

Uncertainty or Indeterminacy? Reconfiguring Curriculum through Agential Realism

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Abstract

Understanding how indeterminacy is different from uncertainty is crucial to posthumanism and has major implications for reconfiguring curriculum. Uncertainty has to do with *epistemology*, about not knowing whether a state of affairs is or is not; for instance, one would not know whether something is here or there, now or then. Indeterminacy, however, is *ontological* and eschews the idea of individually existing determinate entities, proposing instead phenomena-in-their-becoming and a radically open relating of the world. Karen Barad, a feminist queer theorist, uses Niels Bohr's quantum physics to show how atoms possess an inherent indeterminism or lack of identity in space and time. Indeterminacy is thus an un/doing of identity that unsettles the very foundations of being and non-being. Furthermore, neither space nor time are predetermined givens, but come into being intra-actively through the emergence of phenomena. This article shows how an understanding of space/time indeterminacy is important for thinking otherwise in curriculum studies.

Keywords: indeterminacy; agential realism; Barad; diffraction; intra-action; entanglement; curriculum

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Introduction

The call for papers for this *Education as Change* Special Issue titled “Re-imagining Curriculum Enquiry/Inquiry in Times of Unprecedented Uncertainty” requested contributions that, among other concerns, address alternatives that the posthuman condition might provide for navigating prolonged uncertainties through the curriculum, as well as “curriculum enquiry/inquiry in times of uncertainty”. My concern in this article is to challenge the idea that uncertainty is related to posthumanism, by thinking with the scholarship of Karen Barad (2007, 2008, 2010, 2012a, 2012b, 2014a, 2014b, 2015, 2017a, 2017b, 2017c, 2019), a queer quantum physicist and philosopher, who has diffractively read the work of quantum physicist Niels Bohr through poststructural philosophers such as Judith Butler, Michel Foucault and Jacques Derrida.

My contention is that it is *indeterminacy* and not uncertainty that has the potential to provide a radical reconfiguring of curriculum. Indeterminacy has to do with *ontology* and the *nature of reality*, whereas uncertainty is about *epistemology* and *knowledge*. This article uses the work of Barad to think with the notion of indeterminacy and the implications it has for the curriculum and pedagogy. Barad maintains that indeterminacy is at the heart of quantum physics and that this has profound implications for the nature of reality, including academic practices such as curriculum studies. This would question the notion that the curriculum should be informed by predetermined outcomes and criteria-based learning, as this is incommensurable with indeterminacy-in-action, which does not assume a givenness of being. Rather, using indeterminacy to reconfigure curriculum requires sensibilities of curiosity and wonderment, of being alive to the world in its materiality. This is only possible through a continual response-ability or ability to respond to, of re-memembering, of taking stock of multiple pedagogical contexts and times (Barad 2012a, 2012b). The virtuality of indeterminacy-in-action (Barad and Gandorfer 2021) is about being in touch, touching the vibrancy and dynamism of everything and nothing, here/there, now/then, as part of the curriculum. Planning a curriculum involves both re-turning (turning over and over again the ghosts that have been forgotten) and contemplating the future, which needs to take indeterminacy into account, for, as Barad (2021) reminds us, “futures are indeterminate, not uncertain, the political difference is enormous”. This article sets out to unpack the enormous political difference between indeterminacy and uncertainty and why this understanding is important to apprehend for curriculum studies.

The etymology of the concept “curriculum” is derived from the Latin infinitive word *currere*, which means “to run”, and some authors have emphasised curriculum as running a course, foregrounding curriculum as process rather than curriculum as object (Egan 2003; Kincheloe, Slattery, and Steinberg 2000; Sellers 2013, 2020). In the 1970s, Madeleine Grumet and William Pinar (Pinar 1974, 2020; Pinar and Grumet 1976) were also critical of object-oriented approaches to curriculum and developed an autobiographical curriculum theory, using phenomenology to focus on the embodied lived experience of the curriculum for individual students.

Deleuzian approaches, such as those developed by David Cole (2011), Noel Gough (2015), Kaustuv Roy (2003), Marg Sellers (2013, 2020), Warren Sellers (Sellers and Gough 2010), Inna Semetsky and Diana Masny (2013), and Jason Wallin (2010), have attempted to rethink the concept *currere* in relation to temporality, subjectivity, and transcendence (Semetsky and Masny 2013). Among other things, this takes forward the notion of *currere* as a course of life, the immanence of curriculum-as-lived, which becomes an open plane for experimentation (Wallin 2010). The emphasis here is on the virtual, the singularity of a pedagogical life, rather than the arborescent and standardised orthodoxy of curriculum-as-plan (a term originally proposed by Aoki [2005]). Seeing curriculum as an event, as *something happening*, signals that curriculum in itself does not exist a priori, but happens again and again in different ways (Manning and Massumi 2014).

