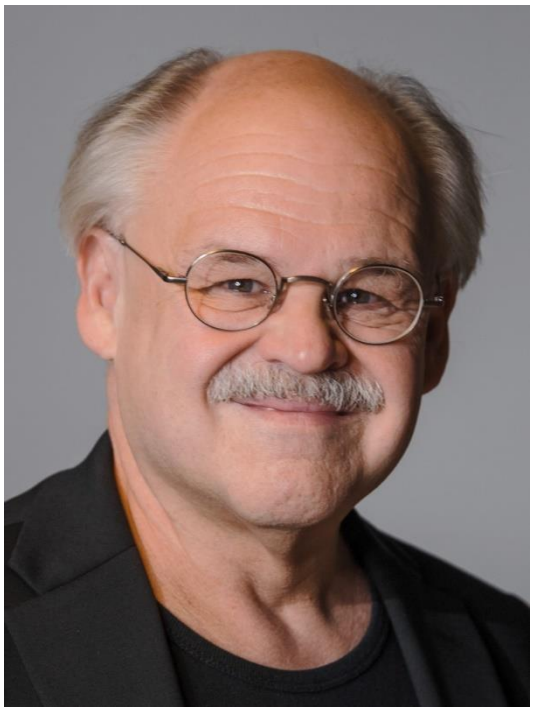
 # OPINION PAGE

Does Agential Realism have quantum physical insights or is it just confused thinking and obscurantist writing?*

ISMO T. KOPONEN, University of Helsinki, Department of Physics
e-mail: ismo.koponen@helsinki.fi



Ismo T. Koponen is a Professor of Physics in the Physics Department, University of Helsinki, Finland. His background is in computational and statistical physics. His current research interests include complexity science, complex networks and quantum information theory. For twenty years, he has been involved in physics teacher education and physics education research. In the latter, his focus has been on role models, experiments, and scientific language in learning physics.

Introduction

In science education research, we have seen increased attention in recent years on the role of material practices and materiality as a perspective on science education and science education research.[i] The basic tenets regarding the roles of matter and materiality of such views are derived from the so-called new materialism, and most often from the version that emphasizes the agential role of matter as well as performative agency, thus termed performative new materialism to highlight the agential or active role of matter.[ii]

Some science education researchers have recently claimed that the active or agential role of matter, materiality, and material practices have too long been ignored in science education and thus turned to performative new materialism as a remedy for the recognized

shortcomings.[iii] In these views, "materiality" is used to refer to anything that materially exists in a school laboratory or in the context of learning science topics, including not only man-made objects but all material objects and all kinds of material existence that are relevant to the context of learning.[iv]

Many scholars who favor such a broad view of "materiality" appear to share common philosophical underpinnings in performative new materialism, in particular in the form of Barad's agential realism (Barad 2007).

The focus of my commentary is on those recent studies in science education research that have adopted Barad's agential realism to support new materialism at a sufficiently advanced level of science education, in which scientific-like laboratory work with its materials and material practices are central. These framings leave a relatively narrow focus and exclude many other ways in which new materialism is used in science education. Consequently, only a few studies are relevant here.[v]

Focusing on Barad's conception entanglement and how it becomes visible in the studies mentioned above, I attempt to pin down the reasons for adopting the quantum physical insights of agential realism in new materialism-inspired approaches to science education. I attempt to clarify whether or not such underpinnings, obviously important to Barad's thinking, are equally important in the context of science education. As possible answers to this basic question, I have in mind three options.

The first option is that agential realism provides genuinely new phenomenon-based conceptualizations with new concepts, thus allowing the researcher to design empirical research settings. It would also allow ways to analyze the results that show how something materially new comes into existence through entanglement in phenomena related to science education. Such materially real emergence is important for Barad's agential realism, as will be discussed in detail below. When agential realism is applied in learning situations, a legitimate question is how far such views can be pushed, and what it may mean to claim that one can see entanglements or materially new realities coming into existence. Is it indeed possible that the notion of entanglement retains similar meanings as in phenomena in quantum physics? If the answer were positive, that would open a completely new viewpoint to learning phenomena. If the answer is negative, one must ask why the quantum background and thinking is needed at all.

The second option for endorsing agential realism in science education research is that it provides a kind of motivational metaphysics. By motivational metaphysics I mean a similar stance as motivational realism, a term used by some philosophers of science (Darling, 2003; Fine, 1996) about positions where metaphysics provides motivation and guidance but has relatively few practical consequences, if any. Pragmatic considerations – whether the outcomes of empirical research provide useful results or lead to useful, reliable practices – determine whether the adopted views are viable, adequate, and acceptable. In the context of application to science education research, it is worth asking whether the situation is more like this second option than the first.

The third option is that quantum physics-inspired concepts of agential realism provide a kind of metaphorical talk and a figurative way of speaking about familiar events but does not lead to changes or inventions in empirical practices that produce genuinely new phenomena and designs to create them (e.g. as in quantum physics). This is obviously the least controversial

way to use agential realism but it seems to water down the ambitious ontological goals of Barad's agential realism. Nevertheless, this third option must be kept as a possibility in works where agential realism is applied by other authors.

Each of these three options has its own advantages and benefits. The first option is possible, credible, and empirically accessible in the case of quantum phenomena. However, in the context of classroom phenomena that are relevant to education, I see it as a quite implausible possibility. At present, no empirical evidence supports that possibility, and it is beyond empirical study in any ordinary sense of empirical research. The last option may be useful as a source of inspiration and may give satisfaction in the form of the experience of gaining insights, but then, not through evidence-based and rationally explicated argument.

The middle option is interesting, because then agential realism may be of value in guiding attention, inspiring research questions and empirical studies without the need to take the motivational metaphysics and quantum physics background too seriously. In this case, the value of agential realism derives from its power to guide useful action in practical situations e.g. in addressing practical questions of how to design and evaluate teaching situations.

