A material-dialogic perspective on powerful knowledge and matter within a science classroom

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A Material-Dialogic Perspective on Powerful Knowledge and Matter within a Science Classroom

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Introduction

"Powerful" disciplinary knowledge has the potential to enrich students' lives by providing access to understanding beyond everyday experience (Young 2011). Learning science or any other school subject requires understanding of the core body of content within an academic discipline. However, contemporary discussion of disciplinary knowledge remains at the sociological level, offering little clarity around how such knowledge manifests in the complex and unique contexts in which people learn. The framing of powerful knowledge inherits a dualist philosophical assumption that a curriculum concept is a universal phenomenon, acquired through a myriad of activities and applied in new situations, but nevertheless something which is acquired (or not) (Hardman, 2019). The question then becomes how these universal concepts are acquired through the unique context of a specific classroom.

Gericke et al. (2018) begin to address this question by highlighting the *transformations* made as disciplinary knowledge is taught in schools. These transformations occur at the societal, institutional and classroom levels. The term 'transformation' is an umbrella term reflected in both the tradition of didactics, for example, 'didactic transposition' (Chevallard 2007), 'omstilling' (Ongstad 2006) and 'reconstruction' (Duit 2013), as well as within the curriculum tradition in Bernstein's (1973) notion of 're-contextualization'. As well as considering transformations, the term e*pistemic quality* moves us towards conceptualizing how classroom activities have differing qualities in conveying the epistemology of disciplines (Hudson, 2018). In this chapter, we focus on the classroom, and seek to address the overarching question of:

How can the transformation processes related to powerful knowledge and epistemic quality be described?

Our contention is that the notions of transformation and epistemic quality hold the potential to frame the ways in which disciplinary knowledge and epistemology manifest in the classroom. However, as these notions are being developed, in this book and elsewhere, we wish to guard against any simplistic framing whereby idealised disciplinary understandings are in some way *represented* in classrooms. In our view, a learner does not receive a reduced, simplified form of some universal understanding. Understanding of a subject discipline, in terms of both knowledge and the epistemology of the discipline, emerge from the dynamic, messy and material contexts of classrooms. In this chapter, we consider how a *material-dialogic* frame (Hetherington et al. 2018; Hetherington and Wegerif, 2018) might contribute to this discussion. We first briefly lay out the material-dialogic frame and our reasons for proposing it. After that, we use a case study of a science classroom to support the usefulness of the frame in considering transformations of disciplinary knowledge in classrooms.

Emergence over Representation: The Material-Dialogic Frame

Mollenhauer (1983) argues that in the 16th and 17th centuries children were first placed in classrooms and separated from the world they were to learn about. Since then, curricula have been developed aimed at providing children with the knowledge they will require in their adult lives. Education in most societies is concerned with representing the 'real world' in a way that allows students to learn about that world 'as it is' (Osberg and Biesta 2004). But, as Osberg, Biesta and Cilliers (2008) argue, such real world representations do not account for meaning-making as an emergent process within classrooms. They advocate seeing:

> schooling as a practice which makes possible a dynamic, self-renewing and creative engagement with "content" or "curriculum" by means of which school-goers are able to respond, and hence bring forth new worlds. (Osberg, Biesta and Cilliers, 2008: 225)

Therefore, while considering the transformations between academic disciplines and school subjects, we need to foreground the emergent nature of those understandings. Students do not simply receive an imperfect or reduced version of disciplinary knowledge in schooling. Likewise, disciplinary knowledge is not purely derived from everyday experience; this is Young's (2011) argument that powerful knowledge is that which takes students beyond their everyday experiences and opens up new ways of seeing the world. However, rather than simply argue against "top-down" or "bottom-up" accounts of transformations, we wish to argue against any stratification of disciplinary knowledge and school knowledge in how

transformations might be characterized: they are not ontologically distinct. A teacher brings their own understandings of a subject discipline (or disciplines) into the classroom as they deploy resources and activities which they hope convey something of disciplinary knowledge, and the nature of that knowledge, to pupils. The teacher's disciplinary knowledge and pedagogy meet the experiences of the pupils and the material resources and context of the classroom. Rather than an imperfect conveying of knowledge and epistemology, framed as some ideal, we argue that transformations should be seen as emergent. Emergence involves the coming together of different influences in a dynamic and unpredictable way such that new meanings emerge. In Osberg, Biesta and Cilliers' (2008) terms, 'new worlds are brought forth' as disciplinary understandings, everyday understandings, resources and context come together.

To further this characterization, we draw on 'new materialist' perspectives which suggest that the material in classrooms itself has a role to play in agentic processes of meaning-making (Coole and Frost 2010). We develop this by focusing specifically on what we are calling a *material-dialogic* perspective, which we have already begun to develop in relation to science education (Hetherington et al. 2018; Hetherington and Wegerif 2018), although we feel it has potential to also shed light on other subject areas. The perspective begins to recognize some of the complexity of transformations by framing teacher, pupil and content as entangled within the material circumstances of classrooms.

