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Applying Barad’s ontology to reconceptualize teaching and learning mathematics for social justice

Lee Melvin Peralta

This chapter discusses Karen Barad’s (2007) theory of agential realism and its implications for critical theoretical education research. Drawing on the concepts of intra-action, diffraction, and agential cuts, Barad (2007) approaches scientific and social scientific practices by narrowing in on their ontological dimensions while also addressing questions of epistemology and ethics. Agential realism draws heavily on quantum physics, and Barad’s most well-known publication, Meeting the University Halfway: Quantum Physics and the Entanglement of Matter and Meaning, contains lengthy descriptions of particles, double-slit experiments, and Schrödinger wave functions (Barad, 2007). Despite its reliance on the language of quantum physics, agential realism has had a significant impact across fields as diverse as early childhood literacy (Taguchi, 2009; Wohlwend, Peppler, Keune, & Thompson, 2017), archaeology (Marshall & Alberti, 2014), environmental policy (Bauhardt, 2013), mathematics education (de Freitas, 2017; Palmer, 2011), urban education (Niccolini & Pindyck, 2015), and masculinity studies (Mellström, 2016).

Consistent with the widespread receptivity of Barad’s work, this chapter explores how agential realism can serve as a useful research method for critical theoretical research that moves beyond a focus on the empirical. First, this chapter discusses agential realism within the context of the ontological turn in the social sciences. This chapter then applies agential realism as a research method to reconceptualize pedagogy and scholarship widely known as teaching and learning mathematics for social justice. Finally, this chapter concludes with implications of agential realism for critical theoretical research in education.

An overview of agential realism

Agential realism is an ontological, epistemological, and ethical framework for conceptualizing knowledge and reality (Barad, 2007). As a trained physicist, Barad (2007) relies on the language of and experiments within quantum physics to articulate her framework. She also draws on “developments in political theory, cultural geography, political economy, critical race theory, postcolonial theory, and feminist theory” to “consider the dynamic and contingent materialization of space, time, and bodies” (Barad, 2007, p. 35). Barad’s (2007)
Agential realism emphasizes the importance of the ontological, the material, and the non-human. These ideas are not unique to Barad and must be seen in the context of what is known as the *ontological turn* in the social sciences. This section will begin by describing the ontological turn, which serves as a necessary backdrop toward understanding agential realism. Key concepts within agential realism will then be discussed, including the ideas of *intra-action* and *diffraction*.

**The ontological turn**

The ontological turn can be understood as building on and responding to the linguistic turn in philosophy, social sciences, and the humanities (Lather, 2016). The linguistic turn frames reality as being conditioned by collectively constructed discourse (Rorty, 1967). This emphasis on discourse is a reaction toward oppressive and marginalizing perspectives that view differences among people as natural and absolute (Bennett, 2010).

Some scholars, however, question the idea that all reality is mediated by language (Barad, 2007; Braidotti, 2013; Butler, 1990; de Landa, 2002; Grosz, 2005; Haraway, 2003; Kirby, 1997; Latour, 2005). The ontological turn embodies a feeling among researchers who seek to study how “*matter comes to matter*” (Barad, 2007, p. 192). These researchers foreground differences-in-being rather than focusing exclusively on differences created through language-mediated constructions (Zembylas, 2017). Instead of regressing to the naive realism that objects have inherent properties, the ontological turn locates meaning in embodied and enacted practices (Lather, 2016). An emphasis on ontology shifts focus from a purely human-centered perspective to an emphasis on the doings, actions, and agencies of both human and non-human bodies (Barad, 2007; Bennett, 2010; Braidotti, 2013; Deloria, 1999; Kirby, 1997; Latour, 1999, 2005; Marker, 2018; Martin, 2017; Simpson, 2017; Watts, 2013). Scholars have pointed out the ways in which the ontological turn echoes, but often fails to cite, Indigenous thinking (Rosiek, 2018; Rosiek, Pratt, & Snyder, 2020; Sundberg, 2013; Todd, 2016; Tuck, 2014).

In education research, the ontological turn has both methodological and political implications. Methodologically, the ontological turn attends to the emergent relation between researchers and subjects (Niccolini & Pindyck, 2015) and between people and spaces and materialities surrounding them (Palmer, 2011; Wohlwend et al., 2017). The ontological turn is also a political commitment to the possibilities of being and becoming inherent in matter (Barad, 2007; Massey, 2005). Many critical scholars whose research is explicitly or implicitly grounded in social constructivism promote the idea of multiple worldviews of a single world; in contrast, the ontological turn foregrounds not only multiple worldviews but also multiple worlds (Paleček & Risjord, 2012).

As Zembylas (2017) states:
the contribution of the ontological turn is that it develops a theoretical, ontological basis for a critical orientation in education and learning that can realize the possibility of shifting between different realities (or different “worlds”) as an opening that holds great implications for the quest of a radical politics that could develop a radically different world.