I begin my commentary with a short critical summary of Barad's agential realism. Next, the role of agential realism as a basis for theorizing in humanistic, social, and behavioral sciences is briefly outlined, before focusing on its uses in science education. On the basis of these two sections, I discuss what reasons, as well as what problems, can be recognized behind the adoption of agential realism, with its quantum-inspired background thinking and quantum physics-related terms, in new materialist approaches in scholarly studies in science education.

Background: New materialism and agential realism

Advocates of new materialism in science education claim that current trends in science education do not adequately address the material aspects of learning, at least not in the sense of how that materiality is understood in new materialism. The supporters of new materialism criticize three aspects as the main shortcomings of current trends in science education. First, what they see as the "active agency" of matter and materiality is not taken into account in ways they find appropriate.[vi] Second, they claim that constructivism-dominated views in science education are too strongly affected by separation between knower and known, between subject and object, which they refer to as "Cartesian dualism". Third, these researchers believe that science education pays too much attention to language and the linguistic aspects of learning, and consequently undervalues the material aspects of learning science. The new materialism movement therefore seeks to overcome these shortcomings by better acknowledging what they call the "active role of matter".[vii]

Here, I focus on the narrow set of studies in science education described above, because they discuss the topic of interest at a sufficiently advanced level, where experimentation and experiments utilizing laboratory instruments and devices are important. In these studies, the researchers aspire to stick closely to Barad's key concepts, in particular entanglement, intra-actions, and agential-cuts. This warrants asking how the researchers have managed to take into account the centrality of quantum-inspired thinking and the quantum physics origins of Barad's agential realism.

Agential realism and active agency of matter

When specifying what the active role of matter might mean, the advocates of new materialism in science education have turned to so-called agential realism, introduced by the feminist theorist and philosopher Karen Barad (2007). One obvious reason to endorse Barad's agential realism as an underpinning for new materialism movement is its agential and performative nature. It motivates the active role and agency of matter in events and processes that are relevant in science education in laboratory settings.[viii] Barad's agential realism is well suited to that purpose because it pays close attention to "*relationalities of becoming, of which we are a part*" (Barad, 2007, p.393), and how "*matter does not refer to a fixed substance; rather, matter is substance in its intra-active becoming – not a thing, but a doing, a congealing of agency*" (Barad, 2007, p.822).

For example, Julksjær et al. have summarized such aspects of the agential realist position as follows:

> [A]gential realism undoes the division between being and knowing – ontology and epistemology. This undoing is marked by the concept of onto-epistemology: knowledge practice is a practice of worlding; the world, and "us" with it, are continuously performed; that is, continuously coming into being. Research is of the world, is part of the world's ongoing reconfiguration. (Juelskjær et al. 2020, p. 13-14)

Accordingly, agential realism is clearly meant to be an ontological position, "onto-epistemology", not only about epistemology but an overarching view on how world is: a view of "coming into being".

For Barad, the quantum physics connection is an important part of agential realism, not a metaphorical or analogous way of speaking, but an empirically testable theory of being or coming into being. Commenting on the agential realist position, Barad has noted that:

> [A]gential realist interpretation is vulnerable to empirical results, as it should be. It has to cohere with what we know. And likewise, yes, scandalous as it may be to some, agential realism could ultimately prove to be wrong, or at least not sufficiently responsive to various 'human' and 'nonhuman' intra-active engagements that matter. That vulnerability, to my mind, is a real strength of any theory ('scientific' or otherwise), not a failing. (Barad 2011, 446-447)

For Barad, this stance is not restricted to agential realism as applied to physics only, but goes through all of their thinking. If agential realism is a position of such weight and strength as Barad and Barad's supporters claim, and if we believe that agential realism provides more than metaphorical talk, similar criteria to those in the quotation above should also be valid when agential realism is applied within science education research. It is also interesting to ask what empirical evidence (in the same sense as in the quantum experiments Barad uses as inspiration) becomes available for classroom entanglements, or what actually is materially coming into being (as in quantum experiments).

Agential realism's terms as Baradian quantum lingo

Given that Barad's agential realism is meant to be a onto-epistemological interpretation of reality and its constitution, based on quantum physics, it is astonishing to find it borrowed and gaining favor when theorizing in social sciences, certain areas of the humanities, and

behavioral sciences. Recent critical analyses have pointed out deficiencies and fault-lines in adopting such stances.[ix] One possible reason behind such uncritical adoption of the quantum physics underpinnings of agential realisms is related to difficulties in translating ideas between different fields of inquiry (Jaksland, 2021).

Barad's expertise lies mainly in feminist and posthumanistic studies but, in addition, Barad has received PhD in theoretical physics and contributed to a few physics research papers, and thus also has the necessary expertise in physics to act as a competent translator.[x]

However, when scholars in fields of humanities, social, and behavioral sciences borrow ideas, views, and terminology from a field they have little if any familiarity with (here quantum physics) through a translator (here Barad), they lack the ability to critically examine the validity and credibility of the ideas that they adopt as underpinnings of their own studies (Jaksland 2021).

One reason behind the growing popularity of agential realism in humanities, social, and behavioral sciences might be the very special and imaginative vocabulary Barad has used to express their views and which is part of vocabulary of agential realism. In what follows, I will use term "Baradian lingo" to refer to Barad's use of terms and expressions that are borrowed from quantum physics but stripped of their definite and mathematical content to emancipate them from the constraints of normativity and make them more flexible.