The material-dialogic frame draws on the work of Karen Barad, who defines an onto-epistemological position she calls 'agential realism' (Barad 2007). This position is onto-epistemological in the sense that it challenges the separation of mind and matter implied in epistemologies where mind is seen as learning *about* matter. Rather, Barad draws on quantum physics to challenge the distinctions made between mind/body, known/knower and meaning/matter, which are instead all seen as entangled:

> To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. (Barad, 2007: 19)

In this way, 'matter matters' (Barad 2003: 803) in processes of meaning-making. However, in Barad's relational ontology, matter is not given separate agency (c.f., Latour's Actor-Network Theory) but is an active participant within an entangled 'material-discursive process'. New materialism, therefore, challenges the focus upon a single aspect of teaching and learning: talk, gesture, models, values and identity cannot be separated out within research, nor divorced from the physical and historical contexts in which they are situated.

As well as Barad's agential realism, the perspective we propose draws on dialogic theories of learning and teaching (Mercer and Howe 2012; Wegerif 2011) in order to consider the role of materials in the processes of learning science. Dialogic theories draw from Bakhtin, who notes that: 'I hear voices in everything, and dialogic relations among them' (Bakhtin et al. 1986: 169). Through a review of both science education literature and research on dialogic education, we make the case that Barad's ideas have the capacity to develop both and provide a way to better understand the role of the material in science classrooms (Hetherington et al. 2018). We see practical materials, whiteboards, videos, diagrams, computers and any other artefact as having a *voice* in the classroom, along with the verbal, gestural and narrative voices which inhabit the "dialogic space".

Whilst we will not rehearse our arguments in full, it is useful here to foreground a couple of theoretical elements of this frame, before delving into its relation to transformations through a case study. We already mentioned the importance of entanglements in Barad's work, and to this we add the notion of *intra-action*, as opposed to *interaction*. Whereas an interaction sees separate, pre-existing entities coming together in some way, Barad's intra-action refers to the entangled co-emergence of a *phenomenon* which cannot be separated into constituent parts or ascribed simple causal processes. In Barad's terms, a *phenomenon* is therefore the unit of analysis rather than the separate elements which have a voice within the classroom, be they people, diagrams, equipment, gestures etc. Barad (2007) explains how phenomena emerge within specific historical and social contexts through the intra-actions of humans and non-humans.

Gericke et al. (2018) make a compelling case for transformations as a viable area of research in relating powerful disciplinary knowledge to classroom practices and suggest that:

> An initial transformation is made in the planning phase, when the teacher draws up the lesson plans, selects the teaching content and considers how it should be represented in such a way that it will be possible for the students to grasp. A second part takes place in the actual teaching situation, when teachers and students are confronted with the representations of content. In this way, the transformation can be described as a process of continuous reconstruction. (Gericke et al. 2018: 437)

This account recognizes the continuous reconstruction of disciplinary knowledge into content and then into the material through which content is "represented'" in the classroom, as well as the ways it is enacted and perceived. Gericke et al. draw on the *didaktik* tradition in which the situational aspects of teachers' disciplinary and pedagogic knowledge, students' prior knowledge and material contexts are all considered. As such, their formulation of the notion of a transformation recognizes that representation is not a simple process of mapping from a

discipline. Barad's framework also implies a rejection of representationalism (Milne and Scantlebury 2019) in favour of the continuous (re)emergence (not reconstruction) of phenomena from their material-discursive context. This matters because this perspective foregrounds the co-implication of the teacher's disciplinary and pedagogic knowledge, pupils' prior knowledge and understanding, and material contexts in which learning is taking place. Disciplinary knowledge, then transformed into teaching content and materials, is not static representations but evolving material-discursive phenomena. Barad's frame therefore echoes the rejection of simple representation when considering transformations but goes further in suggesting that the meaning and matter cannot be separated; both emerge from the dynamic interplay of influences within a setting.

Barad's frame thus brings into relief any implicit characterization of transformations as "top down", in which disciplinary knowledge and epistemology are represented in content, which is itself represented in students' minds. A materialist frame denies the presence in a classroom of disciplinary knowledge as abstract universals which are represented only in imperfect form. Instead, the teacher, pupils, materials and environment constitute all there is, and disciplinary knowledge involves the entanglement of these. However, such a frame does not assume that a pupil's understanding emerges "bottom up" from experience either. The teacher has their own disciplinary understandings which are brought into the dialogic space alongside the pupils' ideas; disciplinary knowledge also exists within resources, materials and activities. The intra-action among all these elements, human and other-than-human, means that all enact agency in the processes of teaching and learning. Therefore, disciplinary knowledge itself enacts agency in the teaching and learning taking place, meaning that knowledge matters, and is materialized, in a way that is neither simply representational *nor* simply emergent. Knowledge is transformative, and transformed as learning takes place in a material-dialogic space.