Recent calls to decolonise the curriculum have been emphasised in various parts of the planet—including various takes on the South African #FeesMustFall and #RhodesMustFall movements (Soudien 2021), the hybridity of *mestizo latinoamericano*'s curriculum beyond the limits of Eurocentric modernity to rethink the curriculum (Johnson-Mardones 2021), and the proposal of a new ecological beginning of distinctly Chinese onto-epistemological curriculum (Zhao 2021). Paraskeva (2016) rejects the abyssal divide¹ of the Western Cartesian modernity model as arrogant in its claim to address global social issues in curriculum studies. For reimagining curriculum studies, Paraskeva proposes an itinerant curriculum theory of difference and subaltern contestations of the colonial project. My contention in this article is that Barad's indeterminacy, which is at the heart of their (the gender-neutral pronoun, "their", is Barad's preferred gendered identity as a non-binary queer philosopher) agential realist philosophy, provides a fruitful way of building upon these Deleuzian modes of thinking, and for reconfiguring curriculum studies today.

The article is structured in the following way: The first part is an attempt to assist the reader to understand the notions of uncertainty and indeterminacy by outlining their philosophical roots and the ways in which they differ from each other. In order to do so, Werner Heisenberg's uncertainty principle and Niels Bohr's indeterminacy and complementarity principles are discussed. The second part of the article shows how a diffractive reading of the indeterminacy and complementarity principle and poststructural theories has laid the ground for Karen Barad's framework of agential realism, which queers the notions of space, time and matter. In this section, I also discuss Barad's methodology of diffraction, which is an important contribution to curriculum studies. The final part of the article outlines what agential realism might mean for the curriculum and pedagogy in higher education. I argue that a number of issues are at

¹ Dividing the world into humans and sub-humans (Soudien 2021). Abyssal comes from the work of Glissant (2010) and refers to three kinds of abyss—the belly of the slave boat, the depths of the sea, and that which has been severed and left behind.

stake in the conceptions of uncertainty and indeterminacy—ethically, epistemologically, ontologically and politically.

Uncertainty or Indeterminacy? Heisenberg and Bohr

Bohr and Heisenberg were major figures in the field of quantum physics, and Bohr was Heisenberg's mentor. Both were Nobel laureates, and their work was known as the Copenhagen interpretation of quantum mechanics. Heisenberg was known as a leader for his uncertainty principle and Bohr was known for his work on the complementarity principle and indeterminacy.

There are many misconceptions regarding indeterminacy and the uncertainty principle, as Barad (2011) notes in their response to Trevor Pinch's review of *Meeting the Universe Halfway* (Pinch 2011), as well as their analysis of Michael Frayn's play *Copenhagen*, which is about the controversy surrounding Bohr and Heisenberg's meeting in 1941 (Barad 2007). According to Barad (2007), both Pinch and Frayn use common sense notions of uncertainty, rather than Heisenberg's uncertainty principle, that is why they refer to these conceptions as "Pinch's uncertainty principle" (Barad 2011) and "Frayn's uncertainty principle" (Barad 2007, 4). Barad (2011) calls it "Pinch's uncertainty principle" as Pinch does not recognise that the complementarity entails both mutual exclusivity and mutual necessity; he only mentions mutual exclusivity.

Secondly, Pinch does not consider how complementarity involves both epistemology and ontology, but regards only the epistemic limitations—what can be humanly known, which he uses in his misinterpretation of feminist science studies, according to Barad (2011). Frayn erroneously applies Heisenberg's uncertainty principle when he draws parallels between the impossibility of knowing everything about human thinking to the limits of our knowledge of physical objects, moving from the realm of epistemology where he is concerned with the uncertainty of human intentionality, to the undecidability of morality. Here he is arguing that if one can never really know what people are intending, and why they are doing what they do, then one cannot make any judgements about their behaviour or about what happens. Both of these authors, Pinch and Frayn, remain stuck in binary views of the world where sciences and the humanities, nature and culture, internal and external, among others, are seen as separate. For Barad, Frayn and Pinch are also both trapped in an individualist metaphysics where entities such as atoms and humans are assumed to be discrete and to have inherent characteristics (such as intentionality).

So, what is Heisenberg's principle of uncertainty and what is Bohr's complementarity principle? As Barad (2007) points out, there are significant differences between Heisenberg's and Bohr's interpretations of quantum physics. Bohr and Heisenberg were in disagreement about the uncertainty principle. Heisenberg's uncertainty principle points to the limits of *simultaneously knowing* two states of a particle—such as the momentum and the position. Heisenberg argues that we cannot know the position and

momentum of a particle at the same time. However, for Bohr, it is not, as Heisenberg put forward, about whether we can *know* about the position and momentum of a particle simultaneously, rather that particles do not *have* determinate values of position and momentum simultaneously. According to Heisenberg, in measuring something you disturb the premeasurement values—which means that the more one knows about a particle’s momentum, the less one will know about its position and vice versa. For Heisenberg, measurements are disturbances that are epistemologically uncertain in that they place a limit on knowability (Barad 2010). However, for Bohr, measurement is about indeterminacy—that which is determinate is complementary to that which is indeterminate and vice versa. According to Barad (2007), Bohr understands the reciprocal relation between position and momentum in semantic and ontic, and only derivatively epistemic, ways. This is because it is impossible to definitively know something about which there is nothing to know. It is not about the knowability but about complementarity—how variables such as position and momentum are not simultaneously determinate. For Barad (2007), this is highly significant, and deeply profound, as Bohr is actually calling the nature of reality into question, not merely our knowledge of it. Barad maintains that Bohr is troubling the whole notion of Western metaphysics, which assumes that the world is made up of individual entities with pre-existing determinate characteristics or properties.