Barad's agential realism borrows quite a lot from the terminology of quantum physics and, for example, "entanglement", "diffraction", and "apparatus" are key terms of agential realism and of central importance to it. However, many of the terms contained in agential realism are specific to it, for example, "intra-activity", "agential cut", and "spacetimemattering". In the case of terms simply borrowed from physics (e.g. entanglement"), Barad and Barad's followers use these terms in much broader and flexible ways than they are used in quantum physics. Such augmented meanings remain, however, obscure, and much is left to the reader in deciding the connotation of a term in different contexts of its use.

It is difficult to take a stance on the Barad's use of language, because although it is associated with quantum physics, it has eventually developed into a quantum physics-inspired lingo with meanings that are difficult to decipher because Barad's prose is so dense and convoluted.[xi]

It is productive to be able to discuss views inspired by quantum physics in humanistic sciences and social and behavioral sciences as well as arts and literature, to provide broader ways to understand phenomena in those areas of scholarship (compare Schaffer & Barreto Lemos, 2021). Therefore, it is important to pay explicit attention to how we use the ideas and terms borrowed from quantum physics to provide new viewpoints and ideas in other fields of scholarship. Thus, it should be clear if one is using terms like "entanglement" (a favorite of those who endorse agential realism) by keeping close to their original sense (when fidelity to quantum theory matters) or only metaphorically, as a source of inspiration and motivation (when much creative freedom is possible).

Finally, a scenario that needs to be taken into account is that the quantum-lingo of agential realism is another example of how postmodern and posthumanistic philosophizing uses obscure and ambiguous language and terms, and extend and alter the meanings of the terms from those in their original context. Many examples of such introduction and use of terms, drawn from postmodern and posthumanistic philosophizing, are discussed in detail in several

critical reviews.[xii] In that case, complicated terminology is not necessarily a hallmark of profundity, but rather, "*verbal smoke and mirrors to suggest depth and insight where none exists*" (Buekens & Boudry, 2015, p 126).

In my reading, Barad's agential realism, utilized as a research methodology (see e.g. Juelskjær et al. 2020) or as a viewpoint in science education (see e.g. Milne & Scantlebury, 2019) appears to come close to such verbal "smoke and mirrors". Perhaps, however, the apparent obscurantism is just a consequence of a certain style of writing typical of the social sciences, where expression contains many new neologism-like and term-like substantives, attributes, and adjectives instead of plain language. Such a writing style has been claimed to be abundant in social sciences, as discussed in detail with examples by Billig in his book *Learn to Write Badly: How to Succeed in the Social Sciences* (Billig, 2013).

After this background discussion, I next turn to the main issue of my commentary, to scrutinize how agential realism's quantum physics background and its related terminology, in particular the concept of entanglement, are seen and used by researchers who utilize agential realism.

Agential realism as a basis of theorizing

Agential realism is gaining popularity as a research approach in the new materialism movement and in the more focused field of new materialism-inspired science education. A representative example of the hopes and enthusiasm attached to agential realism is provided by Juelskjær et al. (2020) in their recent book *Dialogues on Agential Realism*, and, in the context of science education, in an edited volume *Material Practice and Materiality: Too Long Ignored in Science Education*, by Milne and Scantlebury (2019). Also in some recent articles focusing on science education and science teacher education.[xiii]

I begin here with agential realism as discussed in the broader context of theorizing related to new materialism, as exemplified by Juelskjær et al. (2020), and then narrow down to the discussion as found in new materialism within science education research. In what follows, the Baradian conception of "entanglement" is the focus, because much of the assumed power of agential realism seems to revolve around that conception.

Agential realism provides lenses to see research topics differently, and, in addition to lenses, it provides Baradian quantum lingo to frame and conduct discourse about research topics. It is instructional to ask how those who have found agential realism useful express their ideas, views, and motivations to use it, and how they make use of the Baradian lingo.

The Baradian understanding of world, existence, and knowing is a central theme in new materialism, which, according to Juelskjær et al. (2020), attempts to dissolve the boundary between subject and object; becoming and being are seen as a continuous process, reality emerging in a continuous creation of existence in joint performative acts of humans and non-humans. In this process, "entanglement" plays a key role:

> [A]gential realism starts out in a fundamental connectivity or entanglement. A quantum entanglement. The thinking/theory as such, and all agential realist concepts, are designed and defined through this premise of entanglement and more-than, less-than or other-than human performativity. (Juelskjær et al. 2020, p. 14)

Here, the importance of "entanglement" becomes evident, as many key ideas of agential realism are related to entanglement. Crucially, it is emphasized that the entanglement in question is "quantum entanglement". Taken at face value, speaking about quantum entanglement entails being able to define the (quantum) states that are entangled. Otherwise, we must take "quantum entanglement" only metaphorically. Attempts to clarify "entanglement" by equating it with "fundamental connectivity" and using the attributes "more-than, less-than or other-than" to connect it with "human performativity" do not help us understand the meaning of the sentence any better.

Soon after, the authors elaborate the meaning of "entanglement" by noting that:

> Through quantum entanglement, we note that the constitution of space, time and matter in its specificity is part of the nature and workings of the entanglements and the phenomena they enable and are enabled by. (Juelskjær et al. 2020, p. 14)

In this passage, new claims are made about "quantum entanglement". We can think (but it is not necessary) that "the constitution of space, time, and matter" is indeed "part of the nature and workings of the entanglement" but it does not help us to understand any better the notion of the entanglement, and furthermore, it is even more difficult to understand what the rest of the sentence means. It sounds profound but probably has no unambiguous meaning and it is left to a reader to construct a meaning. Therefore, the entanglement as outlined in these passages is somewhat distant from quantum entanglement. This way of characterizing quantum entanglement is itself so entangled that all sound basis or practical utility of speaking of quantum entanglement is lost; only metaphorical talk is left.