(p. 1410)

**Agential realism**

Agential realism shares many features of the ontological turn, including a return to materiality, a recognition of multiple realities, a move toward human and non-human agency, and a skepticism toward the masterful human subject (Barad, 2007; Lather, 2016). Agential realism’s unique contribution is to provide a nuanced and transdisciplinary elaboration of how reality operates as an entanglement of human and non-human materialities (Barad, 2007; de Freitas, 2017).

**The double-slit experiment**

Agential realism’s starting point is Niels Bohr, a physicist who wrote about the philosophical implications of the double-slit experiment in quantum physics (Feynman, Leighton, & Sands, 1965). The double-slit experiment was developed to determine whether matter behaves like a particle (e.g., ping-pong balls) or a wave (e.g., ocean waves as they spread and crash into one another). Light is projected through a plate with two slits cut into it, wherein the light passing through the slits is observed on a screen behind the plate. The answer of whether light is a particle or wave can be inferred based on the pattern that forms on the screen. Under regular conditions, light exhibits a wave behavior. However, the experimental setup, or apparatus, can be adjusted to detect which photons of light pass through which slits. In this case, the pattern that forms on the screen will indicate a particle behavior. In short, when light is measured using one experimental apparatus, they are waves; if they are measured using a slightly different apparatus, they are particles. This extraordinary result in physics led physicist Richard Feynman to state it was “a phenomenon which is impossible, absolutely impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it contains the only mystery” (Feynman et al., 1965, pp. 1–8).

For Bohr, the double-slit experiment implies that reality consists of mutually exclusive conditions of possibility (Bohr, 1963). Each possibility is inseparable from the specific experimental apparatus one uses to measure reality (Bohr, 1963). Barad (2007) contrasts Bohr’s philosophy with the epistemological claim of his contemporary, Werner Heisenberg. According to Heisenberg’s uncertainty principle, there are limits to the precision with which humans can measure certain quantities of a particle, such as the particle’s simultaneous position.
and momentum (Feynman et al., 1965). In contrast, a Bohrian account of the double-slit experiment suggests there is an indeterminacy with respect to reality rather than an uncertainty with respect to human knowledge (Barad, 2007; Bohr, 1963). Reality becomes determinate only within an experimental context. For instance, a particle’s position becomes meaningful only when a specific experimental apparatus is used to measure it. But outside an experimental context, the concept of position is incoherent, as is any property of any object (Barad, 2007; Bohr, 1963).

**From the double-slit experiment to intra-action**

Barad (2007) extends Bohr’s ideas by reading them against the ideas of scholars such as Michel Foucault. Bohr conceived experimental apparatuses as mere laboratory setups operated by a human scientist whose role was to pull levers and interpret scientific marks displayed on a screen (Barad, 2007). For Barad (2007), an experimental apparatus is any material and discursive practice that does not just observe reality but rather produces reality by demarcating boundaries within it. Barad (2007) describes Foucault’s discourse as the “local sociohistorical material conditions that enable and constrain disciplinary knowledge practices” (p. 147). Barad (2007) extends this definition by conceptualizing discourse as a more-than-human practice through which meaning is made. Moreover, whereas Foucault treats discourse as only weakly constrained by bodies and matter, Barad treats bodies, matter, and discourse as ontologically equivalent (Marshall & Alberti, 2014). Drawing on this extended conception of discourse, Barad (2007) states that experimental apparatuses consist of both human and non-human materialities that produce “the material conditions of possibility and impossibility of mattering; they enact what matters and what is excluded from mattering” (p. 148). In other words, experimental apparatuses do not just produce and constrain meaning, they alter reality itself by reconfiguring the nature of matter.

These experimental apparatuses are inherently indeterminate until they are set against other matter (Barad, 2007). Every object and its properties are indeterminate until they are measured by an experimental apparatus – which, as previously stated, is a material-discursive phenomenon – and this holds true even for experimental apparatuses themselves (Barad, 2007). However, when objects, properties, and ideas come together, they become momentarily determinate (Barad, 2007). This is what Barad (2007) refers to as intra-action. The concept of intra-action emphasizes that things and people are not pre-defined, but they can become defined through one another:

The neologism “intra-action” signifies the mutual constitution of entangled agencies. That is, in contrast to the usual “interaction,” which assumes that there are separate individual agencies that precede their interaction, the notion of intra-action recognizes that distinct agencies do not precede, but rather emerge through, their intra-action.

(Barad, 2007, p. 33)
Consider Taguchi’s (2009) example of a lesson where elementary students are asked to construct a clay figure and turn it back into a lump of clay. A naive realist perspective would attend to the “true knowledge” associated with the successful completion of the activity (Taguchi, 2009, p. 52). This knowledge includes the quality and temperature of clay as well as the techniques of manipulation that would allow the clay to be successfully molded. In contrast, a discursive view might highlight the ways in which the clay figures might be gendered, possibly as a result of dominant discourses and cultural practices that equate human with man. Under both perspectives, students’ bodies and the clay material are treated as inherently separate, humans are seen as the sole actors with agency, and the clay is seen as a passive object.