Bohr proposes that particular measuring apparatuses make some properties become determinate, while others are specifically excluded. Which properties become determinate has nothing to do with the will or desire of the experimenter, but with the specificity of the apparatus, in other words, with the material arrangements. Because of these material arrangements, only some properties can become determinate at once, while others are necessarily excluded. This is where the complementary principle comes in. There are two complementary sets of principles for any given apparatus—those that are determinate are said to be complementary to those that are indeterminate and vice versa. Complementary variables require different and mutually exclusive apparatuses for their coming into being (for example, one with fixed parts to measure position and one with moveable parts to measure momentum); therefore, the variables are reciprocally definable (when one is definable the other cannot be). Apparently, Heisenberg did accept this interpretation eventually, when he conceded to Bohr’s interpretation in a postscript to a paper he wrote on the uncertainty principle, but this is barely acknowledged (Barad 2007).

From Bohr’s perspective, then, there are no individual entities that possess inherent properties, such as position and momentum, which Newtonian physics assumes. Rather, it is through particular measuring apparatuses and measuring interactions that some properties become determinate and others are excluded. One state necessarily precludes another, and both states cannot exist simultaneously. Other than position and momentum being complementary states dependent on material arrangements of measuring devices (a stable and fixed platform for position, or one on springs which allows movement), particles and waves also do not pre-exist but come into being

through measuring devices. The particle/wave identity can be demonstrated by using a two-slit apparatus, which is a screen that has two holes. In classical physics, if you want to know whether an entity is a particle or a wave, you send it through the slits over and over again so that a pattern develops over time. If there is a scatter pattern where the entities land directly across from one slit or another, then it means they are particles. If a diffraction pattern appears, it means that it is a wave. A diffraction pattern happens when waves meet a barrier or a slit, such as in the two-slit apparatus. These waves bend and spread out in the area beyond the barrier or slit, producing a new pattern—a diffraction pattern, resulting from the disturbance or interference which goes through both slits at once. A particle goes through either one slit or the other. Particles and waves produce different patterns. According to Bohr, however, particles and waves do not pre-exist their measurement; they come into being through the apparatus. Quantum physics thus calls into question Einstein’s classification of entities into either particles or waves. Bohr disagreed with Einstein, maintaining that an experiment called the “which-slit experiment” (Barad 2012a, 41) demonstrates his notion of complementarity—which is that an entity is not a particle or a wave, but rather that it behaves like a particle or a wave depending on the measuring apparatus that is used. In this which-slit experiment, when watched, the pattern is a scatter pattern, performing like a particle, but when not watched (when there is no which-slit detector), it reverts to wave behaviour. This shows that the ontology or the nature of an entity is indeterminate, and it only becomes determinate through a measuring apparatus.

In summary then, the uncertainty principle addresses only epistemology and not ontology in that it assumes it is not possible to know the state of something simultaneously, whereas the complementarity principle assumes that entities do not possess an inherent or given ontological identity (for example as a particle or a wave). There are no independently existing entities with determinate and discrete boundaries and properties. Rather, entities or identities are performed and come into being through particular material arrangements. It is through measurement that entities take on determinate properties such as position or momentum, which are complementary states, where one state excludes the other. For example, the #RhodesMustFall movement, which started at the University of Cape Town with the removal of the Rhodes statue and spread to other universities, particularly the historically white universities (HWUs) or historically advantaged institutions (HAIs), created the demand for a decolonised and Africanised curriculum. The #FeesMustFall movement, on the other hand, which was prominent at historically black universities (HBUs) or historically disadvantaged institutions (HDIs), focused on the constraints that students face in their learning due to food insecurity and lack of access to transport and accommodation.

Bohr’s proposition of the lack of an inherent fixed nature is highly significant as it goes against the grain of atomistic metaphysics, as well as liberal social theories and scientific theories, which are all based on the assumption of individually determinate entities or individuals with inherent and separately attributable properties. From Bohr’s perspective, “things” are no longer basic ontological entities, rather entanglements or

phenomena are. Prior curriculum studies theories, even the more radical of them such as those propounded by Pinar (1974, 2020) and Grumet (Pinar and Grumet 1976), focused on students as individuals who are deemed to have separately attributable properties, such as intentionality. Furthermore, the assumption of different disciplines that are discrete and have their own inherent and separately attributable properties is undone by Bohr's notion of phenomena and entanglements.