In addition to entanglement, agential realism uses other quantum physics-related terms that also receive significant extensions and redefinitions, for example the terms "diffraction" and "apparatus". It is not necessary here to provide any detailed scrutiny of the use of these terms. It is enough to note that with regard to applications in educational (as well as in sociological) contexts they are also used in such a vague and metaphorical way that it makes it difficult to take seriously the onto-epistemology that Barad's agential realism attempts to ground on inspirations drawn from quantum physics. Consequently, the quantum physics groundings that are important to Barad, in the context of their applications, can no longer serve the purpose of finding an ontology based on the primacy of phenomena, where material becoming and being takes place; only metaphors remain.

Interestingly, in adopting agential realism and Baradian quantum lingo, Juelskjær et al. are quite aware that Barad's reading of quantum physics and Bohr's views is intentionally "queer". They explain that:

> In agential realism, quantum physical experiments and physics philosophy discussions are read differently; that is, Barad underlines how this reading of quantum physics is not "straight" ... Rather it is queered, employing agential realism to contribute with new physics interpretations vis-à-vis the sensitivity to difference, power dynamics, subjectivity and situatedness embedded in feminist theory, postcolonial thinking, queer studies and other critical social theories. (Juelskjær et al. 2020, p. 14).

Such a reading of quantum theory and Bohr's views (or views in any other interpretation of quantum theory) is quite acceptable as a basis to form a motivational metaphysical stance (i.e. a set of beliefs to provide meaning and purpose to believe in a preferred kind of ontology and

constitution of world) or as the basis of a metaphorical way of speaking. Similar reasons to adopt quantum physical views as a basis for theorizing outside physics are discussed by e.g. Shaffer & Barreto Lemos, 2021.

Such an attitude would also save positions based on agential realism from criticism of false pretensions to be an ontologically credible view that somehow finds support from quantum physics. However, they can be fruitful and useful in other ways for purposes of scrutinizing, e.g.. "power dynamics", "feminist theory", "postcolonial thinking", or "queer studies", although then agential realism loses its power to provide ontological support or authority borrowed from natural sciences.

The advocates of agential realism, however, appear not to be satisfied with giving up the strong ontic stance contained in Barad's agential realism, which is an essential part of it. In addition, they seem to believe that quantum theory and Barad's interpretation of Bohr's views lend credibility to agential realism. This is evident from many passages in interviews contained in *Dialogues on Agential Realism* (Juelskjær et al., 2020). For example, one of the interviewees mentions:

> Barad shows that quantum ontology entails an entirely new conceptual mixture. Agential realism tracks this mixture in the actual quantum experiments performed by Bohr and others, carefully examining the experimental event for how particular quantum concepts thrive and mutate. In other words, Barad looks to experimental practice to show how scientific research entails a particular metaphysics. (Juelskjær et al., 2020, p 78)

The tone is strongly convincing, with assuring expressions "showing" how "actual experiments" are "carefully examined" in the context of "experimental practices" to demonstrate how such scrutiny "entails a particular metaphysics". Such prose greatly exaggerates how Barad's views have received support from experiments or experimental practices, or their interpretations.[xiv] In many instances, in the interviews of supporters of agential realism (see Juelskjær et al., 2020), we can find similar assurances and attempts to draw credibility from quantum physics and its authorities (mostly Bohr) in quantum physics. A crucial question is: why are such assurances needed?

Taken as a kind of speculative theorizing for a metaphorical way of speaking, the adoption of agential realism would not need any support from the authority of quantum physics (or natural sciences in general). The credibility of agential realism could also come from its utility and practical success in fields where it is applied (e.g. in social and behavioral sciences, political sciences, or feminist and queer studies) without help from quantum theory.

However, gaining credibility through practical utility requires that agential realism be helpful in finding new successful and beneficial practices or useful changes in practices and actions. At least, it should help us to find out what actions are needed to change to better practices and outcomes.

Next, to better understand the possible uses of agential realism, ways to apply it, and the possible utility (or futility) of its quantum lingo, I turn to applications of agential realism in attempts to understand phenomena of interest in science education.

Agential realism and science education research

In science education research, the so-called material-dialogical approach has adopted agential realism as its theoretical underpinning in addition to Bakhtian material-discourse.[xv] Paralleling the new materialism movement (Scantlebury et al., 2019; Scantlebury & Milne, 2019) in science education, Hetherington et al. (2018) note that "*engaging with the materiality of that world is integral to both empirical experimentation and theorizing within science*" (Hetherington et al. 2018, p. 141).

There is nothing to object to in this statement (nor is there anything very informative either) but the authors are clearly seeking something more when they claim that "*the role of the material remains undertheorised, not only within practical science inquiry, but also in relation to the broader materiality of classrooms*" (Hetherington et al. 2018, p 141). To address the "broader materiality", they evoke the Baradian conception of entanglement.

Hetherington et al. condense the idea of entanglement (Hetherington et al. 2018, p. 162) by quoting Barad: "*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, loc. 19). Here, as in Juelskjær et al. (2020), entanglement has a strong ontic meaning. The idea of entanglement is next clarified through notions of "intra-action", which highlights (supposedly refers to) an "*entangled, co-emergent, co-productive relational stance*". Such "intra-action" is closely related to phenomena in the sense that "*phenomena are continuously performed through intra-action*", as is outlined in a passage:

> Barad uses the neologism intra-action rather than interaction, to highlight this entangled, co-emergent, co-productive relational stance. Similarly, instead of referring to 'objects' in the world, with determinate boundaries and properties, Barad's basic unit of reality is not the object but the phenomena, which are temporarily bounded and continuously performed through intra-action. (Hetherington et al. 2018, p 162).

Here, the authors motivate the ontological primacy of phenomena, out of which objects in the world emerge. This appears to be consistent with Barad's views, and in a broad sense compatible with strong ontic interpretations of quantum theory (with the epistemic interpretations being the exception) as it concerns quantum entities (see e.g. Boge 2018).

