this approach has both rigour and legitimacy that does not derive from a sense of replicability, or representation through thick description, but instead arises from the synergy between questions, theoretical framework design and analysis (Onwuegbuzie & Johnson, 2006) alongside meticulous documentation of the processes through tracing and mapping intra-actions between data, theory and questioning (Lenz Taguchi, 2016). Through this diffractive process, the research emerges – materialises meaning – in intra-activity. It is not representational but is part of a living inquiry and an ongoing reconfiguring. In this way, diffractive methodology itself can be seen as part of a unique research assemblage, emerging and developing in response to the ongoing study.

In the study at hand (described in more detail in the next section), data was collected by the teachers involved in the project using a pre- and post-questionnaire (designed by the teachers) that explored pupils’ perceptions of art, science and their relationship to environmental responsibility through short qualitative responses, alongside pupils’ self-report on their identity as a scientist and/or artist and a Likert-style question rating their interest in science and art on a 5-point scale. Artefacts produced by the pupils and photographs of their activities were also collected, and the teachers involved were recorded explaining their perceptions of the project to other teachers and University of Exeter researchers involved in the broader science/arts research project. Questionnaire data was analysed quantitatively and qualitatively, producing a summary of the students’ perceptions using descriptive statistics and themes drawn from coding of students’ open-ended responses, to produce a written summary of questionnaire findings. Excerpts from this summary, alongside direct quotations from the questionnaire responses, quotations from the teachers’ descriptions, and photographs of artefacts and objects generated through the activity, were used within the analysis where they pushed themselves into the analysis as “glow moments” (see above). This inclusion of questionnaire data was therefore not about data integration and synthesis in a way that could be seen as oppositional to the diffractive approach taken (St Pierre & Jackson, 2014). This is because the coding of qualitative responses does not replace their potential inclusion as separate “glow moments” within the assemblage. Instead, the coding itself is treated as another piece of data which can diffract through the theory/other data. In a sense, the coded data enables the exploration of entangled phenomena where boundaries are temporarily drawn around the [group of pupils-questionnaires] as an entangled complex learning system, as well as around individuals, acknowledging the nested levels of complexity within the materialising learning system (Hetherington, 2019).

## THE PRACTICE CONTEXT: SCIENCE|ARTS|ENVIRONMENTAL EDUCATION

The practice we explore in this chapter was one of the science|arts activities developed using the CREATIONS features of creative pedagogy (Chappell et al., 2015) as part of a wider research project. Science and art teacher pairs in six UK secondary settings worked with researchers from the University of Exeter to engage in research that involved them in designing and researching a science/arts interdisciplinary activity using the features. Teachers from all sites came together three times with the university research team, initially to frame the project, midway through the project to share progress and inspiration, and at the end of the project to share outcomes and explore implications both in their own practice and more widely. The projects the teachers created varied substantially, showing the diverse creativities associated with the generative, emergent and contextualised nature of teachers' intra-actions with theories of creative pedagogy, their disciplines and each other (see Chappell et al., 2019 for a diffractive analysis including two of these case studies not explored here).

In this chapter, we draw on data generated in one of these sites, a secondary mixed-gender faith school serving a diverse urban community in central England, where the focus was placed on science|arts creative pedagogies to explore environmental issues. For the activity, 52 pupils aged 14–15 participated in a day-long interdisciplinary science|arts project in which a range of activities were set up in different rooms within the school. Pupils were invited to explore metals, plastics, dyes and textiles from the perspective of both disciplines, and to explore the issue of plastic in the ocean through both art and science. Some pupils took inspiration from the day into their ongoing textiles projects, and images of early outcomes from these projects were included in the dataset. It is quite rare for creativity to be linked to education for sustainability and/or environmental education: a literature review conducted for a different project (Hetherington et al., 2019a) suggests that, where links in existing studies are found, environmental education and sustainability are often used as a context to teach “skills” of problem-based learning and creativity, or creativity is seen as a required skill to be taught to foster environmental responsibility.