Phenomena, Intra-Actions and Causality

If, as Bohr maintains, entities such as waves and particles do not have inherent properties and are not bounded entities, as classical physicists such as Einstein assumed, the objective referent for concepts such as waves and particles is what he calls the "phenomenon". A phenomenon, from Bohr's perspective, is the entanglement or inseparability of object and apparatus, which emerges from the experiment. Bohr's performative perspective of entities brings into focus the entanglement of measurement apparatuses and the object of measurement. In the which-slit experiment referred to in the section above, evidence of which slit the atom goes through can be erased after it has already gone through the slits. In this case, the diffraction pattern that is characteristic of waves comes back into being (as in the two-slit apparatus without the which-slit detector). This means that it can be determined after an entity either goes through the apparatus as a wave (through both slits simultaneously) or a particle (one or the other slit), indicating that ontology is not fixed but could be open to both future or past reworkings. Barad explains it in this way:

The evidence is in fact consistent with this point, that it's not that (in erasing the information after the fact that) the experimenter changes a past that had already been present. Rather, *the point is that the past was never simply there to begin with and the future is not simply what will unfold*; rather, the "past" and the "future" are iteratively reworked and enfolded through the iterative practices of spacetime-mattering—including the which-slit detection and the subsequent "erasure" of which-slit information—are all one phenomenon. Space and time are phenomenal, that is, they are intra-actively produced in the making of phenomena; *neither space nor time exists as a determinate given outside of phenomena.* (Barad 2007, 315; italics added)

The concept "spacetime-mattering"² is difficult to comprehend, but in the quotation above it is apparent that quantum physics is proposing that space, time and matter are not simply there but come into being or are constituted through phenomena and intra-active performances of the world. The point of this experiment is that the past can be changed because there was not a metaphysics of presence to begin with, and the future is not something that just unfolds. Rather, because there are no particles separated in space and time, it is through iterative practices that the past and future are reworked. Space and time are indeterminate and are only produced through phenomena. This spacetime-mattering dynamism of indeterminacy creates a radical openness for an

² Barad (2017a, G111) describes spacetime-mattering as a dynamic ongoing reconfiguring of a field of relationalities among "moments", "places", and "things" (in their inseparability).

infinity of possibilities for undoing conventional and colonising notions of curriculum and reconfiguring it and making it matter (Barad and Gandorfer 2021).

Phenomena are what Barad (2012a, 49) refers to as ontologically primitive relations or relations without pre-existing “relata”. Relata come into being in phenomena through specific intra-actions. Barad (2007) constructed the neologism *intra-action* to indicate its difference from interaction. Interaction assumes the prior existence of determinately bounded and propertied entities, which come into contact with each other. Intra-action indicates ontological inseparability of phenomena where relata exist as a result of relations—“*relata-within-phenomena emerge through specific intra-actions*” (Barad 2007, 140; italics added). From this perspective, identity is undone as an inherent characteristic, and only emerges through intra-actions. Likewise, a phenomenon is a specific intra-action between an object and the measuring agencies in quantum physics, which means that the object and measuring agencies emerge from, rather than pre-existing, the phenomenon. Objects are not separable and bounded but emerge contingently from intra-actions. This troubles traditional notions of causality that always already assume an independent and determinate object and the relations between such objects, where one affects or changes the other. If, however, separate entities do not pre-exist their relations, it is the phenomenon that is causally significant. The measurement, which is a causal intra-action, is what makes marks on bodies. Barad (2007, 176) explains causal intra-action in the following way:

The larger apparatus (e.g., the specific configuration of barriers, slits, particle sources, and screens) is causally significant. It is not that a preexisting entity receives a mark from a separately determinate entity but rather that the marking or specific materializing “effect” identifies the agencies of observation as agentially separable from its “cause” (the “object”) within the phenomenon. The marks left on the agencies of observation (the effect) are said to constitute a measurement of specific features of the object (the cause). In a scientific context, this process is known as a measurement. (Indeed, the notion of measurement is nothing more or less than a causal intra-action.) Whether it is thought of as a measurement, or as part of the universe making itself intelligible to another part in its ongoing differentiating intelligibility and materialization, is a matter of preference. Either way, what is important about causal intra-actions is that “marks are left on bodies”: bodies differentially materialize as particular patterns *of* the world as a result of the specific cuts and reconfigurings that are enacted. Cause and effect emerge through intra-action.

This is a profound conceptual shift in the notion of causality. It also means that there is no distinction or way to differentiate between the apparatus and the agencies of observation. Bohr maintains that phenomena are quantum entanglements of objects and agencies of observation. It is the physical apparatus that marks the subject/object boundary. What does this mean for curriculum studies? Firstly, the notion of an essentialised identity of students, disciplines, and universities is undone, with identities and subjects and objects only coming into being through agential cuts, which remain connected to the larger phenomenon. Secondly, concepts such as particle/wave or

momentum/position, in the absence of specific material conditions, elude linguistic categorisation. This has enormous implications for curriculum studies, as it means that concepts are not free-floating ideas in the human mind, but are only immanent through particular material arrangements—through the dynamism of indeterminacy; matter and meaning are inseparable (Barad and Gandorfer [2021] describe concepts as “matterphorical”). Thirdly, concepts as material enactments of the world are then performative rather than descriptive, and it matters what apparatus is used to discern concepts. Fourthly, a politico-ethico-onto-epistemology is inseparable and inextricably entangled. Finally, the human subject does not exist separate from the world, and does not pre-exist the doings of the world of which it is a part. What we do in curriculum studies matters, but “we” do not pre-exist outside the world of iterative reconfigurings of curriculum studies. Curriculum-making, then, is necessarily iterative and collaborative, involving transdisciplinary work to study the sedimented historicised materialisations of particular phenomena, or in order to open up thinking in more expansive ways (Barad describes this as “letting concepts breathe” by “aerating them”, materialising them in certain ways but not others [Barad and Gandorfer 2021, 31]). Thus in curriculum processes, opportunities should be provided to rework taken-for-granted notions and reiteratively rework the disciplines and academics involved with them.