The advocates of the material-dialogic approach, paralleling Juelskjær et al., (2020), make sporadic rhetorical references to the authority of quantum physics and draw rhetorical advances from the authority of Bohr in stating:

> Inspired by quantum physics (the discipline in which she holds a doctorate), in particular Niels Bohr's 'philosophy-physics' ... Barad deploys a number of entwined ideas to develop a distinctive way of thinking about the 'naturalcultural' world. (Hetherington et al. 2018, p 162).
>
> [Barad] uses key concepts from quantum physics (in particular Bohr's 'philosophy-physics' drawing out the ontological and epistemological stances that emerge from quantum theory's insights. (Hetherington & Wegerif 2018, p 29).
>
> "Barad builds on the insight from research into quantum level reality by showing that the way in which experiments ... brings apparent reality into being. (Hetherington & Wegerif, 2018, p 30).

Here, we again find insinuations to accept agential realism by noting Barad's expertise in physics and on the basis of authorities in quantum physics. Let us imagine that the authority of quantum theory and physics is not available to support how agential realism is applied here.

For the sake of argument, assume that Barad's views cannot be licensed by quantum theory and no support is coming from interpretations of quantum theory, nor from Bohr's thinking. In that case, expressions different from Barad's quantum lingo should do equally well: for example, instead of "entanglement", the word "enmeshment" might serve just as well. Is the position of agential realism then still compelling? This should be the case if one is dealing with a robust philosophical or theoretical underpinning for educational research, in no need of support from quantum theory.

When agential realism is applied in learning and school contexts, advocates of the material-dialogic approach speak of the emergence of phenomena – phenomena coming into being or existence – but not about "worlds" coming into existence, as for example in Julskjær (2020). Consequently, as applied to science education, the strong ontic position of "worlds" coming into existence or ontologically real material reality coming into being through agency is now elided.

This is a good move in emphasis, but if only phenomena are coming into existence, but the students, teacher, blackboards, calculators, and all the furniture of the school class remain as they are, how is that then different from our ordinary understanding of phenomena? The ontic power of agential realism seems to be greatly diminished in such a watered-down application.

Not much has been reported regarding the use of agential realism as a research approach and how it might make better sense of the roles played by, for example, devices, study materials, and other material aspects in science education. However, some reports are already available. Hetherington and Wegerif (2018) focus on the role of the materials and materiality in dialogic pedagogy and discuss teachers' perspectives on their practices. Data based on interviews was interpreted using a material-dialogic viewpoint, thus including the perspective of agential realism. Researchers noted that the teachers involved in the study thought of the materiality of practical work with objects and tools from the vantage point of how they are used to illustrate concepts. On the other hand, the materiality of whiteboards and other technologies of communication was thought of in terms of opening and supporting dialogue, but there was "*little evidence of clear pedagogical thinking about the role of these materials in the dialogue*" (Hetherington & Wegerif, 2018, p 34-35).

In discussing the results, the researchers note that the teachers' views do not correspond to the desired picture of the basis of the material-dialogic approach, nor do they show the attitudes one could wish from the perspective of agential realism. This they clearly see as a deficiency, in need of remedy.

As a remedy to the shortcomings of teachers in paying attention to the role of materiality and materials in the proper way required by new materialism and agential realism, the researchers suggest that:

> Looking at the data using this [material-dialogic] lens, we can see that teachers, students and materials enact agential cuts through their intra-actions that enable particular learning

> phenomena to emerge ... In the classroom we see how discourse and matter conspire to produce key decisions that shape learning. (Hetherington & Wegerif, 2018, p39).

In such passages, the researchers have chosen to say that they have "seen" agential cuts enacted, through intra-actions, as well as "how discourse and matter conspire". This is very metaphorical and figurative speech, and instead of seeing or observing such things, researchers have used Baradian quantum lingo to interpret or dub what they have seen or observed. Such dubbing is of course possible, but we must ask: what useful views are the outcomes of that dubbing? The researchers go on to endorse and recommend:

> [P]edagogy in which science teachers are explicitly aware that their intra-action with both the students and the material generates distinct phenomena that matter in the world; that the becomings of material-student-teacher (i.e. learning) are enabled and constrained by the choices that are made through those ongoing intra-actions. (Hetherington & Wegerif, 2018, p 39).

Such a description implies that more profound things than ordinary learning are at stake, where what is important is an awareness of how intra-actions generate phenomena and how learning is the becomings of material-student-teacher, produced through intra-actions.

A final example comes from a study of learning chromatography in a classroom (Hardman et al., 2022). In this case, the learning situation is rather conventional, but the researchers analyze it through the lenses of the material-dialogic approach and new materialism. In this case, the researchers provide a description of a classroom situation, dubbed in Baradian quantum lingo. Having provided a description of how students use interactive whiteboards – in writing and in drawing – and exercise books, and in one case, bend a mini whiteboard to pass a "covert message", researchers decide that the example allows them to "*see that the materials of the classroom are intra-acting with the understandings of the teacher and the pupils.*" (Hardman et al., 2022, p 165).

Researchers also note that, in making an observation, some pupils misunderstand and misinterpret it, which "*emerges within the dialogic space as pupils intra-act with the experimental findings (the ink and the paper)*" (Hardman et al., 2022, p 165). Shortly, afterwards, when the authors discuss how students' misconceptions might arise, they note that:

> 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. (Hardman et al., 2022 p 167).

A little later, in concluding, the authors note that:

> We believe that a material-dialogic perspective ... 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." (Hardman et al. 2022, pp 171-172).

In all these cases (and in many more to be found in the study) the descriptions of learning situations are based on Baradian quantum lingo. It is difficult to see the advantages of such dubbing of commonplace observations and findings, and what is gained by using the terms "intra-acting" and "being entangled" instead of more commonplace term "interacting" and "being involved". In addition, the "agency of material" is claimed but no evidence is provided as to how this agency manifests itself.