### DIFFRACTION 1:

#### WHEN/WHERE/HOW DO OBJECTS/SUBJECTS OF INQUIRY MATTER IN STEAM (RE-)CONFIGURINGS OF PRACTICE?

Inspired by Areljung's (this volume) use of active verbs to explore dynamic, material phenomena with young children, Renold and Ringrose's (2019) description of their JARring methodology, and a particular photograph from the data set in this study (Figure 13.1), a “netting” approach was developed to respond diffractively to the first question. These diffractions emerged through my intra-actions with the data assemblage and must therefore be influenced by my disciplinary perspective as a science educator: had one of the other members of the Exeter team engaged in this analysis from their arts backgrounds, the emergent responses would be different.

**[Place Figure 13.1 here]**

A net is defined in the *Oxford English dictionary* (2019) as “an open-meshed material made of twine, cord or something similar” that can be used to catch fish or other animals, or people/objects as a safety net or in a trap, or with a support structure to catch balls in a goal, or as a communications network as in a shortened term for the internet. In this diffraction, I undertook “netting” as a means of enacting an “agential cut” to bring glowing theory and data

together in a specific orientation with which we explored the enmeshed and entangled images and theoretical concepts. To achieve this, I created a net out of knotted string and laid it out on a table. I dropped cut-out “glow moment” images and quotations onto the net, lifted it, and pinned the paper pieces to the net where they were captured. I then laid the net flat onto a large sheet of paper, orienting the data pieces so they could be seen, before annotating them in coloured pen as an initial layer of responses to our key question (Figure 13.2).

**[Place Figure 13.2 here]**

The netting of glow moments for this first assemblage brings to the fore the reconfiguring of objects/subjects within the science|arts day exploring ocean plastics. “Everyday” material objects (plastic bottles, pieces of fabric) and “everyday” methods (a hairdryer) were put to work via a combination of scientific processes (the breaking and making of polymer chains, combustion, melting and freezing of solder) and artistic processes (sculpting of warmed plastics, painting, plaiting and sewing of plastic bags and fabrics) to create new matter/meaning. New objects were created that were themselves works of art (the plastic jellyfish image in the centre of the net, Figure 13.3), and new understandings of science, art and of the students themselves emerged (changing interest levels in science and art, Figure 13.4).

**[Place Figures 13.3 and 13.4 here]**

One of the features of creative pedagogies we have been working with through the creations project is “transdisciplinarity”, which we understand to be drawing on ideas and processes from any discipline in order to answer the questions being asked: in effect, this is about transdisciplinary practice as a form of inquiry. As Kerry put it in the quotation in the assemblage from a research project meeting with the teachers (Figure 13.5), the pupils are engaging in an ongoing process of “curious questioning”.

**[Place Figure 13.5 here]**

STEAM practices may be interdisciplinary, involving the weaving together of different disciplines such that they support each other but retain their bounded nature (Harris & de Bruin, 2018), and this appears to be at least partially the case here with the production of a GCSE Textiles portfolio. However, as Kerry points out, the student is reaching for science or arts knowledges and processes as needed to respond to her continually emerging “curious questions”. At the same time, we can also view transdisciplinarity using Barad’s theoretical lens of entanglement and the ongoing (re)configuring of the disciplines as temporarily or fluidly bounded phenomena. The glow moments captured in the net are suggestive of such an entangled, transdisciplinary reconfiguring of material objects, subjectivities, and the disciplines of science and art as they are continually (re)created and embodied through ongoing entangled intra-actions. As the pieces of data drawn from the thematic analysis and the textiles workbooks show (Figure 13.6), the pupils enacting this science|art practice associate creativity in both disciplines with *making*, with *colour* and with *inquiry*, but these manifest differently in each discipline. This is suggestive of creativity as a transdisciplinary practice that materialises within, and in the gaps between, disciplines.