This shift in focus afforded by a material-dialogic frame suggests to us two interrelated things which are in line with the notion of transformations: first, disciplinary understandings cannot be considered in isolation but must be considered as entangled within the phenomena of classrooms. Second, the understandings of teachers and pupils around school subjects are not "representations" of academic disciplines in the sense that there is a simple mapping of one to the other. In considering the importance of powerful disciplinary knowledge and epistemic quality in education, we recognize that the phenomena of a classroom differ from the phenomena of a scientific research laboratory, for example. The transformations of scientific understandings from one to the other involve fully recognizing the entanglements of matter and meaning within each. We think that this framing allows the full complexity of teaching and learning to be acknowledged, without losing sight of the importance of engaging

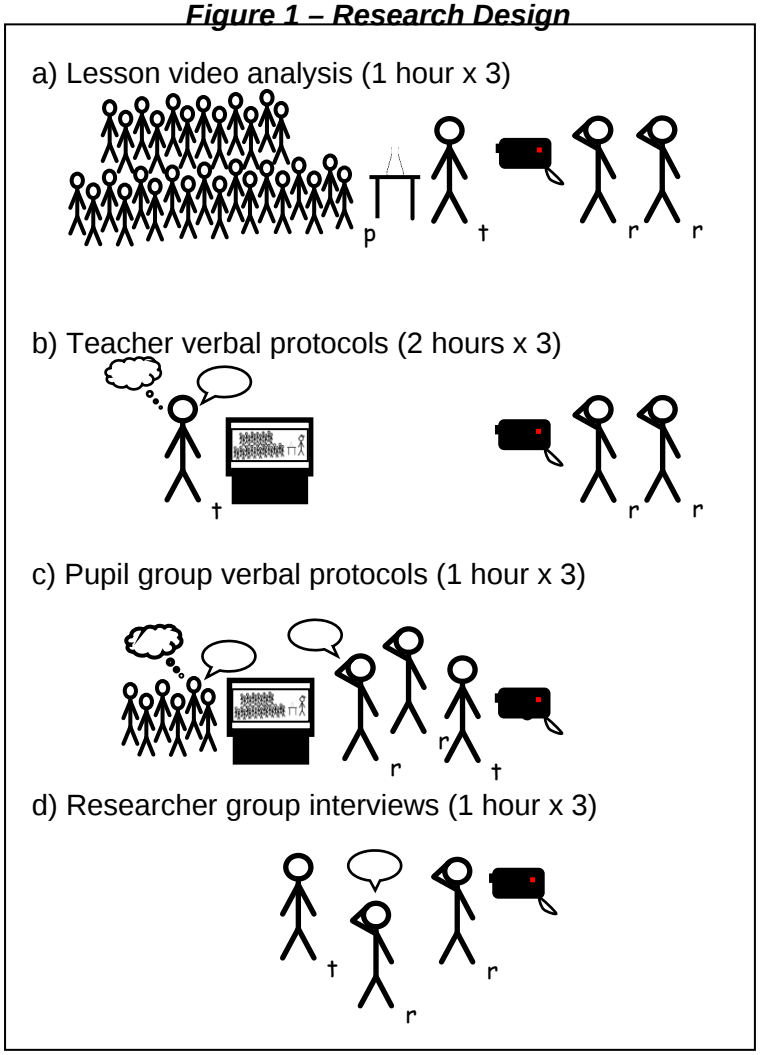
young people in developing understandings which relate to subject disciplines. In order to further this view, we now draw upon a case study of a science classroom.

An Empirical Test Case

The case study in question is drawn from a research project exploring instructional strategies to promote conceptual change (Riordan 2014; 2020). Figure 1 summarizes the research design, although a more detailed account can be found elsewhere (Riordan et al., in press). From the outset of this project, we recognized the material influences upon the teacher, learners and classroom, as well as discussions throughout the project, included the material dimension. Therefore, alongside coding of the data to respond to the project's wider research questions, the data set was further analysed using the material-dialogic frame in order to identify what, if anything, this theoretical frame can add to considerations of classroom transformations and their role in practice.

The case focuses on three lessons on chromatography taught by an experienced science teacher: David. Chromatography is the process by which chemicals are separated according to their different properties. In a simplistic guise in early secondary education, this often takes the form of a thin strip of paper suspended in a beaker so that it just touches some water (the solvent in this case). Dots of ink from pens are made towards the bottom of the paper, and as the water migrates up the paper the different inks within the pen (solutes) are deposited at different distances up the paper. The pattern made on the paper (the chromatogram) reveals the different inks and their solubility (how easily they dissolve). The lessons took place in a large comprehensive school in London and were taught to a group of high-attaining Year 8 students (12–13 year olds). David was asked to plan and teach the lessons as he would normally within the sequence determined by the science department.