Quantum Leaps

In addition to there not being bounded, discrete individual pre-existing entities, but rather phenomena that are produced contingently through material arrangements, quantum physics provides more queering of time, space and indeterminacy through what are known as *quantum leaps*. Barad (2012a) refers to quantum leaps as queering our presumptions of continuity through quantum dis/continuity. The slash in the word dis/continuity is a form of indeterminacy that signifies it is not discontinuous or continuous, or discontinuous and continuous, but that there is no fact of the matter whether it is continuous or not. Barad describes quantum leaps in the following way:

Quantum “leaps” are not mere displacements in space through time, not from here-now to there-then, not when it is the rupture itself that helps constitute the here’s and now’s, and not once and for all. The point is not merely that something is here-now and then there-then without ever having been anywhere in between—that’s bad enough, of course—but that here-now, there-then have become unmoored: there’s no given place or time for them to be. (Barad 2010, 247–48)

This disruption of the determinacy of space and time, continuity and discontinuity undoes many presumptions of what is possible in curriculum studies and pedagogy and how it might be enacted or performed. It encourages the questioning of any cuts or binaries as taken to be already given and requires us to pay attention to how cuts, such as the human/non-human binary, are materialised in certain ways in the first place and what gets sedimented by accepting them as given. These are important political issues in the making of disciplines and sense-making in pedagogical contexts (Barad and

Gandorfer 2021). This tracing of entanglements in their specificity is what Barad (2021) refers to as objectivity.

Quantum Superposition

Quantum superpositions trouble essentialised notions of identity and being in that they show how being or becoming is actually an indeterminate matter. In order to illustrate this, Schrödinger's thought experiment with a cat is invoked. Here the cat is put in a steel cage, where its life or death depends on whether a radioactive atom decays and emits radiation or not. The superposition of alive or dead means that there is no fact of the matter that the cat is in a definitive state of being alive or dead (Barad 2010, 251). It is therefore an indeterminate matter, which entails an unending dynamism until it is measured, in which case it becomes one state or another—alive or dead.

Barad (2012b) discusses the void or no/thingness in relation to indeterminacy. The void is not empty and is not nothing or something. Particles can live and they can die in the void. Virtual particles, which are indeterminate, come in and out of existence rapidly where they can seem like a ghostly non/existence, so that the void may be regarded as a spectral realm. Indeterminacy is thus key to both existence and non-existence, with virtual particles on “the razor edge of non/being” (Barad 2012b, 12). The void may also be regarded as a lively tension of desiring towards being/non-being. With respect to reading and writing, Barad (2012b, 13) observes:

The blank page teeming with the desires of would-be traces of every symbol, equation, word, book, library, punctuation mark, vowel, diagram, scribble, inscription, graphic, letter, inkblot, as they yearn toward expression.³

Quantum superpositions mean that all bits of matter are always already a multitude as each is constituted by all possible histories of intra-actions with others. This alerts us to the other in the self (although Barad would maintain there is no self) and how difference is apparent from within (the stranger at home) (Barad 2012b, 16). Ontological indeterminacy and quantum superposition allow for a radical openness towards the other and towards possibilities for reconfiguring curriculum in higher education. As Barad puts it:

Ontological indeterminacy, a radical openness, an infinity of possibilities, is at the core of mattering. How strange that indeterminacy, in its infinite openness, is the condition for the possibility of all structures in their dynamically reconfiguring in/stabilities. Matter in its iterative materialization is a dynamic play of in/determinacy. (Barad 2012b, 16)

³ See also Bozalek et al. (2021) for more information on thinking-with the virtual in academic contexts.

Agential Realism

The differences in Heisenberg's and Bohr's approaches to quantum physics feature centrally in Barad's (2007) book, *Meeting the Universe Halfway*. Barad draws heavily on the work of Bohr and his response to Heisenberg's principle of uncertainty. As discussed in the section on indeterminacy or uncertainty above, Heisenberg's uncertainty principle is epistemological rather than ontic-semantic. Heisenberg's uncertainty principle assumes *inherent values of entities* that exist prior to their measurement. Contrary to this, Barad and Bohr claim that prior to measurement, particles and waves do not exist in fixed states.