An agential realist perspective would see the children’s bodies, hands, and linguistic practices, as well as the clay itself, as being entangled with and mutually constituting one another (Taguchi, 2009). Minds, bodies, hands, and clay material are all agentic; they shape one another. Hands and clay do not interact as pre-existing entities but rather intra-act, giving one another a particular form and existence. This is not to reject the idea that discourse is irrelevant. On the contrary, agential realism relies on the idea that experimental apparatuses are material as well as discursive. As Taguchi (2009) explains,

[D]iscursively thinking hands mould the clay, but the clay also moulds hands and the student’s discursive thinking. The clay with its plasticity and three-dimensional agentic qualities makes itself intelligible as clay to the students, with its specific qualities and potentialities.

(pp. 58–59)

**Diffraction, not reflection**

Barad’s (2007) ontology relies on the concept of diffraction. Diffraction comes from physics to describe the way waves overlap and combine when they encounter one another or an obstruction (Barad, 2007). Similar waves combine additively – like consonant harmonies in music – whereas dissimilar waves form cancelling effects (Barad, 2007). Thus, differences among waves can produce an infinite number of possible combinations, or superpositions, transforming the waves themselves (Barad, 2007).

Diffraction is thus an integral part of how different materialities become determinate through intra-action (Barad, 2007). Through diffraction, differences come to matter, and through these differences, objects and their properties emerge (Barad, 2007). This emphasis on differences and diffraction comes from Trinh Minh-ha (1988) and Donna Haraway (1992), who draw on diffraction to attend to the relational nature of differences among materialities. Diffraction “does not figure difference as either a matter of essence or as inconsequential” (Barad, 2007, p. 72) and goes beyond the traditional, Western philosophical approach of treating differences as something to be captured, assimilated, or erased (Minh-ha, 1988).
Barad draws on diffraction to critique the optical metaphor of reflection and reflexivity prevalent in science and social science research (Barad, 2007; de Freitas, 2017; Hollin, Forsyth, Giraud, & Potts, 2017). As a metaphor, reflection is a way of studying a phenomenon that assumes an outside world that either pre-exists or is discursively constructed by an observer (Barad, 2007). Reflection emphasizes representing the world through sameness and separateness; the researcher’s goal is to mirror the world with as little distortion as possible (Hollin et al., 2017). Even critical scholars who want to examine their own activity through a process of reflexivity sometimes fail to apply this process toward their own analytical tools. As Barad (2007) states, “Turning the mirror around, as it were, is a bad method for trying to get the mirror in the picture” (p. 418).

Diffraction is a description of how materialities emerge through intra-action, but it is also the methodology that Barad (2007) uses to develop her theory of agential realism. Barad (2007), for instance, reads Bohr against Judith Butler to conceptualize a new understanding of the concept of performativity, which Barad then incorporates into agential realism. Butler (1990) argues that gender is performed through repeated bodily acts through which bodies are reworked and inscribed with conventions and ideologies of the social world around us. Barad (2007) draws on the ideas of intra-activity, which she develops from Bohr’s philosophy-physics, to refine Butler’s theory of performativity. Barad (2007) points out that Butler focuses on human bodies and treats matter as a mere surface effect of human bodies. Instead, “[a]ll bodies, not merely ‘human’ bodies, come to matter through the world’s iterative intra-activity – its performativity” (Barad, 2007, p. 152). Barad (2007) also diffractively reads Butler’s theory of performativity against Bohr’s focus on experimental apparatuses. Whereas Bohr treats experimental apparatuses as mere laboratory setups, Barad (2007) calls into question exactly what constitutes an experimental apparatus and where bodies are located within such apparatuses. For Barad (2007), what counts as a body is a performative achievement based on specific material practices. Experimental apparatuses, then, are dynamic, open-ended, and iteratively refined and reconfigured phenomena that include laboratory equipment but also human and non-human bodies as well as concepts such as class, economics, and gender (Barad, 2007).

Applying agential realism toward teaching and learning mathematics for social justice

Agential realism provides a methodology for conceptualizing pedagogy and scholarship widely known as teaching and learning mathematics for social justice (TLMSJ). This section provides an overview of TLMSJ, discusses epistemological and ontological dimensions of its contemporary articulations, and applies agential realism as a method to explore new possibilities for understanding TLMSJ.
An overview of TLMSJ

TLMSJ is an approach to mathematics education scholarship and pedagogy that centers ideas of liberation, anti-racism, equity, and social change. Larnell, Bullock, and Jett (2016) characterize TLMSJ as resting on two foundations: (1) the work of critical mathematical literacy and social justice projects advanced by Mary Frankenstein (1983) and Rico Gutstein and Bob Peterson (2013) and (2) the civil-rights-based work of Robert Moses and Charles Cobb (2001) in the Algebra Project. How teachers respond to and enact TLMSJ in their classrooms has been studied within teacher education (Bartell, 2013). Although TLMSJ began primarily in the context of K-12 education, scholars in recent years have begun to explore the use of TLMSJ in mathematics courses at the university level (Karaali & Khadjavi, 2019).