**[Place Figure 13.6 here]**



This leads to another aspect of the question with which I began this diffraction: having engaged with the ongoing reconfigurings of objects/subjects – of entangled and embodied matter/meaning – in my exploration of the netted assemblage so far, I have not yet considered when/where/how this reconfiguring occurs in such science|art practices. The data excerpts in the assemblage come from a range of times and places and with different groups of human and other-than-human agents, and yet it seems impossible to pin down particular “whens”, “wheres” or “hows” from this data: each excerpt contains some aspect of the ongoing materialisation of matter/meaning within this creative science|arts work, whether in pupils’ conversations with teachers, working with particular processes, creating artefacts, responding to questionnaires, researchers analysing questionnaire data, or teachers and researchers engaging in dialogue about the research. Rather than try to answer this aspect of the question with respect to each element of the practices in this case (which readers can interpret themselves as they engage diffractively with the data assemblage presented), I instead return to theory to help me explore and respond to the question, reconfigured in light of my first diffraction through new materialist theoretical concepts of entanglement and transdisciplinarity.

#### DIFFRACTION 2:

(RE-)CONFIGURED QUESTION: WHEN/WHERE/HOW DO ENTANGLED AND EMBODIED MATTER/MEANING/OBJECTS/SUBJECTIVITIES EMERGE AND DYNAMICALLY RECONFIGURE IN AN ENVIRONMENTAL SCIENCE|ARTS EDUCATION PRACTICE?

**[Place Figure 13.7 here]**

Zooming in on a corner of the net (Figure 13.7), I find some images that sprang out as relating to our conceptualisation of embodied dialogue and material-dialogic space. Within a relational ontology, the concept of embodied dialogue has increasingly become, to us, a crucial feature of creative pedagogies in transdisciplinary practices. Related to Barad’s concept of intra-action, we have elsewhere (Chappell et al., 2019), developing an earlier conceptualisation of “living dialogic space” (Chappell & Craft, 2011), articulated in detail how embodied dialogue can contribute to the enactment and materialisation of creative transdisciplinary pedagogies. Further, in Hetherington et al. (2019b, 2019c) we explore how bringing theory from Barad and Bakhtin together can help us consider where and how such an embodied dialogue can occur. Citing Shotter (2013), Carlile et al. (2013) also note how the work of these two theorists can be usefully brought together as they both work with a relational ontology. Dialogic theory holds that dialogue can only occur when there is an “other” with whom a dialogue can proceed – where there is no difference, no other, then there can be no dialogue (see Wegerif, 2019). However, dialogue need not be between human subjects: the material/non-human other also contributes a “voice” in the dialogue. For Barad, objects cannot pre-exist their intra-action but are produced by and productive of it *by means of that intra-action*. Dialogue is possible between these temporarily bounded, temporarily “othered”, agentially intra-active entities. Wegerif (2019) uses a helpful concept in his discussions of dialogic theory: dialogic space. Dialogic space is a shared, relational space that emerges in a dialogue. Chappell and Craft (2011) termed the dialogic spaces that are produced in creative pedagogical practices “living dialogic spaces” in order to encapsulate their fluidity and dynamism as those engaged in creative dialogue respond to and create (with) each other. Hetherington et al. (2019c) explore the materiality of dialogic space where other-than-human and embodied human voices are foregrounded with/in the dialogue.