Barad's agential realist philosophy is based on a relational ontology, which presumes that relationships are what bring things into being as part of the world. Their notion of intra-action, or "the mutual constitution of entangled agencies" (Barad 2007, 33), which has also been introduced in the section on phenomena above, is important for their agential realist framework in that intra-actions cut together-apart, both entangling and differentiating at the same time in the making of phenomena. Phenomena are topological reconfigurings or relationalities that are entangled across both space and time. Intra-actions are also not limited to human practices but may be seen as part of the world making itself intelligible to other parts of the world. An agential cut enacts a resolution in a phenomenon, where the indeterminate becomes contingently determinate. This is known as agential separability as it is both separate and together at the same time (what Barad [2007, 141] calls "exteriority-within phenomena"). This agential cut also contingently separates the agencies of observation from the measured object, and in so doing enacts a causal intra-action. The agential cut is different from a Cartesian cut where an inherent distinction—say between subject and object—is already assumed. Agential cuts do not enact absolute separation in that they entangle and separate at the same time. What matters in the world happens through specific intra-actions that bring phenomena into being. What must be borne in mind is that mattering is differential—some things matter and others are excluded from mattering. Temporality and spatiality also emerge in this process and the world's intra-activity is an entanglement of spacetime-matterings. This means that one cannot assume a distance or an external position as one is always already entangled in what one is doing.

Barad's agential realism is what they refer to as a posthumanist performative approach, which provides alternatives to representationalism (the independently determinate existence of words and things), in the form of practices, doings and actions. Even matter is a doing—it is a dynamic congealing of agency; it is not "a property of things but, like discursive practices, must be understood in more dynamic and productive terms—in terms of intra-activity" (Barad 2007, 150). Matter does not refer to given or fixed objects, but to phenomena in their ongoing materialisation. Constraints and exclusions affect the process of materialisation. Space, time and matter are mutually brought into being through intra-actions.

Barad's agential realist approach eschews both social constructivism and traditional realist views by reading quantum physics through poststructuralist theory and thinking with the cultural and natural together. One of the most important aspects of their agential realist approach is the diffractive methodology they have developed, which will be described below.

Diffraction

The notion of a diffractive methodology was initially suggested by Donna Haraway (1992) as an alternative to reflection and reflexivity, and was taken forward by Barad (2007). Barad (2007) refers to diffraction as a *physical phenomenon* that is part of wave behaviour—which pertains to light, water, or sound waves. Diffraction is where waves “combine when they overlap and the apparent bending and spreading out of waves when they encounter an obstruction” (Barad 2007, 28), such as an obstacle or a slit in an apparatus. These waves bend and spread out in the area beyond the barrier or slit, producing a new pattern. In combining, waves can be amplified by being superimposed upon one another.

Barad uses this physical process of diffraction as a methodology that engages affirmatively with difference. In a diffractive methodology the details of one theory or philosophical position are read attentively and with care through another in order to come to more creative insights about a certain issue.

Diffraction can be both temporal or spatial. Spatially, a given particle can be in a superposition—two or more places at one time. Less well known, however, is that it can also be in multiple times simultaneously. Quantum theory in its indeterminacy troubles unilinear time. Temporal diffraction refers to the proposition that the past is not something that can ever be left behind, but exists in the present and in the future—where temporalities are entangled and thickly threaded through one another. Temporal diffraction means that as a result of the energy-time indeterminacy principle, a given particle can be in a state of superposition at different times; one particle can materially co-exist in multiple spaces and times—here and there, and yesterday, today and tomorrow (Barad 2017a). As Barad (2017a) notes, hauntings are not just subjective human experiences, where a recollection of the past makes itself present in a subjective way. Quantum field theory allows us to understand how hauntings are lively indeterminacies of time-being, materially constitutive of matter itself, showing the “dynamism of ontological indeterminacy of time-being, being-time in its materiality” (Barad 2017a, G113). Being in touch with indeterminacies of the entanglements of what exists and does not exist, and material historicities of phenomena, and how particular kinds of configurations matter and not others, is important for curriculum studies. For example, students from a number of different disciplinary contexts can get together and trace the nature of the entanglements of particular phenomena, as Barad does in their classes. Barad explains how they engage students with this collaborative process in their undergraduate pedagogy (Barad and Gandorfer 2021; Juelskjær, Plauborg, and Adrian

2021), with the proviso that “[n]o issue is ever resolved, finally. No past is ever finished, finally” (Barad and Gandorfer 2021, 33; italics in original).

Curriculum and Pedagogy

What might these notions of indeterminacy in quantum physics and agential realism mean for curriculum and pedagogy? In this section, I discuss how indeterminism in agential realism would involve a reconfiguring of curriculum and pedagogy. Firstly, I discuss how the notion of concepts is different from traditional notions of concept, in terms of the material-discursivity that agential realism proposes. Secondly, I consider how theorising takes on new enactments from an agential realist viewpoint. Thirdly, I focus on critique and alternative ways of reading and writing from an agential realist approach, and finally I consider how curricula might be differently reconfigured taking indeterminacy into consideration.