The National Council of Teachers of Mathematics, as part of a wide range of activities that support mathematics educators, promotes TLMSJ through teacher guides and model lessons to help teachers use mathematics to introduce and engage students in addressing issues of social injustice (Berry, Conway, Lawler, & Staley, 2020; Wager & Stinson, 2012). These guides and model lessons are part of a rich body of literature documenting how teachers have used classroom mathematics to identify and explore social issues such as lottery purchases in low-income neighborhoods (Rubel, Lim, Hall-Wieckert, & Sullivan, 2016), voter registration (Moses & Cobb, 2001), liquor stores (Brantlinger, 2013; Tate, 2013), map projections (Gutstein, 2013), and school conditions (Turner & Strawhun, 2013; Yang, 2009). TLMSJ places particular emphasis on the study of hegemonic practices that result in the marginalization or displacement of specific groups of people (Gonzalez, 2009; Leonard, Brooks, Barnes-Johnson, & Berry, 2010). The goals of TLMSJ are diverse. However, certain commonalities among contemporary approaches to TLMSJ can nonetheless be identified, particularly regarding the epistemological and ontological dimensions of TLMSJ.

Epistemological dimensions of TLMSJ

TLMSJ entails an epistemological commitment toward challenging traditional, widespread notions of mathematics as objective, neutral, and value-free (Frankenstein, 1983; Skovsmose, 2011). This stance mirrors scholarship across disciplines that challenge the political neutrality of mathematics (Appelbaum, 1995; Borba, 1990; D’Ambrosio, 2006; Eglash, 1997; Ernest, 1998; Fasheh, 1982; Gerdes, 1998; Gutiérrez, 2013; Hersh, 1999; Iseeke-Barnes, 2000; Knijnik, 2012; Martin, 2000; Poovey, 1998; Porter, 1995; Skovsmose, 2011; Tate, 1995). Instead of elevating mathematics’ alleged purity and close connections to technology and the natural sciences (Skovsmose, 2011), TLMSJ treats mathematics as a tool to critically examine social issues, thereby bringing mathematics closer to civics education (Mauch, 2005).
The theoretical roots of TLMSJ can be traced to Freire’s (1993) critical epistemology. Freire’s concept of *conscientização* draws attention to a person’s participation in his or her liberation through reading and writing the world through education (Freire, 1993). His philosophical stance draws on dialectical materialism, which is a framework “for understanding that humans can become actively conscious of both the conditions themselves and their sources, and for changing these conditions through human (social) intervention and action” (Au, 2007, p. 3). Freire’s liberatory pedagogy as applied to TLMSJ goes beyond a functional literacy that focuses on using mathematics to prepare students for the workforce (Leonard et al., 2010). Instead, TLMSJ seeks to help students use mathematics to develop a sociopolitical awareness and orientation toward issues such as critical literacy (Frankenstein, 1983), civil rights (Moses & Cobb, 2001), and sustainability (Gutiérrez, 2017). The act of incorporating social justice into mathematics education creates new opportunities for expanding students’ sense of what counts as legitimate mathematical activity (Gutstein, 2006).

**Ontological dimensions of TLMSJ**

Much less has been explicitly written about the ontological dimensions of TLMSJ. However, certain ontological assumptions can be inferred from the literature. Descriptions of TLMSJ lessons suggest that on an ontological level, mathematics is seen as a mediating tool that grants students a more critical view of reality. For instance, Frankenstein (1983) states that “when students overcome their math anxiety and learn math, they have a concrete, deep experience that ‘things can change.’ They also develop the ability to critique and they increase their questioning of the conditions in which they live” (p. 335). The lack of mathematical literacy, for instance, might lead people to believe that social welfare programs are responsible for a lower standard of living (Frankenstein, 1983). Statistical knowledge can help students see disparities in different forms of subsidies given to wealthy individuals versus poor individuals (Frankenstein, 1983; Staples, 2013). Likewise, topics such as perimeter and area, when used in the context of a quilting activity, can be used to give students artistic and literary voice in relation to a lesson on the Underground Railroad (Lipka et al., 2005).