Figure 1 – Research Design



Three 1-hour lessons were video recorded from three angles; the teacher had a lapel microphone and other microphones were positioned on desks in the centre of the room. Two researchers (Riordan and Hardman) observed the lessons and took field notes. Following the lessons, and over a period of several weeks, the teacher was engaged in three sessions of *teacher verbal protocols*, in which he watched the videos of the lessons and commented upon what was happening, without input from the researchers. This process was also videoed. Retrospective debrief interviews then allowed further discussion with the teacher, which was also videoed. The complementary use of video protocols and retrospective debriefing follows Taylor and Dionne (2000) and allowed us to include teacher commentary on their thinking and actions. In order to also obtain the perspective of pupils, clips were selected which were of interest to the two researchers. These were then shown to a self-selecting group of six pupils who undertook *pupil verbal protocols* – commenting upon the videos with minimal input from the researchers. They were then asked questions to prompt further discussion. Three of these were conducted: one for each recorded lesson.

To analyse the rich data we had gathered, two researchers coded the videos related to the first lesson separately, including the video of the lesson itself, of the verbal protocol with the teacher, the retrospective debrief with teacher, and the protocols and debrief with students. The teacher also coded the lesson himself. The researchers and teacher then met to discuss their initial coding. The teachers and researcher then coded all of the videos relating to each of the two subsequent lessons (videos of the lessons, of teacher verbal protocol and pupil verbal protocols). There was a further meeting once all of the coding had been completed (which was also video recorded).

The layering of verbal protocols in which teachers and pupils retrospectively analyse the classroom phenomena, videos of which are then also analysed, can in itself be seen as a material-discursive process in which meaning is made by the teachers, pupils, researchers and the video of the classroom intra-acting with each other across these multiple layers. Our understanding of the transformation of knowledge about chromatography as a material-dialogic practice thus emerged through a *diffractive* process in which data, theory and emerging insights are read and re-read through one another (Mazzei 2014). We do not have space here to lay out the full implications of new materialist frames for research methodology. Suffice to say that we see the outcomes as emergent from the processes of research, rather than as a simple representation of the case we explored.

Our consideration of a material-dialogic frame within this case study fits within the broader question outlined at the start of this chapter (and elsewhere in this book): How can the transformation processes related to powerful knowledge and epistemic quality be described? The frame suggests that greater attention must be paid to how disciplinary knowledge and epistemic quality actually manifest in a classroom via material-discursive intra-action, and how this leads to new understandings. We therefore take up this question by focusing on how the concept of chromatography was manifested in the classroom through intra-actions between the teacher, pupils and materials.

Transformations of Disciplinary Knowledge through “Non-Human” Materials

One finding of relevance to supporting a material-dialogic interpretation is our coding of David being in dialogue with “non-human means”. Whilst there is much to be debated about the utility of enumerating the interactions with specific aspects of the classroom, we coded 308 such intra-actions over the three lessons. Whilst this number is of course a product of our research process, it highlights the role of classroom resources and context in transformation processes. The most frequent engagement with material was the Interactive Whiteboard, used to project

images to the class, but also to make notes, show images of the experimental setup, and to agree definitions of key terms. The mini whiteboards were used by pupils to generate models of the process of chromatography, and the teacher continually refers to these within the teaching. The mini whiteboards are also used in nonconventional ways – sometimes displaying a “covert message” to another class member, but even at one point being bent by a pupil to demonstrate the curvature of the chromatograph (the paper on which ink flows upwards when dipped in a liquid). Pupil exercise books contain drawings and descriptions of the process of chromatography. Here we see that the materials of the classroom are intra-acting with the understandings of the teacher and the pupils.

Our suggestion that the material within a classroom is important in learning will not be controversial to readers, however we contend that this has not received a great deal of attention in relation to transformations. This is not to say that every material intra-action in our data becomes meaningful. For example, the blinds blow in the wind, a mobile phone goes off, there is noise outside the classroom. Here the dialogic space is open to the broader world, but the teacher and class downplay the significance of some incidents like this both through observed intra-actions (or absence thereof).

In order to exemplify the role of material in transformations of disciplinary knowledge in classrooms, take the observation that some pupils developed the misunderstanding that the lighter colours travel further up the paper. This initially emerges within the dialogic space as pupils intra-act with the experimental findings (the ink and the paper). Figure 2 shows example chromatograms which David displayed on the interactive whiteboard during discussion. During the first lesson we recorded, David asks for ideas about what might be influencing how far the inks travel up the paper. Figure 3 shows that pupils suggest ‘Dark vs Light’ as one factor they believe to be important. In the second lesson we recorded, a pupil writes an account of chromatography (examples of which are seen in Figure 4) on a mini whiteboard:

> “Water attracts most particles, so inks which are lighter colour have less pigment and go further”

The pupil verbal protocols show that this idea persists for some of the pupils after the lessons. During teacher verbal protocols, David watches back video of the discussion he has with a pupil at the time, and reflects on this, saying:

> [pupil] says “I meant pigment”, and I didn’t give them the word at all. They, they picked up that word from somewhere at the, in the first lesson, where they started doing the actual experiment. And I’m, I’m bugged by that word, because I think it’s got in the way of ever such a lot because they keep going back to this thing about pigment.