Material-Discursive

In a similar way that individual entities do not pre-exist relationships, from an agential realist perspective, words are not the primary semantic units—material-discursive practices are (Barad 2007, 141). Discursive practices for Barad do not refer to language or linguistic performances:

In an agential realist account, *discursive practices are specific material (re)configurings of the world through which the determination of boundaries, properties, and meanings is differentially enacted. That is, discursive practices are ongoing, agential intra-actions of the world through which specific determinacies (along with complementary indeterminacies) are enacted within the phenomena produced.* (Barad 2007, 148–49; italics in original)

For Barad, concepts (such as momentum and position) come into being through material arrangements in the world rather than existing as ideations in the human mind (Barad 2007; Barad and Gandorfer 2021). Meaning is made possible through specific material practices. Through the apparatus creating an agential cut within the phenomenon, the inherent indeterminacy between the object and the agencies of observation is resolved, as is its inherent semantic indeterminacy, through creating a concept such as momentum or position, particle or wave. Material-discursive practices are also not just enacted by humans, and humans are also the products of material-discursive practices. Agency is also not a property of individuals but part of an enactment and the ongoing reconfiguring of the material-discursive in curricula. Agential realism makes it possible to think about concepts and thinking in new ways—as coming into being through particular material arrangements.

Outside of specific intra-actions, and specific material conditions that make them intelligible, words and things are indeterminate. Both concepts and the boundaries and properties of objects become determinate, contingently and temporally, as an inseparable part of a phenomenon. In the absence of an intra-action there would be no

fixed essence or closure—no determinate object—and nor would there be any determinate concept to describe it.

Theorising

Theory in agential realism is also a material-discursive practice and is seen as an experimental way of intra-acting as part of the world. In order to theorise and make sense of the world, it is necessary to trace entanglements and ask questions about taken-for-granted assumptions. Barad acknowledges the political aspects of knowledge and seeks to ask questions all the way in order to unravel quantum physics' complicity in what has happened regarding, for example, the atom bomb. The same can be done with any discipline or curriculum. Theorising is radically open “to an infinity of possibilities for reconfiguring the very conditions ... for materializing the world in particular ways and not others, including making it matter differently, involving a process of ‘getting underneath thought’” (Barad and Gandorfer 2021, 17).

Theorising, according to Barad, is also not solely limited to what human beings do. It is not trying to “capture” or describe what is going on in the world, but is rather part of what the world does:

The world theorizes as well as experiments with itself. Figuring, reconfiguring. Animate and (so-called) inanimate creatures do not merely embody mathematical theories; they do mathematics. But life, whether organic or inorganic, animate or inanimate, is not an unfolding algorithm. Electrons, molecules, brittlestars, jellyfish, coral reefs, dogs, rocks, icebergs, plants, asteroids, snowflakes, and bees stray from all calculable paths, making leaps here and there, or rather, making here and there from leaps, shifting familiarly patterned practices, testing the waters of what might yet be/ have been/could still have been, doing thought experiments with their very being. (Barad and Gandorfer 2021, 15)

In this way, intelligibility does not rely solely on humans, but can be seen as one part of the world making itself intelligible to another part. Like other entities, humans themselves are not discrete, bounded and intentional, possessing agency, as the liberal humanist conception of the subject would have us believe, but are part of the ongoing reconfiguring of the world. Agency is an enactment, not something that is possessed, either by humans or non-humans.

Theorising from an agential realist point of view involves an experimental tracing of entanglements and a concern with what matters in the world. It is not merely an “anything goes” practice, as following particular entanglements may be more fruitful than pursuing others. Because of the indeterminacy of time-being, nothing can be assumed to be given or fixed. This means that the curriculum and pedagogy need to remain open to being reconfigured, rather than assuming a givenness of what is. The important thing is to try to get underneath what is assumed to be fixed and given and to trace through questioning how phenomena as material entanglements of spacetime-matter have come into existence. If time, space, and matter only come into

being through specific intra-actions, then it is necessary to trace the sedimentations of the iterative intra-activity—where they have been cut-together apart or differentially entangled.

Critique

Critique is a ubiquitous practice in academia, which is assumed to be valuable and essential in leading the way to successful scholarship and inquiry. Critique assumes a spatiality of separateness and exteriority; it tends to essentialise whatever is under its gaze, more often than not, regarding it negatively.

For Barad, critique from the outside is highly problematic, and can even be destructive, making people feel attacked and leading to epistemological damage (Juelskjær and Schwennesen 2012). In an interview with Rick Dolphijn and Iris van der Tuin, Barad reported critique to be used largely out of habit and as such, to be “over-rated, over-emphasized, and over-utilized, to the detriment of feminism” (Dolphijn and Van der Tuin 2012, 49).

Critique is trapped in Cartesian representationalism and Newtonian ontology, and it requires being removed from what is being studied—reflection from a distance rather than an engagement as part of the world. In an agential realist interpretation of the world, it is impossible for a knower to stand at a distance from what is being observed, as we are all part of the world that we seek to understand in its iterative becoming and ongoing intra-activity. Agential realism reinforces the inextricability of entanglements between politics, ethics, knowing, being or becoming and doing. Knowing, being and what matters are not separable—we know as part of the world in its differential becoming, and are part of the cuts and exclusions that contingently and temporally resolve indeterminacy—that is why Barad refers to agential realism as politico-ethico-onto-epistemology (Barad 2017a).