TLMSJ’s ontological treatment of mathematics does not depart from how mathematics has long been treated as a tool that provides its wielder with a more privileged view of the world. TLMSJ may be a radical epistemological project that helps students know the world in new and emancipatory ways by foregrounding the subjective, politically non-neutral, and socially constructed nature of mathematics. However, TLMSJ remains a traditionally ontological project that continues to treat mathematics as (1) human-centered, (2) primarily discursive in nature, (3) primarily cognitive, and (4) fundamentally distinct from people and the things and phenomena they describe. Figure 10.1 models this ontological treatment of mathematics within TLMSJ:
In this view, there is a distinct reality of oppression and marginalization that has been ignored by society and that mathematics can help students reveal. Mathematics is a revelatory device that helps students gain a perspective on reality they otherwise could not achieve without mathematics. In many ways, Figure 10.1 resembles the mediation triangle developed by Vygotsky (1978), who theorized that tools such as signs and symbols mediated human beings’ experiences with the world. In a similar manner, TLMSJ treats mathematics as a conduit between human subjectivity and external reality.

TLMSJ sets itself apart from traditional mathematics education by framing mathematics as a socially constructed mediating tool and by emphasizing that social justice is an important goal for mathematical activity. However, ontologically, TLMSJ maintains the status quo in mathematics education by treating mathematics as a discourse constructed by humans to serve human needs. Humans are considered to be exceptional in their freedom and willfulness as they manipulate passive mathematical concepts to uncover hidden or ignored truths about the world, particularly as they relate to the experiences of marginalized and oppressed people. As Figure 10.1 suggests, people, tools, and phenomena are treated as distinct. People act on mathematics without mathematics acting back. The role and agency of non-human materialities are not considered to be relevant toward a social justice-oriented view of mathematics education. Instead, agency is located primarily within the human mind.

**Applying agential realism toward TLMSJ**

Agential realism offers new possibilities for conceptualizing the epistemological and ontological dimensions of TLMSJ. These new possibilities do not merely represent “newness” for its own sake. Instead, agential realism provides a potential way to move beyond the ontological limitations that may be a source of tensions within TLMSJ. Gutiérrez (2017) states:

> In the social justice mathematics tradition, students are taught to use classical mathematics as a tool to read and write the world, in order to develop their sociopolitical consciousness and mathematical proficiencies. But, in general, the tool itself is not questioned. Recognizing the limitations of
using the master’s tools to dismantle the master’s house (Lorde, 1984) leads me to argue that we must also be willing to question and reconceptualize what counts as mathematics in the first place, thereby taking up issues of epistemology and ontology.

(p. 3)

The use of classical mathematics as a tool to promote social justice might be one reason why scholars and teachers interested in TLMSJ have faced challenges in their work. For instance, one teacher’s attempts to conduct a lesson on the prevalence of liquor stores in South Central Los Angeles had the effect “to potentially reinforce the dominant worldview that the problem with South Central is the people who live there” (Brantlinger, 2013, p. 172). Mathematics may have had the unintended effect of perpetuating bias against marginalized communities instead of identifying the underlying causes of injustice. One possible explanation is that TLMSJ treats mathematics as a mediating tool to gain a privileged view of reality. To be sure, TLMSJ has had many successes in elevating social justice as a concern within mathematics education. However, these successes may have come at the price of reproducing a representationalist view of mathematics that sees the role of mathematics as a tool to mirror the reality of injustice. Implicit in this view is the idea that there is an independently existing world of injustice to locate and identify. This leads to potentially narrow views of injustice, such as those held by students who attribute social injustice to the actions and decisions of marginalized communities themselves.

Barad’s agential realism provides a non-representational alternative for TLMSJ. Under an agential realism ontology, TLMSJ can be conceptualized as a form of intra-activity among a diverse network of material-discursive agencies. The exact meaning of the teacher, students, mathematics, and phenomena of social injustice in a TLMSJ lesson emerge by intra-acting with one another. Students act on mathematical concepts, but mathematical concepts also act back. Important questions to ask are: To what extent are students engaging in a reflexive understanding of their own mathematical activity? How does mathematics shape and become shaped by students’ bodies and by extensions of their bodies such as calculators, protractors, computers, and chalkboards (de Freitas & Sinclair, 2014)? To what extent are students conscious of the ways mathematics can dominate, what counts as mathematics, and how different mathematical practices impact themselves as well as the world of human and non-human bodies (Gutiérrez, 2017)?

Moreover, agential realism asks how mathematical apparatuses render certain forms of social injustice determinate while keeping other forms of injustice indeterminate. The means of measuring the world cannot be separated from the phenomena of social injustice under investigation. Just as light is a wave under one experiment and a particle under a different experiment, inequity with respect to a particular phenomenon might take one form when approached statistically and another form when approached through a geometric lens.
Importantly, neither form represents the single truth of that phenomenon. Within a TLMSJ lesson, a social justice issue takes its particular shape through the diffractive process of a coming together of differences among human and non-human materialities. For instance, how might a calculator and pencil, set against a student and their bodily gestures, in the context of a particular classroom space, during a lesson on a particular mathematical concept, bring forth a particular instantiation of social injustice to be discussed, analyzed, and acted on by students? By understanding the world in terms of intra-activity and diffraction, researchers are encouraged to ask to what extent students think deeply and relationally about social justice—thehow instances of injustice connect to systems of oppression, marginalizing discourses, material conditions, mathematical concepts, and themselves.