At best, the study by Hardman et al. (2022) manages to show that Baradian dubbing is possible. From the study, however, it is difficult to pin down what it claims to achieve apart from succeeding in translating rather commonplace activities into curious-sounding Baradian quantum lingo although clearly quite ordinary and everyday actions are taking place that could be described as such. Admittedly, in a metaphorical sense, the Baradian quantum lingo appears to be flexible enough to allow its use in dubbing such commonplace learning situations, but the outcome appears to fall short in providing insights or helping us see what benefits such dubbing provides.

Discussion and conclusions: metaphysics or metaphors?

The examples of the uses of agential realism in science education begs the question of the necessity of the quantum physics insights of agential realism as it is used as an underpinning in science education. Should we take it seriously, as an "onto-epistemological" position with real power to guide research and help us understand how to improve science education, goals that all science educators can share and that are recognizable as teaching of science? Alternatively, is it merely a motivational metaphysics, providing profound-sounding metaphorical talk, or in the worst case, mere fashionable nonsense?

The utility of agential realism as a metaphysical underpinning for research approaches in empirical research and in generating plausible empirical hypotheses to be tested appears to be low. Such possibilities are barred because the basic conceptualization as agential realism presents them – most evidently, entanglement, apparatus, intra-actions, and agential cuts – are so vaguely defined that it seems impossible to derive any empirically testable claims by using them.

Moreover, the possibility that phenomena relevant to quantum physical entities and phenomena are also relevant at the macro level and, in particular, applicable to classroom phenomena is bold and finds little if any support from reported research still.

Of course, this is not a refutation of the possibility that mathematical modelling of phenomena with models similar to those employed in quantum theory might turn out to be feasible and useful (see e.g. Cantley, 2015, 2017). However, the transferability of mathematical models from one area to another does not indicate that the phenomena are the same (see also Schaffer & Barreto Lemos, 2021).

In any case, agential realism is not about the transferability of models, nor does it provide any usable models of its own. Consequently, whether as a viable realistic ontology or as a fruitful source of analogies for modelling, we have every reason to reject the viability of agential realism as an underpinning of educational applications.

We still have the idea that the basic terms and notions of agential realism provide motivational metaphysics. Even if one cannot derive hypotheses to be tested, nor use the

theory as a basis to design empirical settings, we can use it as a source of inspiration as well as lending personal meaning and significance to results. Then the theoretical underpinning is capable of providing a motivational metaphysics, a psychologically satisfying belief system akin to an ideology, which provides a coherent framework of thought and actions, but either remains beyond empirical testing or does not make empirically testable predictions. In a sense, this is analogous to the role of various popularizations based on quantum physics interpretations (see e.g. Schaffer & Barreto Lemos, 2021).

Motivational metaphysics generates neither new scientific knowledge nor empirical claims, but it may generate ideas and inspiration to try out new experiments and provide satisfying metaphysical interpretations of the results so obtained. This, of course, is useful (although perhaps not exactly what agential realism desires to achieve). The usefulness of motivational metaphysics in this sense comes from its ability to provide a belief system that has practical benefits as a motivation for actions that may indirectly help to produce robust and reliable science. If such benefits exist, they are enough to make the belief system useful, but no more than as a motivational metaphysics (because the empirical success is not derived from the belief system, although motivation is).

Here, one approaches what is usually called ideology: an overarching belief system that provides a way to see and interpret everything (like in new materialism), but which evades discussion under ordinary scientific criteria of rationality and logic, as well as empirical conscientiousness if it pretends to make empirical claims.

If it turns out that agential realism also falls short as a motivational metaphysics (which seems quite likely in the light of the published results), we are left with its possible role as a source of metaphors, a generator of metaphorical and figurative speech. A greatly extended (and exaggerated) use of scientific vocabulary of quantum theory may provide grand interpretations of world, humanity, sociology, organizations, etc., and we get, for example, ideas about the possibility of quantum brains (see e.g. Wendt, 2015) leading to the theorizing of humans as walking wave functions (Wendt 2015). Quantum-inspired ideas as well as Barad's views have also fundamentally affected socio-cultural theorizing (Kirby, 2011).

These broader issues, going beyond Barad's work, have recently been discussed in detail in several critical commentaries.[xvi] Such metaphorical use of agential realism is of course acceptable and provides momentum for new ideas, and may eventually even be useful to the progress of understanding. There is no reason to object to or diminish the value of metaphorical and figurative talk, but also every reason to understand that it is not yet science in the sense that one could evaluate and scrutinize the arguments based on such figurative talk.

Finally, the bleakest (and unfortunately the most likely) reason for the current popularity of agential realism as part of the new materialism movement in science education might be due to Baradian quantum lingo. The curious terms and expressions of Baradian quantum lingo and its convoluted sentences with ambiguous meanings readily provide an appearance of profundity where we actually have commonplace notions and trivialities in the guise of deep truths.

This is a well-known and widely discussed case of the obscurantism and nonsense of pseudophilosophies.[xvii] Moreover, agential realism as its supporters use it shows signs of what has been called a fashionable nonsense (Sokal & Bricmont, 1998), in which new ideas

and views circulate and are repeated uncritically, and the bases of claims are accepted as such and not scrutinized conscientiously.

Despite these critical remarks, agential realism may, after all, have its advantages in directing attention to the importance of devices, apparatuses, and material aspects in interacting with world and in gaining knowledge through those interactions. In addition, it directs attention to the role of conceptualization and language as part of that process, not separate from it but essentially connected and intertwined with it. However, it should be remembered that agential realism aspires to more than that. According to agential realism, quantum mechanics provides a sound ontological stance to assume that the entanglement process is crucial in producing something materially real and new, and where constituents of reality do not have independent separable existence.