By deploying a material-dialogic frame we can draw attention to the nuance of this situation. The original experimental results combined with the everyday understanding of pupils around ink pigments lead to the emergence of a new understanding. This enters the dialogic space and is crystallized on the whiteboard during discussion. When the pupils come to then express their ideas on mini whiteboards, these materials – the chromatogram, the classroom whiteboard and the mini whiteboards – influence the understandings that some pupils have.

Figure 2: The chromatograms engaged with over the lessons

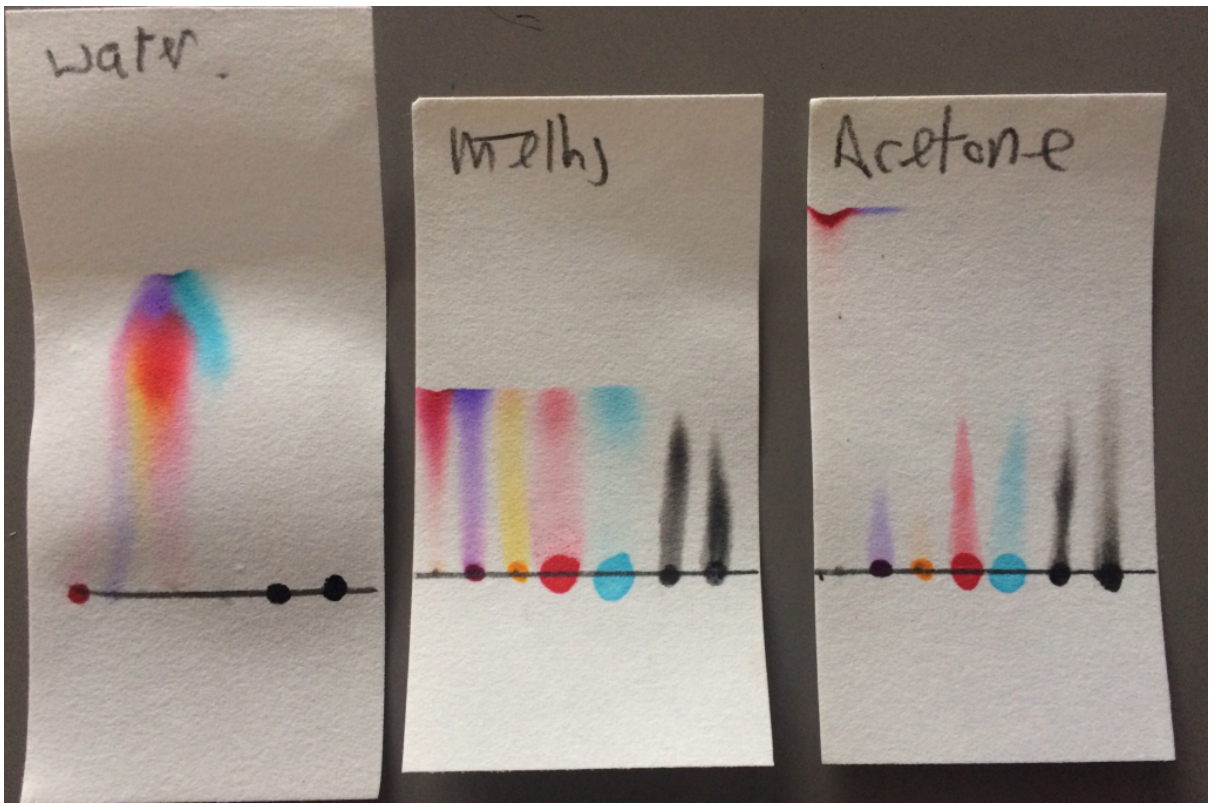


Figure 3: The classroom whiteboard: a dialogic space

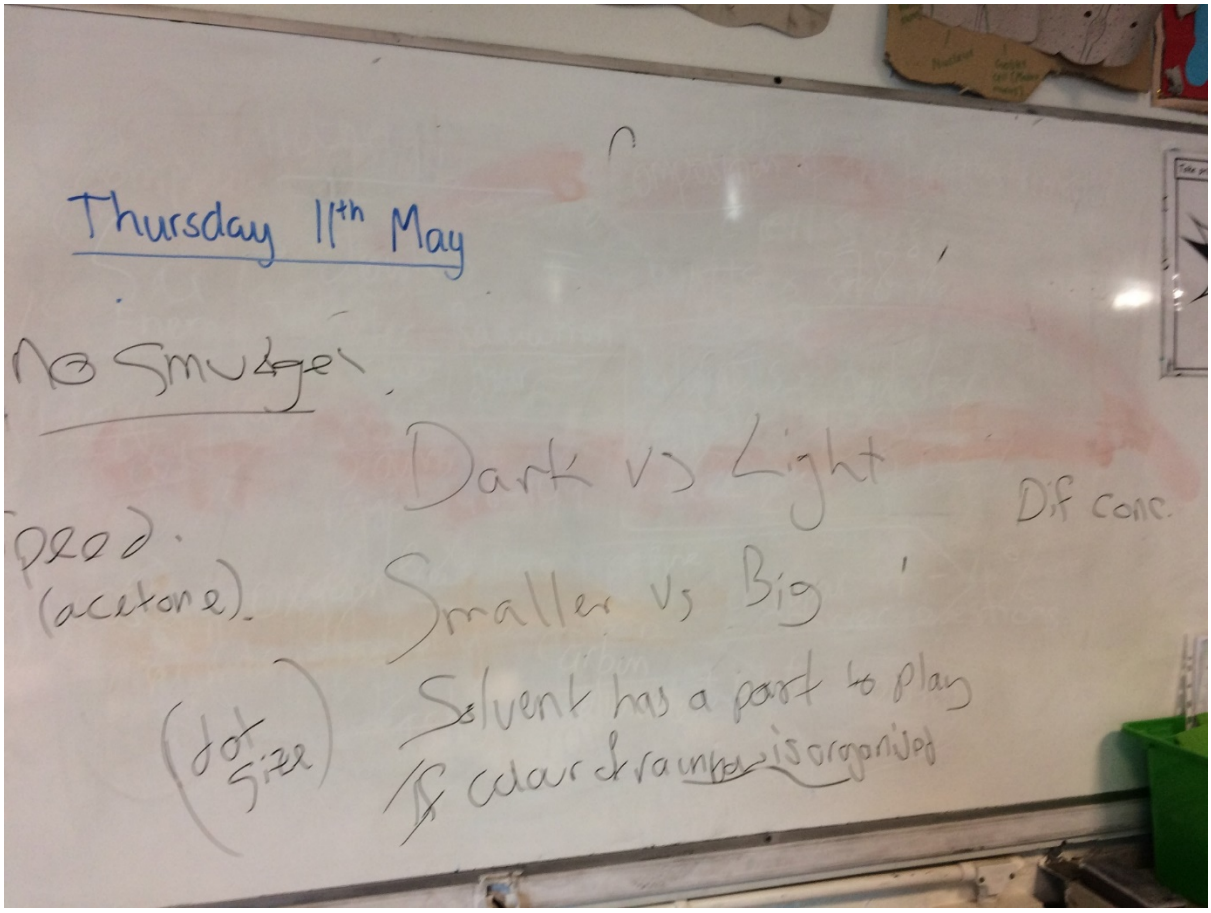
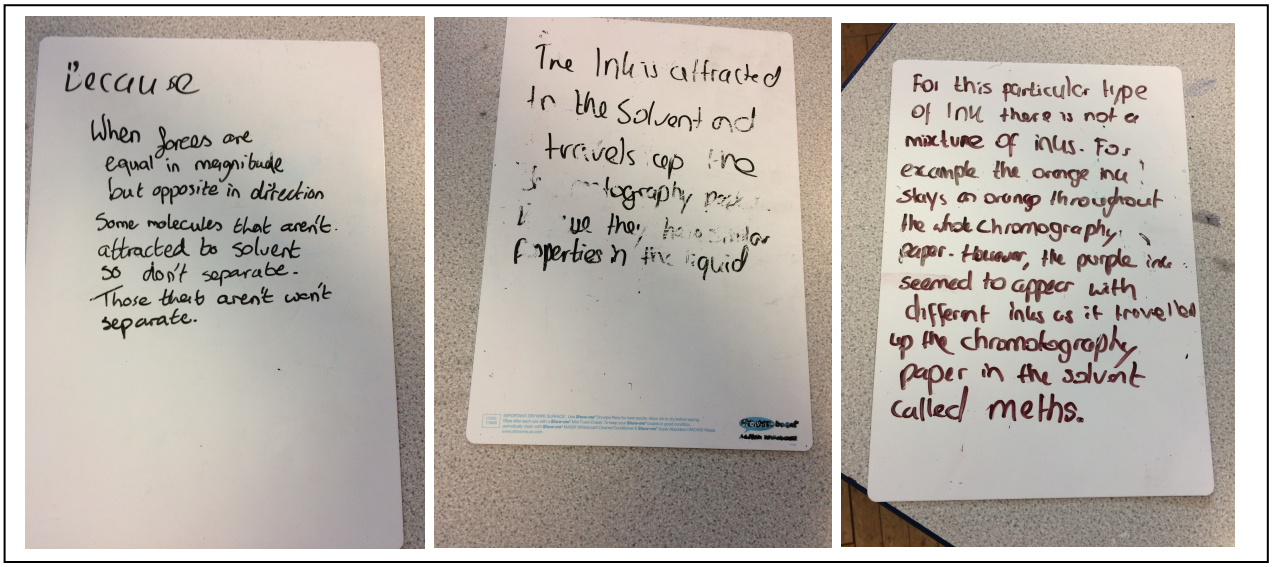