The elements of data in the assemblage that I home in on in this diffraction suggest to me that the material and embodied reconfigurings in this science|arts|environmental practice took place in what could be considered a living material dialogic space. Pupils, teachers, materials and ideas were brought together in a physical and ideational space (as shown in the photograph of teacher, student and plastic in dialogue in the school hall in Figure 13.7), where “science and art combines our imagination and reality” (as the student quoted in the assemblage put it). People, materials and ideas flowed in and out of this space as they moved around the different classrooms during the science|arts day and onwards into their lives and other lessons, changing things and being changed as the entangled, temporarily bounded intra-acting entities (by which we include groups of pupils, or pupil-objects) shifted and moved both through physical space and time. Barad might call the phenomena produced in this living material-dialogic space “spacetime mattering” (Barad, 2007: 142). The importance and relevance of the idea that living material-dialogic space stretches and flows through time is shown through the photograph at the bottom of the assemblage (in Figure 13.7). Taken on an action research project day in which the six science and art teacher pairs from each school visited the University of Exeter for a day to work with the project research team, sharing and discussing their own research in the context of the wider creations project framework, the photograph shows what we came to call the “sharing table” at the end of a discussion of three teacher pairs’ work. It is interesting to see the materials the teacher brought to share and discuss: graphs of outcomes from the questionnaires along with photographs of students’ work from the case that we are exploring in this chapter physically bring together approaches that are commonly associated with “scientific” or “arts-based” methodologies but stretch beyond disciplinary boundaries and associations as they are brought through space and time to intra-act in response to our creative research inquiry. The artefacts from the case we explore in this chapter lay over and are overlain by artefacts from other projects, with the teachers’ and researchers’ bodies just visible around the edge of the table. The artefacts (material-dialogic objects that “came to matter” in the project) therefore extend the phenomena produced within the dialogic spaces on the science|arts day, stretching the material-dialogic space through time and bringing them into new dialogues with new artefacts, objects and people in an ongoing creative research process as well as a pedagogical one.

The where/when/how question of entangled and embodied (re)configurings of objects/subjects in a science|arts transdisciplinary practice could therefore be answered: through embodied/material dialogue, within a living material-dialogic space. The importance of this space as fluid, dynamic and shifting through time as well as physical and ideational space is foregrounded in the diffractive assemblage produced through the “netting” process, linking images and quotations from the project day through to the teacher-researchers’ dialogues on the research sharing table and Kerry’s quotation from the analytical conversation at the research meeting. In the context of a science|arts day that was intended (on the teachers’ part) to engage pupils in thinking about environmental responsibility, and therefore future making, the importance of space, time and materiality together highlighted in diffraction 2 leads us to a new question: In a creative science|arts transdisciplinary practice about ocean plastics, in what ways does environmental responsibility come to matter?

DIFFRACTION 3:  
IN A CREATIVE SCIENCE|ARTS TRANSDISCIPLINARY PRACTICE ABOUT OCEAN  
PLASTICS, IN WHAT WAYS DOES ENVIRONMENTAL RESPONSIBILITY COME TO  
MATTER?

The notion of environmental responsibility holds within it a sense of temporality: responsibility towards the environment with/in and of which we are a part both in the present and the future. In my last diffractive response, I reached a point where the analysis of the practices suggested the importance of material-dialogic space extending through time within creative pedagogical practice and research: a dialogic spacetime-mattering. Taking this as a starting point, I again used the “netting” process to bring together a data assemblage responding to the question of how, in this practice, environmental responsibility came to matter. As with the previous diffraction, the whole net is shown in Figure 13.8, with zoomed in photographs to show the data excerpts more clearly as the diffraction proceeds.

**[Place Figure 13.8 here]**

In the questionnaires completed before and after the science|arts day, the pupils were asked for their ideas about whether scientists and artists had a responsibility to protect the environment. Data excerpts show that their reasoning drew on their ideas about scientific knowledge, collective and individual responsibility, communication and creativity, in responses that, for me, are about exploring the agency of “scientists” and “artists” to protect the environment, with questions of “Who can act?” and “In what ways?” To respond to the question prompting this third diffractive piece, then, we turn to the CREATIONS feature of creative pedagogies: empowerment and agency.

In the context of a humanising perspective on creative pedagogy with which we began our work on the CREATIONS project, agency and empowerment are important for both teachers and students to be able to work creatively. Agency is commonly understood as the “capacity to act” and it could be argued that, in order to be creative, freedom to choose one’s actions is a necessity. In an educational context, the freedom for teachers and students to take risks and play with possibilities is rooted in the idea that they have agency over what and how they learn. However, agency can be understood not simply as an individual, human capacity but as a relational performance within an entangled assemblage of material and human actors, where agency is enacted “intra-actively” (Barad, 2007). Intra-actions enact “agential cuts” which determine the boundaries between phenomena and thus make objects or concepts (phenomena, for Barad) meaningful. Creativity through embodied/material dialogue occurs as boundaries between objects/concepts are creatively performed by agential intra-action within an entangled, living dialogic space that acts to open out new possibilities.