Consider a mathematics lesson on liquor stores in South Central Los Angeles (Brantlinger, 2013). In this activity, a teacher asked non-white, low-income students in Chicago’s north side to investigate the ratio of liquor stores to movie theaters and community centers in South Central LA as part of a larger lesson on the 1992 Rodney King riots. The students used Google Maps, geometry, scaling, and measurement to compare this ratio to the ratio in an affluent Chicago suburb. They found that the proportion of liquor stores in South Central far exceeded the proportion of liquor stores in the Chicago suburb. As mentioned, some students took a deficit view toward people in South Central, with one student stating, “All they do is drink” (Brantlinger, 2013, p. 171). Brantlinger (2013) stated that next time, he would open up the political whole-class conversation and invite the students to share their thoughts on claims such as “All they do is drink.” Leonard et al. (2010) analyzed the lesson from the vantage point of culturally responsive teaching (Ladson-Billings, 1995; Tate, 1995), noting that Brantlinger could have encouraged students to first explore data drawn from their own communities to make the social justice connection as intended.

Agential realism would build on the analysis of Brantlinger (2013) and Leonard et al. (2010) by noting that the lesson deals with an issue bound up with the tools used to measure it. Intra-action would ask to what extent students reflect on why they are using certain geometrical concepts and what effect these concepts have on them. How does a tool such as Google Maps shape the nature of reality? How does it shape where our eyes move and influence what we believe to be true? For an agential realist, the issue of analyzing liquor stores is not just about opening up a political conversation or collecting data from one’s community. Instead, analysis entails rendering the issue of liquor stores determinate through intra-active, boundary-making practices among teachers, students, pedagogical theories, bodies, chalkboards, protractors, and physical gestures, to name a few. Moreover, the distribution of liquor stores is itself better understood as a volatile mix—a diffraction—of alcohol bottles, profit motives, highway systems, housing prices, physical dependencies, legislation, economic theory, race, gender, and architecture. By attending to the complexity and entanglement of phenomena, agential realism can help TLMSJ broaden the range of
places to look for sources of harm and oppression as well as broaden the sources of tools to address them.

TLMSJ not only promotes equity outside of the classroom but also within it (Leonard et al., 2010). TLMSJ can empower students from marginalized backgrounds by imbuing them with an increased sense of agency and motivation (Leonard et al., 2010; Tate, 1995). An agential realist approach to TLMSJ would extend these efforts by asking how TLMSJ not only reshapes students’ knowledge and perceptions but also reshapes students ontologically. For instance, how might a classroom conversation on liquor stores performatively shape the meaning of students’ bodies, particularly the bodies of Black, Latinx, and Indigenous students? How might this lesson make black and brown bodies intelligible in new ways? How might this lesson and other TLMSJ lessons help enact new categories and ontologies of race, gender, class, sexuality, and disability that may not be present in a traditional mathematics lesson?

These questions build on the work of scholars such as Danny Martin, Maisie Gholson, Rochelle Gutiérrez, Robert Berry, Uenuku Fairhall, Tony Trinick, and Tamsin Meaney, among many others, whose research includes studying the mathematical experiences of Black, Latinx, and Indigenous students (Berry, 2008; Fairhall, Trinick, & Meaney, 2020; Gholson, 2016; Gholson & Martin, 2014; Gutiérrez, 1999; Martin, 2012; Meaney, 2010). Martin (2012), for example, argues that the mathematics education research community should pay greater attention to what it means to learn mathematics while Black by studying the “complex relationships among cognitive, non-cognitive, structural, institutional, and ideological factors influencing patterns of participation and socialization as well as achievement outcomes among Black children” (p. 49). By attending to complexity, Martin (2012) combats essentializing explanations for negative test score outcomes among Black students. Rather than rejecting this line of research, an agential realist approach to TLMSJ would seek to extend Martin’s (2012) emphasis on sociocultural context by attending to the ways bodies and non-human materialities come to matter in TLMSJ.

The potential limitations of an ontological reframing of TLMSJ must also be considered. For instance, Gholson (2019) addresses an Indigenous project to reformulate mathematics in terms of people’s relationship to land, which Gutiérrez (2017) calls mathematx. Gholson (2019) argues that this project may inadvertently re-inscribe anti-Blackness. Although mathematx seeks to re-establish meaningful connections to land, water, humans, and non-humans, there remains an open and uneasy question about whether mathematx can engage in such ontological reimaginings while also giving sufficient attention to the uneven geographies experienced by marginalized students, especially Black populations for whom there exists an erroneous assertion that they lack geography (Gholson, 2019). Likewise, agential realism, which highlights the role of bodies and non-human materialities, must also address the uneven topographies by which bodies and non-human materialities are experienced by marginalized populations or else risk promoting Eurocentrism and anti-Blackness in TLMSJ.
Implications for critical theoretical research