Figure 4: Pupil explanations of chromatography on mini whiteboards



It is through material-dialogue between the teacher, pupils and materials that a misconception emerges. Our data therefore suggest that considering transformations involves recognizing the agency of material aspects of the classroom. Pupil prior knowledge (here about pigments) intra-acts with the class experimental results during dialogue. Here we have what diSessa

(2006: 265) called the primary difficulty, ‘students must build new ideas in the context of old ones’. The pigment idea is expressed in writing on a mini whiteboard which then learners and teacher engage with further. Prior knowledge can in other circumstances be generative of new ideas in a more positive way, but in this case an idea emerges, and persists, which is counter to established scientific understanding.

A material-dialogic frame allows us to ask questions of what it is that the teacher and pupil are actually in dialogue with, and how meaning emerges from this. This role of material resources is often overlooked in attempts to describe how intended content is enacted and learned in relation to school subjects.

Models, Matter and Phenomena

Beyond the foregrounding of matter, we believe a material-dialogic frame offers other affordances in considering transformations. We found that in synthesizing the material and the dialogic it becomes fruitful to frame ‘phenomena’, in Barad’s (2007) terms, as involving entanglements between people and the models of chromatography present within the classroom. Throughout the lesson physical, mathematical and schematic models are presented, developed and discussed. Indeed, the repeated dialogue with interactive and mini whiteboards occurs when the teacher is asking pupils to develop and explore models, and on occasions these individual models are “amplified” as they are discussed with the whole class. There are also gestural models which have significance to the teacher and the pupils, and which are repeated several weeks after the original lessons – for example, gestures around the movement of particles. The experimental results have meaning and are mentioned several times. Whilst not strictly ‘models’, they are signifiers of findings within the experiment.

In considering how powerful disciplinary knowledge is transformed in classrooms, the material-dialogic frame allows us to see that teacher and pupils are in dialogue with the physical manifestations of a scientific concept; in this case, chromatography. The concept is not present in the room as some universal, ontologically distinct ideal, but is present in the models which have a material presence in the classroom. These models are physical, mathematical and diagrammatic, but also manifest in gestures, verbal descriptions, written definitions, videos and animations.

This realization fits with a philosophical shift in how models are characterized in both science and science education. Gilbert and Justi (2016) reflect on the development of model-based learning over the last few decades and are explicit in their shift away from seeing models as simply representations which denote and support acquisition of universal concepts. Instead,

they chart a move towards seeing models as ‘artefacts’ which are developed in classrooms and through which people reason. This approach corresponds with a shift in the philosophy of science to seeing models as artefacts (e.g. Knuuttila 2011) and positions models not just as things which are reasoned about, but as artefacts which are integral to reasoning in science, and in learning science (Hardman 2017). Similarly, Tytler et al. (2013) chart the development of research into drawings, diagrams and visual representation in science education, and detail their position that students reason through the representations which they generate as part of learning science. We suggest that the material-dialogic frame furthers this literature by seeing models and drawings as emergent from the material-dialogue of classrooms. It also allows us to see such phenomena as involved in the transformation of powerful disciplinary knowledge and epistemological understandings within processes of teaching and learning. In our data, we found that models and diagrams, as artefacts within the classroom, were central to the processes of teaching and learning. In this sense, we might go as far as proposing that disciplinary knowledge is transformed as these models emerge within classrooms.

Yet, the focus on materials within a material-dialogic space is not just confined to the considering of models. Embodied cognition (e.g. Barsalou, 2008) is another research area which highlights the need to reconsider learning as involving material aspects of the classroom; the role of the body and its actions in how we come to understand the world is being better understood, although it remains in its infancy. Related to this is the role of gestures in science education and the growing understanding of the role these play in learning (Callinan 2014; Carlson et al. 2014; Johnson-Glenberg and Megowan-Romanowicz 2017). Even how a science teacher demonstrates a scientific technique may be affected by the relative position of students in the room: Jackson, Meltzoff and Decety (2006) found that observing actions from a first-person perspective is more tightly coupled to the sensory-motor system than from a third-person perspective, which requires observers to also process visuospatial information. Bringing these existing accounts of the material aspects of classrooms together with the material-dialogic frame suggests to us that powerful disciplinary knowledge is manifest in classrooms within the models that teachers and pupils are entangled with, but also in the gestures, demonstrations, equipment and even phrases that are deployed. In thinking about transformations, this shows us that the disciplinary knowledge and pedagogic knowledge of the teacher are intra-acting continuously within a dynamic context involving pupils’ ideas and material resources.