A relational view of agency suggests *relata*<sup>5</sup> within a living material-dialogic space that also has a temporal dimension. Emirbayer and Mische (1998) describe the temporal nature of agency as formed of a “chordal triad” of past, present and future influences acting together in the moment of agentic action. Thus, agency has a “projective” dimension, in which agents act towards an imagined future, a “practical-evaluative” dimension in which present conditions are taken into account, and an “iterational” dimension in which past experiences informing action are considered. This is a useful framing for the way in which actants relate to experiences across time as well as space. However, Emirbayer and Mische’s is a solely human perspective on agency and also assumes that the future can be envisioned and extrapolated.

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<sup>5</sup> The term “relata”, taken from Barad, refers to the objects/subjects that emerge through relations. An agential realist ontology “does not take separateness to be an inherent feature of how the world is. But nor does it denigrate separateness as a mere illusion, an artefact of human consciousness led astray. Difference cannot be taken for granted; it matters – indeed it *is* what matters. The world is not populated with things that are more or less the same or different from one another. Relations do not follow relata, but the other way round. Matter is neither fixed and given nor the mere end result of different processes. Matter is produced and productive, generated and generative” (Barad, 2007: 136).

Turning to our data assemblage, it seems that, at the outset of the day, many of the pupils associated the capacity for environmental protection with scientists' knowledge, and appeared to suggest that artists' responsibilities are part of a collective sense but did not offer a specific responsibility rooted in the discipline (excerpt from questionnaire analysis summary, Figure 13.9, and quotation "It is everyone's responsibility to look after the environment", left, Figure 13.8). Taking Emirbayer and Mische's (1998) conceptualisation of temporal agency, this could be explained by the idea that, as a result of their (past) knowledge, scientists are able to envision the future and act in the present, based on that knowledge. However, this begs the question of how agency can be enacted without reference to any special knowledge, not least under conditions of real uncertainty about the future, as are currently faced in relation to Earth's responsive global climate change. This could be addressed through Hetherington's (2012) development of a further dimension of agency, "creative agency", which comes into play under conditions of radical uncertainty when the future cannot be envisioned and, instead, agency must be enacted to open the space of what is possible without knowledge about what the outcome of that action might be. It could be argued that, through the science|arts day, pupils increasingly engaged with the need for creative as well as iterational agency in terms of environmental responsibility. However, this was still situated firmly within a human perspective.

**[Place Figure 13.9 here]**

In the data assemblage, we also see excerpts from the students' work during the day, intra-acting in a transdisciplinary sense with plastic materials and each other within a material-dialogic space that, as argued above, creates new objects and subjectivities in practice. In the netting, these excerpts are brought into relation with quotations from pupils' perspectives at the end of the day that appear to indicate some change in their subjectivities in relation to environmental responsibility. There is an acknowledgement of interdisciplinary and transdisciplinary creativity that "propels ideas forward" in time, with "new discoveries" (Figure 13.10) that, whilst unknown, might help protect the environment in a creative orientation to the unknown future. This shift in perspective resulting from the material-dialogic creative practices appears to show one way in which environmental responsibility comes to matter: as embodied pupils physically and dialogically intra-act within an interdisciplinary and at times transdisciplinary practice, new objects/subjectivities are made in relation to environmental responsibility. The pupils began to recognise that artists can, through art, contribute directly to environmental protection through their use of waste materials in the way the pupils did themselves on the day, but they also recognised the communicative potential of such science-art outcomes, and the creative potential in bringing the disciplines into relation.