Diffraction Reading and Writing

Barad’s agential realism revolutionises curriculum studies and pedagogy by moving away from academic critique, opting instead for more generous, imaginative and inventive responses involving curiosity, attentiveness and attunement, crafting new ways of doing, thinking and living in academia. Barad proposes a diffractive methodology rather than critique, which she regards as a potentially damaging process of distancing, othering and putting another theoretical or philosophical position down. Whereas critique can be construed as destructive, formulaic and predictable, going only where it has gone before (Juelskjær and Schwennesen 2012), a diffractive reading is both constructive and deconstructive, where the foundational contingency of concepts and ideas are investigated, opening up inventive provocations through other possible meanings.

Diffraction is also a matter of doing justice to the fine details of texts. For Barad, such justice entails “acknowledgment, recognition, and loving attention, ... not a state that can be achieved once and for all” (Barad 2007, x).

A diffractive methodology does not set up one approach/theory/oeuvre against another but rather offers an attentive and care-full reading of the ideas of one through another, leading to generative ideas that come from the possibility of multiple transdisciplinary approaches.

Diffraction is primarily a practice of making a difference in the world and considers what differences matter and for whom (Barad 2007, 90). A diffractive reading is an affirmative methodology that reads insights through different texts, oeuvres or theories, which are already entangled inside one another, rather than comparing one against another. For Barad (2007, 2012), a diffractive reading of building new insights is understood as a form of creative and affirmative engagement, an “iterative practice of intra-actively reworking and being reworked by patterns of mattering” (Barad 2014a, 186). Collaborative ways of reading and writing are important in a diffractive methodology. As Barad notes (Barad and Gandorfer 2021), sense-making is not an individual affair, nor does it happen at one time. Texts can be returned to again and again, each time producing new insights.

The ontic and epistemic violence of imposition of particular knowledge bases and agendas in higher education affected students in the past and continue to have such effects today and will bleed into the future. It is important for curriculum studies to understand the hauntology of these material sedimentations in order to engage in response-able practices and create radical openings for reiterative curriculum renewal in the field of differencing. Ontological indeterminacy means that it is possible to break through the confinement of past violences sedimented in thought through quantum tunnelling.

Conclusion

This article has attempted to give an overview of the vast work on Karen Barad’s agential realism and how indeterminacy is a central feature to their philosophy. Their work is complex and at times difficult to comprehend at first reading and requires patience and determination to make sense of it. I have attempted to give interested readers a way in to understanding indeterminacy and how it may work for curriculum studies and pedagogy.

The article has reiterated in a myriad of ways the proposition that the world is not made up of bounded entities with inherent and determinate characteristics and properties. Ontology is neither given nor fixed but remains radically open to infinite possibilities of being reconfigured in its dynamic indeterminacy. Agential realism offers curriculum studies a performative view of the world by focusing on practices or enactments rather than the givenness of states of being. Through an agential realist framework, it is

impossible to be at a distance from anything; all engagement is as part of the world in its iterative becoming. Concepts are material configurings of the world. Theorising needs to engage with tracing how phenomena in their entanglements emerge.

It is not possible to separate issues of justice or what matters from ethics, politics, ontology or epistemology—they are inextricably entwined. Agential cuts both separate and entangle simultaneously. There is no absolute separation, but a cutting together/apart, thus radically reworking notions of joining and disjoining, of identity and of difference within.

Quantum discontinuity teaches us that there is no fixed line between self and other, interiority and exteriority, past, present and future. Curriculum studies needs to face the ghosts of the past in its materiality, acknowledging the injustices in the content and process of curriculum, in order to engage in theorising that is relevant for the present and future. There will never be an erasure of the past, as sedimented marks on the body (not only the human body, but the bodies of curriculum studies and pedagogies) remain, but responsibility for entangled relations must be acknowledged. This ethics of entanglement provides both possibilities and obligations for making connections and commitments to reconfigure curricula and pedagogies.

Trying to understand and stay in touch with the unending dynamism of indeterminacy opens up a multiplicity of radical possibilities for thinking and doing curriculum otherwise. Being part of particular ways of materialising the world that matter, and not others, creates material-discursive conditions for reconfiguring curriculum studies. This also does not merely rest with the capacity of the discrete intentional human, but curriculum is part of the materiality of the world worlding itself. Curriculum does not consist of free-floating ideas, but material doings or enactments of the world. Indeterminacy in relation to space, time and matter foregrounds the importance of hauntology as a material feature of curriculum studies, for example the gendered, classed and racialised sedimentations that exist as part of the material conditions of curriculum construction and enactment in colonialist, capitalist and racist contexts. Furthermore, indeterminacy means the sedimentations of cuts or divisions between disciplines, theories, and universities cannot be taken as already given at the outset, but should be seen as entangled. Indeterminacy in its dynamism makes curriculum a reiterative process of re-turning, where word and world are inextricably entangled.

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