Such a picture indeed follows if entanglement as an ontic possibility is taken as granted and when an entire worldview is derived from it. However, at present, we have no pressing reasons to assume that quantum physics forces such a strong ontic position on us. Even more pressingly, we have neither rational reasons nor empirical evidence to assume that we need agential realism to understand the real macrolevel world better – in particular as applied to humans, human behavior and interaction, and learning situations in the context of science education. Such a basis is perhaps possible, but it appears to be so implausible that mere possibility is not enough for its acceptance; inability to refute is not an obligation to accept.

Endnotes

[1] Hardman, Riordan & Hetherington, 2022; Hetherington, Hardman, Noakes & Wegerif, 2018; Hetherington & Wegerif, 2018; Milne & Scantlebury, 2019.
[2] See e.g. Gamble, Hanan & Nail, 2019.
[3] See e.g. Scantlebury, Danielsson, Hussénius, Gullberg & Andersson, 2019; Scantlebury & Milne, 2019.
[4] Hetheringnton et al. 2018, 4 Hetherington & Wegerif, 2018, Scantlebury et al. 2019; Scantlebury & Milne, 2019.
[5] Hardman et al. (2022), Hetherington et al. (2018), Hetherington and Wegerif (2018), Milne (2019), and Scantlebury et al. (2019)
[6] Hardman et al., 2022, Hetherington et al., 2018; Hetherington & Wegerif, 2018, Milne, 2019; Scantlebury et al. 2019; Scantlebury & Milne, 2019)
[7] Scantlebury et al., 2019; Scantlebury & Milne, 2019; Hardman et al., 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018)
[8] Hardman et al., 2022; Hetherington et al., 2018; Hetherington & Wegerif, 2018; Scantlebury et al., 2019; Scantlebury & Milne, 2019)
[9] See e.g. Faye & Jaksland, 2021; Hollin, Forsyth, Giraud & Potts, 2017; Jaksland, 2021.
[10]See Jaksland 2021, and Faye & Jaksland, 2021 for a detailed analysis.
[11] For similar difficulties, see review by Pinch, 2011.

[12] Buekens & Boudry, 2015, Elster, 2012, Moberger, 2020, Sokal & Bricmont, 1998, Matthews 2015, pp.415-419.
[13] Hardman et al. 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018.
[14] See e.g. Faye & Jaksland, 2021; Jaksland, 2021.
[15] Hardman et al. 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018.

[16] See e.g. Hollin et al. 2017; Jaksland, 2021; Schaffer & Barreto Lemos, 2021; Waldner 2017.

[17]Buekens & Boudry, 2015; Elster, 2012; Moberger, 2020; Sokal & Bricmont, 1998.

References

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press: Durham.

Barad, K. (2011). Erasers and erasures: Pinch's unfortunate 'uncertainty principle'. *Social Studies of Science 41*(3) 443–454. https:// doi.org/ 10.1177/0306312711406317

Billig, M. (2013). *Learn to Write Badly. How to Succeed in the Social Sciences*. Cambridge University Press: Cambridge.

Boge, F. J. (2018) *Quantum Mechanics Between Ontology and Epistemology. European Studies in Philosophy of Science 10*. Cham: Springer International Publisher. https://doi.org/10.1007/978-3-319-95765-4.

Buekens, F., & Boudry, M. (2015). The Dark Side of the Loon. Explaining the Temptations of Obscurantism. *Theoria, 81*, 126-142. https://doi.org/ 10.1111/theo.12047

Cantley, I. (2015). How secure is a Newtonian paradigm for psychological and educational measurement? *Theory & Psychology, 25*(1), 117–138. https://doi.org/10.1177/0959354314561141.

Cantley, I. (2017). A Quantum Measurement Paradigm for Educational Predicates: Implications for validity in educational measurement. *Educational Philosophy and Theory, 49*(4), 405-421. https://doi.org/10.1080/00131857.2015.1048668.

Darling, K. M. (2003). Motivational Realism: The Natural Classification for Pierre Duhem. *Philosophy of Science, 70*, 1125–1136. https://doi.org/10.1086/377394

Elster, J. (2012). Hard and Soft Obscurantism in the Humanities and Social Sciences. *Diogenes, 58*(1–2), 159–170. https://doi.org/10.1177/0392192112444984

Faye, J., & Jaksland, R. (2021). Barad, Bohr, and quantum mechanics. *Synthese, 199*, 8231–8255. https://doi.org/10.1007/s11229-021-03160-1.

Fine, Arthur (1996), The Shaky Game: Einstein, Realism, and the Quantum Theory, 2d ed. Chicago: University of Chicago Press.

Gamble, C. N., Hanan, J. S. & Nail, T. (2019). What is new materialism?, *Angelaki*, *24*(6), 111-134. https://doi.org/10.1080/0969725X.2019.1684704

Hardman, M., Riordan, J.-P., & Hetherington, L. (2022). A Material-dialogic Perspective on Powerful Knowledge and Matter within a Science Classroom. In B. Hudson, N. Gericke, C. Olin-Scheller & M. Stolare (Eds.), *International Perspectives on Knowledge and Curriculum Epistemic Quality across School Subjects*. (pp 157-176). Bloomsbury Academic:London. https://doi.org/10.5040/9781350167124.ch-009.

Hetherington, L., & Wegerif, R. (2018) Developing a material-dialogic approach to pedagogy to guide science teacher education. *Journal of Education for Teaching, 44*(1), 27-43. https://doi.org/10.1080/02607476.2018.1422611.

Hetherington, L., Hardman, M., Noakes, J., & Wegerif, R. (2018). Making the case for a material-dialogic approach to science education. *Studies in Science Education, 54*(2), 141-176. https://doi.org/10.1080/03057267.2019.1598036.