Much of the teacher verbal protocols and interviews with David involved him evaluating how different actions, approaches and narratives have evolved in his practice and emerged in the studied classroom. For example, when reviewing the first lesson during teacher verbal protocols, he says:

> Then we got these lovely A4-sized ones [mini whiteboards] and it has revolutionized my classroom, because I can go round, and read… I'm not a great believer of putting long ideas into an exercise book, because they are really attached to them once they are there. … I think that they feel far more, um, free to explore their ideas on these mini whiteboards.

David has an understanding of chromatography, which is brought together with the repertoire of strategies he uses in the classroom. This case study shows that David considers chromatography as a topic which lends itself to empirical demonstration/experiment, and then pupils working in small groups to discuss, and using mini whiteboards to generate explanations of how chromatography works at a microscopic level. The pupils experience and come to understand chromatography through experimental results, dialogue involving whiteboards, gestures and embodied understandings within a material-dialogic space. The transformation of disciplinary knowledge into classroom learning emerges from teacher understandings and pedagogical strategies meeting with pupil understandings and the materials of classrooms.

Transformations and the Phenomena of Classrooms

As discussed at the start of this chapter, Gericke et al. (2018) develop the notion of transformations as a way of considering how powerful disciplinary knowledge is brought to the classroom. In this chapter, we added a different theoretical lens, drawing on a material-dialogic account from the work of Barad and Bhaktin. This lens, we believe, further develops a focus upon the specifics of how knowledge manifests within the classroom; how concepts within a curriculum are enacted and learned. We suggest that the role of materials has been underplayed in the discussion to date, but we hope that our case study goes some way to showing that the resources, models and dialogue which emerge within the classroom are indeed the actual stuff of teaching and learning, not some imperfect representation of idealized knowledge.

We therefore propose that a material-dialogic perspective frames disciplinary knowledge as bound within the phenomena of classrooms. Teacher, pupils and materials all play an agentic role as they intra-act, and all bring disciplinary knowledge into play. As a teacher brings their own understandings into the classroom, and their planning unfolds in activities and resources, these become entangled with the embodied understandings of pupils, and the materials within that context. Our case study suggests that powerful, disciplinary knowledge is manifest in the models and dialogue which emerge in the classroom, and which support student understanding. We also suggest that entanglement with models and pedagogical strategies

such as generating hypotheses may contribute to pupil understandings of the epistemology of science. We hope the frame and analysis might be extended to other school subjects.

The entanglements of matter and meaning within classrooms are the site of teaching and learning. Each professional scientist may have different understandings, and be entangled with different people, materials and context – different phenomena. In labelling a transformation between understandings in the professional discipline of science and the science classroom in schools, we draw on patterns and resemblances that we believe link the two. However, this is not a simple case of correspondence, nor is school science a representation of professional science in the sense of being a reduced or simplified version. Whilst our analysis still speaks to the transformations between disciplinary knowledge and school subjects, we contend that a material-dialogic frame challenges the sense in which a re-contextualization, transposition or reconstruction of knowledge might be framed as their being something ideal or universal which is maintained between settings. The phenomena of a scientific workplace and the phenomena of a classroom are different, as every context is different. Teacher understandings, curricula and resources are always entangled with pupils and material contexts in new phenomena.

Recognizing this entanglement matters when we think about teaching and learning because the details of how disciplinary knowledge is transformed into classrooms influence pupil learning. We suggest that pupils, initially at least, come to understand a topic like chromatography through the specific models they generate and enter into dialogue with. These models come about as teacher understandings meet pupil understandings and the resources in the classroom. We have seen that in our case study the experimental results, classroom whiteboards and mini whiteboards were all important in the generation of understanding (and sometimes misunderstanding). The material-dialogic frame suggests that teachers and researchers should pay attention to not just the knowledge or “content” to be taught, but also to the material resources within the dialogic space. We believe that a material-dialogic perspective foregrounds the importance of matter, shifts attention to the phenomena of classrooms in teaching and learning, and guards against simple accounts of representation. It therefore speaks to the messy and emergent nature of teaching, learning and research within school subjects.

Our consideration of a material-dialogic frame has begun to raise further questions for us as well: to what extent are various classrooms (indeed, different material-dialogic spaces) different from each other, and what impact do these differences make to emerging understandings within that space? How do specific activities, contexts and resources condition the disciplinary knowledge and epistemological understandings that pupils develop? We hope

to continue exploring these issues. In relation to how we can describe the transformation processes related to powerful knowledge and epistemic quality though, we suggest that the material-dialogic frame already highlights the need to move past representational accounts. Instead, it allows us to consider how pupils learn through being entangled within phenomena, which emerge from teacher intentions, understandings, pedagogical strategies and the materials within specific classrooms.

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