The theory of agential realism offers a viable method for challenging hege-
monic social structures that moves beyond the dichotomy in empirical social
science research between the passive objectivism of a soon-to-be-discovered
reality (scientific realism) and the relativist nominalism of a constructed
world (social constructivism) (Rosiek, 2018). Under an empirical approach,
a researcher gathers data about the world through observation and interprets
this data through a lens based on particular theoretical commitments. Exactly
what is considered to be data varies across empirical studies depending on
their operational, categorical, and conceptual use (Borgman, 2015; Creswell,
2014). However, commonalities can be found in the ways that data are treated
as “representations of observations, objects, or other entities used as evidence
of phenomena” (Borgman, p. 28, emphasis added). From both positivist and
constructivist lenses, data captures or reflects the physical or social world, thereby
enabling the uniquely agential observer to understand reality in more approxi-
mately accurate ways.

Under an agential realist approach, the lines between gathering, interpret-
ing, producing, and using data are blurred because the act of measuring the
world materially changes it (Barad, 2007). Data are “lively intra-acting ontolo-
gies that are in relation and connection with all bodies beyond them” (Dixon-
Román, 2017). Data should not be understood just by their content but also
by their relation to other ontologies of bodies, measuring apparatuses, techno-
logical hardware, and space and place (Dixon-Román, 2017; Loukissas, 2019).
Through agential realism, data collection does not need to be confined to
instruments such as interview transcripts, participant observations, and surveys.
Instead, the question of what counts as data should be replaced by an emphasis
on the material-discursive conditions that make phenomena intelligible and
render certain knowledges determinate (Dixon-Román, 2017). Critical theo-
retical research, which studies the material-discursive conditions of structural
inequity and social injustice, therefore plays an important role in speaking back
against the representationalist logics of scientific realism and social constructiv-
ism that undergird the empiricism favored within education research.

Moreover, whereas scientific realism and social constructivism are funda-
mentally at odds with respect to the notion of objectivity, agential realism sub-
scribes to a notion of objectivity that respects the performative impact of social
practices (Barad, 2007). An agential realist view of objectivity occurs within a
framework of pluralist realism where the observer and observed diffract to cre-
ate disruptive interactions from which concepts emerge (Barad, 2007). These
concepts are articulations of material arrangements, which are constituted by
human agency as well as the agency of a world that is not necessarily bound by
our constructions of it (de Freitas, 2017).

Everything is agentic including non-human materialities (Barad, 2007). This
agency is expressed in the form of boundary-making practices that render cer-
tain aspects of an open-ended world determinate. Consider an example by
Bohr invoked in Barad (2007) involving a person using a stick to navigate a dark room. If the stick is held tightly, the stick registers as an extension of the human body, serving as part of the measuring apparatus to feel around the room. If the stick is held loosely, the stick becomes the object being measured and does not become part of the measuring apparatus. This example highlights that boundaries are real, but they are also made through one’s choice of apparatus. The idea that the world is actively reconfigured by the material-discursive experimental apparatuses that measure it is what Barad (2007) refers to as bodies making an agential cut in the world. The notion of an agential cut, along with the concepts of intra-action and diffraction, lead to two other implications of agential realism toward critical theoretical education research: encouraging ontological flexibility and re-introducing ethics into critical theory. This chapter concludes with a brief discussion of each.

**Ontological flexibility**

As a theoretical methodology in educational research, agential realism offers an ontological flexibility that can help researchers understand a phenomena’s multiple realities (Rosiek, 2018). Rosiek (2018), for instance, proposes a flexible conception of institutionalized racism in schools by drawing on agential realism. Many analytic frameworks exist for theorizing racism in schools, including individual bias and micro-aggressions, public policy, Marxist analyses of unequal material and economic conditions, and post-structural critiques grounded in discursive signifiers of status (Rosiek, 2018). Rosiek (2018) states that “[t]he problem with choosing any one of these analytic options is that doing so committed the project to treating the other aspects of the reality of racism in this context as if they were derivative or of marginal significance” (p. 413). Agential realism allows all of these theoretical frameworks to describe the reality of racism (Rosiek, 2018). The idea is not to say that all the accounts are simultaneously true or that agential realism can serve as some kind of totalizing framework. Instead, just as light takes on different realities (i.e., particle or wave) depending on the measuring apparatuses used to measure it, “racism is a phenomenon whose ontological nature is dynamic (not static) and agential (not passive). . . . The reality of racism is multiple and changes based on our intra-action” (p. 414).