Hollin, G., Forsyth, I., Giraud, E., & Potts, T. (2017). (Dis)Entangling Barad: Materialisms and ethics. *Social Studies of Science, 47*(6), 918–941. https://doi.org/10.1177/0306312717728344

Jaksland, R. (2021). Norms of Testimony in Broad Interdisciplinarity: The Case of Quantum Mechanics in Critical Theory. *Journal for General Philosophy of Science 52,* 35–61. https://doi.org/10.1007/s10838-020-09523-5

Juelskjær, M., Plauborg, H., & Adrian, S. W. (2020). *Dialogues on Agential Realism: Engaging in Worldings through Research Practice*. Routledge: London.
Kirby, V. (2011). Quantum anthropologies: Life at large. Durham: Duke University Press.
Matthews, M.R. (2015), *Science Teaching: The Contribution of History and Philosophy of Science,* Routledge, London.
Milne, C. (2019). The Materiality of Scientific Instruments and Why It Might Matter to Science Education. In C. Milne C., & Scantlebury, K. (2019), *Material Practice and Materiality: Too Long Ignored in Science Education, Cultural Studies of Science Education 18*. Springer Nature Switzerland AG 2019, pp 9-22. https://doi.org/10.1007/978-3-030-01974-7_2.
Milne, C., & Scantlebury, K. (2019). *Material Practice and Materiality: Too Long Ignored in Science Education, Cultural Studies of Science Education 18*. Springer Nature Switzerland AG 2019. https://doi.org/10.1007/978-3-030-01974-7.
Moberger, V. (2020). Bullshit, Pseudoscience and Pseudophilosophy. *Theoria 86*, 595-611. https://doi.org/10.1111/theo.12271.
Pinch, T. (2011). Review: Karen Barad, quantum mechanics, and the paradox of mutual exclusivity. *Social Studies of Science, 41*(3), 431-441. https://doi.org/10.1177/03063127114006.
Scantlebury, K. & Milne, C. (2019) Introduction: Bringing Matter into Science Education. In C. Milne & K. Scantlebury (Eds.), *Material Practice and Materiality: Too Long Ignored in Science Education, Cultural Studies of Science Education 18*. Springer Nature Switzerland AG 2019, pp 1-5. https://doi.org/10.1007/978-3-030-01974-7_1.
Scantlebury, K., Danielsson, A. T., Hussénius, A., Gullberg, A. & Andersson, K. (2019) Using Spacetimemattering to Engage Science Education with Matter and Material Feminism. In C. Milne & K. Scantlebury (Eds.), *Material Practice and Materiality: Too Long Ignored in Science Education, Cultural Studies of Science Education 18*. Springer Nature Switzerland AG 2019, pp 39-48. https://doi.org/10.1007/978-3-030-01974-7_4.
Schaffer, K., Barreto Lemos, G. (2021). Obliterating Thingness: An Introduction to the "What" and the "So What" of Quantum Physics. *Foundations of Science, 26*, 7–26. https://doi.org/10.1007/s10699-019-09608-5.
Sokal, A. & Bricmont, J. (1998). *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science*. Picador: New York.
Waldner, D. (2017). Schrödinger's Cat and the Dog That Didn't Bark: Why Quantum Mechanics is (Probably) Irrelevant to the Social Sciences. *Critical Review, 29*(2), 199-233, https://doi.org/10.1080/08913811.2017.1323431.
Wendt, A. (2015). Quantum Mind and Social Science: Unifying Physical and Social Ontology. Cambridge: Cambridge University Press.

* Originally published: *NorDiNa* – (Nordic Studies in Science Education), Vol. 20 No. 1 (2024) pp 44-56.

[Repeated endnotes from Opinion Page.]

[i] Hardman, Riordan & Hetherington, 2022; Hetherington, Hardman, Noakes & Wegerif, 2018; Hetherington & Wegerif, 2018; Milne & Scantlebury, 2019.
[ii] See e.g. Gamble, Hanan & Nail, 2019.

[iii] See e.g. Scantlebury, Danielsson, Hussénius, Gullberg & Andersson, 2019; Scantlebury & Milne, 2019.
[iv] Hetheringnton et al. 2018, Hetherington & Wegerif, 2018, Scantlebury et al. 2019; Scantlebury & Milne, 2019.
[v] Hardman et al. (2022), Hetherington et al. (2018), Hetherington and Wegerif (2018), Milne (2019), and Scantlebury et al. (2019)
[vi] Hardman et al., 2022, Hetherington et al., 2018; Hetherington & Wegerif, 2018, Milne, 2019; Scantlebury et al. 2019; Scantlebury & Milne, 2019)
[vii] Scantlebury et al., 2019; Scantlebury & Milne, 2019; Hardman et al., 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018)
[R]eScantlebury & Milne, 2019)
[ix] See e.g. Faye & Jaksland, 2021; Hollin, Forsyth, Giraud & Potts, 2017; Jaksland, 2021.
[x] See Jaksland 2021, and Faye & Jaksland, 2021 for a detailed analysis.
[xi] For similar difficulties, see review by Pinch, 2011.
[xii] Buekens & Boudry, 2015, Elster, 2012, Moberger, 2020, Sokal & Bricmont, 1998, Matthews 2015, pp.415-419.
[xiii] Hardman et al. 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018.
[xiv] See e.g. Faye & Jaksland, 2021; Jaksland, 2021.
[xv] Hardman et al. 2022; Hetherington et al. 2018; Hetherington & Wegerif, 2018.
[xvi] See e.g. Hollin et al. 2017; Jaksland, 2021; Schaffer & Barreto Lemos, 2021; Waldner 2017.
[xvii] Buekens & Boudry, 2015; Elster, 2012; Moberger, 2020; Sokal & Bricmont, 1998.