**[Place Figure 13.10 here]**

With the material intra-actions visible in the data assemblage bringing our attention to embodied and material practices in how environmental responsibility comes to matter in science|arts|environmental education practice, it seems that a materialist dimension is needed with respect to the creative, temporal nature of relational agency. How can we put to work the notion of agential intra-action, and the agential "cut", as a temporally emergent phenomenon? If past, present *and future* are part of an entangled agential material-discursive cut, what does this mean for responsible agential intra-action (for us, in the context of environmental responsibility), where emergent phenomena are radically new, radically unpredictable? Returning to Barad's notion of dis/continuity, the intra-active agential cut

reconfigures the entangled past, present and future – reconfigures spacetime-matter – and constrains *but does not determine* future possibilities (Barad, 2007: 177). The agential cut both opens and closes possibilities, leading to a “dis/continuity between past and future that resists both acausality and determinism” (Barad, 2007: 178). Like creativity, the emergent future can be both radically new, innovative and not *determined* by the past (discontinuous) whilst also being *constrained* by the past (continuous). The both/and logic of the dis/continuity highlights how creative agential intra-action includes entanglements with (using Emirbayer and Mische’s terminology, these would be “orientations to”) the past, the present, the envisionable future *and* the emergent future.<sup>6</sup> In a sense, environmental responsibility comes to matter in science|arts pedagogical practices through the enactment of this dis/continuity. The pupils’ ideas about environmental protection emerged and materialised as they explored scientific knowledge, artistic knowledge and how they can contribute creatively together through intra-action within a material-dialogic space that stretches and flows through time.

#### DIFFRACTION 4 ...? ETHICS AND TRUSTEESHIP AND SPACETIME-MATTERING

In this sequence of diffractions of theory and data drawn from science|arts practice, I have developed the idea of the temporality of material-dialogic space in practice. I have also explored how a creative, temporal dimension to agency within a relational, materialist frame is necessary in reconfiguring creative, inter- and trans-disciplinary practices for education about environmental responsibility. For me, the notion of a temporal material-dialogic space is similar to Barad’s (2007) spacetime-mattering, but more helpful as an inspiration for developing pedagogical practice via the “hook” of the more familiar dialogic, creative pedagogy. Having explored environmental responsibility with this theory-data through the notion of agency, I am left with questions for further diffractive reading of this data in relation to the “ethics and trustee-ship” feature of creative pedagogy, not least in the context of the dynamic nature of the Earth’s global systems of which we are a part. It may be that, in respect of creative educational practices, there is a call not just to reconfigure objects/subjectivities but also to reconfigure anticipatory futures (Osberg, 2018) through intra-action within a fluid and dynamic material-dialogic space, and I leave this final diffractive thought to open a space for teachers and researchers to take forward:

Ethicality is part of the fabric of the world; the call to respond and be responsible is part of what is. There is no spatial-temporal domain that is excluded from the ethicality of what matters. Questions of responsibility and accountability present themselves with every possibility; each moment is alive with different possibilities for the world’s becoming and different reconfigurings of what may yet be possible. (Barad, 2007: 182)

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<sup>6</sup> I use “emergent” here in the sense of “strongly emergent”, where the emergent future is not determined by the past. This contrasts with “weak emergence” in which it would be theoretically possible to determine future outcomes with sufficient data and computing power (Osberg & Biesta, 2007).

In the series of diffractions in this chapter I have connected and entangled new materialist theory, a review of creativities research, and action research practice in which science|arts material-dialogic creativities emerged and came to matter in exploring the issue of ocean plastics. In doing so, I have developed theoretical and practical ideas together, opening a space for teachers to engage with them in their own exploratory STEAM (re)configurings of practice. The chapter does not offer step-by-step guidance for practice, but instead invites and inspires teachers to engage, experiment and improvise with material objects, ideas and disciplines together in question-driven transdisciplinary STEAM creative inquiry to explore environmental responsibility. The diffractions in this chapter suggest practices that open out fluid, dynamic material-dialogic spaces in which materials, processes and ideas drawn from arts and sciences are brought into relation with teachers and students in order to respond creatively to questions about environmental challenges such as the issue of ocean plastics. The temporal, physical and ideational nature of a living material-dialogic space enabled by such a STEAM (re)configuring of practice is crucial to enacting agency in future-making educational practice and research, as it values both innovation for the future (materialising creative agency) and disciplinary knowledges that embody the past (materialising iterational agency) in an ongoing ethical, responsive practice.

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