Researchers might likewise take note of the various ways that TLMSJ can be conceptualized. Instead of focusing exclusively on the epistemological dimensions of TLMSJ, researchers can also try to understand the shifting and dynamic ways in which TLMSJ is ontologically taken up by educators and institutions. Rosiek (2018) states, “the challenge is not that a veil of language or ideology separates us from the objects of our study, but that our ethnographic inquiries are focused on ontologically moving targets” (p. 417). TLMSJ can be considered an “ontologically moving target” toward which researchers should seek to apply multiple frameworks. There is no one true characterization of TLMSJ just as there is no one true characterization of light. TLMSJ, as a phenomenon, depends on the material and discursive apparatuses used to conceptualize
Agential realism

This view encourages new and expansive ways of theorizing TLMSJ that moves beyond empirical studies of TLMSJ. For researchers engaging in critical theoretical education research, agential realism underscores that the world changes just as much as our knowledge of it changes. That the world is ontologically dynamic and open-ended highlights the role of experimentation in theoretical research (de Freitas, 2017). Because different experimental apparatuses create different agential cuts in the fabric of reality, and because theories are experimental apparatuses made up of human and non-human materialities, theorizing has the capacity to effect change (Barad, 2007; de Freitas, 2017). Instead of seeking to reflect the true nature of reality, theorizing is a performative practice that can make real that which it describes (Barad, 2007; Butler, 1990). Theorizing is just as much an ideational and ideological project as it is a material and generative one contingent on bodies, objects, and space and place (de Freitas, 2017). Thus, a significant contribution of agential realism toward critical theorizing is the idea that theory can help researchers attune to the ontological multiplicities of reality while simultaneously participating in its emergence.

Ethico-onto-epistemology

Although agential realism emphasizes the agency of non-human materialities, humans nevertheless play a role in the world’s intra-activity. Far from being mere passive observers of an external reality, humans are responsible for the questions they pose and how they approach them (Barad, 2007; Hollin et al., 2017). Questions, along with the multiplicity of approaches for answering them, do not merely provide a reflection of reality; they reconfigure it by giving rise to new possibilities for the world (Barad, 2007). These agential cuts involve instantiating particular worlds, but they also necessarily entail exclusion (Barad, 2007; Hollin et al., 2017). Exclusion is a central part of Barad’s philosophy, which says that when an experimental apparatus renders one world determinate, another world is necessarily rendered indeterminate. This focus on exclusion generates questions of ethical responsibility. Because different material-discursive arrangements produce different configurations of the world, and because we have agency within these arrangements, we are accountable for our part of the entanglements we weave and the exclusions we create (Barad, 2007). Because “neither is anything and everything possible at any given moment,” we cannot avoid our ethical responsibilities (Barad, 2007, p. 177). The blurring of boundaries between knowing, being, and ethical responsibility constitutes what Barad (2007) calls ethico-onto-epistemology.

In a TLMSJ lesson on liquor store distributions, for instance, the tools used to approach the lesson are not just a matter of knowledge or being, they also entail making choices that will foreground concerns such as race, capitalism, intersectionality, social psychology, and decolonization. TLMSJ becomes determinate through the material-discursive apparatuses used to understand it. These apparatuses include theoretical tools, measuring devices, the bodies of
students and professors, university buildings, and so forth. This complex and entangled web of materialities creates an infinite number of possibilities for the world, and these possibilities entail ethical obligations. Critical theoretical research in education therefore must be seen as an ethical practice. This ethics is not the purely epistemological notion that judges people’s actions at a distance based on their consequences (Barad, 2007) or based on concepts of obligation, intentionality, value, or utility (de Freitas, 2017). Critical theoretical research is a matter of reflexivity and relational thinking that not only matters but also has the capacity to decide what matter comes to matter (Barad, 2007).

Conclusion

This chapter reviewed the implications of agential realism as a critical theoretical research method in education. First, this chapter provided an overview of key concepts within Barad’s ontology, which draws on quantum physics. For Barad, physics is not merely a metaphor; rather, agential realism is an articulation of how the world actually is an open-ended set of possibilities whose instantiation is contingent on the intra-activity among human and non-human materialities (Barad, 2007; de Freitas, 2017; Hollin et al., 2017).

Second, this chapter applied agential realism to TLMSJ. Barad’s agential realism brings into focus tacit assumptions about the ontology of mathematics and social justice issues embedded in TLMSJ pedagogy and scholarship. Intra-action and diffraction create new possibilities for conceptualizing TLMSJ as an entanglement of teachers, students, mathematical concepts, pedagogical techniques, social justice frameworks, and human and non-human bodies. This conceptualization encourages scholars and teachers to interrogate, explore, and build upon pre-existing frameworks within mathematics and social justice education when studying TLMSJ.

Third, this chapter discussed implications of agential realism for critical theoretical research in education. By moving beyond the dichotomy of scientific realism and social constructivism embedded in empiricism, agential realism brings theoretical research back to the realm of the “real” without falling into the trappings of naive realism. Barad does this by treating the world as a plurality of realities that become instantiated through experimental apparatuses, which are themselves material-discursive phenomena. For educational researchers engaged in critical theoretical work, agential realism demands that we closely attend not only to the ideational but also to the material nature of reality and that we understand how both natures are entangled. The goal is not to describe an external reality but rather to attune to our ethical obligations in how our theoretical work produces our world.

References

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