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**Introduction to Special Issue
of *Research in Education***

**The computational turn in education research: Critical and creative
perspectives on the digital data deluge**

de Freitas, E. & Dixon-Ramon, E. (2017). The computational turn in educational research: Critical and creative perspectives on the digital data deluge. *Research in Education*, 98 (1), 3-13.

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In his exceptional survey of current big data methods in the social sciences, Kitchen (2014) describes the current state of affairs as a “data deluge”. Indeed, the diluvian metaphors of flood and deluge abound in our current computational culture, as we surf the dynamic surface of a seemingly inhuman quantity of data. Kitchen (2014) emphasizes the challenges and opportunities for researchers in the social sciences as they delve into this deluge. In the digital datafication of life and learning, the impact on education can already be felt, but has yet to be adequately theorized; there is a growing need for research on how big data and algorithmic methods are shaping the questions and aims of education research. This collection of five articles offers important critical analyses and creative options for education researchers working within this *brave new world* of live data and calculated publics.

We – at least in the affluent north – seem immersed in digital technologies, exponential rates of data production, and market-based technocratic governance. The global proliferation and reach of data mining and software analytics is becoming ever more ubiquitous. New fields of inquiry such as software studies have recently attempted to address the socio-material nature of the computational turn, analyzing the ‘data revolution’ as a cultural and ontological phenomenon, and exploring computational reconfigurations of knowledge, subjectivity and the social (Clough, 2016; Kirby, 2011; Latour, 2012; Manovich, 2013; Nakamura, 2012; Ruppert et al., 2013; Weheliye, 2014). Each of the articles in this journal issue is working on the forefront of this effort. Authors take up the computational turn in education research by exploring how big data and software are becoming the “engine” of society (Manovich, 2013), and producing a new image of “reason” (Parisi, 2013). The articles offer both critical analyses – drawing on Gilles Deleuze, Michel Foucault, Mark Hansen, Manuel Delanda, Sylvia Wynter among others – and creative directions for rethinking the role of software and big data in education research.

Chris Anderson (2008), chief editor of the popular culture magazine *Wired*, infamously declared that big data signaled “the end of theory” and that “big data makes the scientific method obsolete.” These provocative comments point to a monumental shift occurring across various scientific fields as researchers tap into vast data archives and intensive computing power, questioning the role of theory and highlighting the power of new digital research methods. The articles in this collection draw on various social theories to critically examine these new methods, and to shed light on how ‘theory’ is indeed at work. Each article draws on related but different social theorists in order to take a close look at the specific practices that are changing the field of education research, focusing on the social and political implications of big data methods.

The data deluge entails new ways of thinking about the quantitative dimensions of life and learning. The shift from disciplinary to control societies has produced a shift from statistics as a structural constraint, to statistics as live generative force (Thompson & Sellar, 2016). If the former might be characterized by parametric modeling and population census data, and perhaps also associated with Foucauldian analyses of how such measures structure society, the latter is characterized by a more invasive ‘becoming-statistic’ in which social metrics are actively mutated along with that which they measure. In Deleuzian terms, this shift corresponds to a shift from the individual to a more ‘environmental’ system of *dividuals* – a term that designates the multiplicities of flowing traits and tensors that segment and differentiate all Modernist conceptions of the ‘individual’ and ‘society’. The data deluge is a swamp of dividuals. Predictive analytics is at work in both the disciplinary and the control societies, as each mobilizes statistical methods, but today there are radically different ways that statistical instruments plug into the massive material power of new computational devices. Prediction operates differently today, as new ontologies of the social emerge in the midst of this data milieu.

Within the field of education research, the ‘datafication’ of teaching and learning serves particular curriculum and policy stakeholders. Pearson’s Next Generation Assessment agenda, for instance, which focuses on the development and implementation of computerized adaptive testing (CAT), seeks to create a continuously ‘assessing’ digital environment (Sellar and Thompson, 2016). In disciplinary society, statistical information about populations was produced over relatively long periods and in spatially discontinuous units (school, factory, state), while in the control society, the production and analysis of data occurs in rapidly decreasing periods of time; data flows have become deterritorialised and joined up across increasingly linked data infrastructures. Examining the ontologies of big data is particularly important for the field of education as emerging digital technologies meet traditional institutional practices and assessment approaches. This collection of articles provides original theorisations of this transformation across the social sciences.

We see in the collected articles a provocation to think bodies, entities, and ideas as imbricated with algorithmic architectures. A growing need to rethink the more-than-human nature of our world, including the computational dimension, fuels this special collection of articles, as authors pose the impossible question of nonhuman algorithmic performativities. Such algorithmic activity must also be analyzed as racializing and sexualizing material forces, assembling and activating various powers of contraction whereby bodies and organs are constituted and enslaved within the Capitalocene (Dixon-Román, 2016; Haraway, 2016). As Weheliye's (2014) theory of racializing assemblages indicates, these algorithmic forces are as much racialized, classed, gendered, queered, and disabled as the human organisms that assemble with them. Weheliye (2014) argues that the political relations of racialization are perpetuated via technologies and sciences (among other things) and require "the barring of nonwhite subjects from the category of the human" (p. 3). As we surf the data deluge, or tread frantically in its turbulent waters, we need to resist the all-too-easy comfort of a mysterious predictive power, and demand more from education research, examining the ways that bodies and milieus are mixed in new ways.

Indeed, there is a need for both critical and creative approaches as we take on the blissful and terrifying permutational "soft thought" of algorithmic reasoning (Parisi, 2013). This is an image of thought that is at once coercive and transformative, operating through exhaustive combinatorial logics and speculative leaps. We see an urgent need to not simply critique algorithmic reason as anti-human, but to understand how it participates in more-than-human worlding processes in both dangerous and creative ways. Authors in this issue take on the sociopolitical relations of difference that are at work in the more-than-human ontologies of algorithms and the deep undulating sea of big data. And although there is the risk of becoming too speculative as we explore this new imaginary, there is also the risk of not being speculative enough. It is this responsibility to the future that Haraway asks of us, as she explores the many manifestations of SF (science fiction, speculative fact, social fabulation, ...) and suggests we must develop capacities for "staying with the trouble" (2016).

In that spirit, we begin to glimpse on the horizon new machine-human sensitivities, sociabilities, and sociologies, indicative of an emergent form of unfamiliar life, still draped, however, in the old trappings of established social norms. For instance, IBM (2016) has stated that recent developments in machine learning are better understood as 'cognitive learning systems' that have the abilities to marry "man (sic) and machine" where "man (sic) plus machine is greater than either on their own" (p. 10). The new cognitive learning systems rest on better understanding (convolutional) *artificial neural networks*, or what Google describes as policy and value networks (PVN) (Silver et al., 2016). Machine learning that utilizes PVN is said to approximate human learning because of the human skill of making decisions with imperfect information. Parisi (2016) argues that this new image of reason is abductive (rather than deductive or inductive). Gulson and Webb (this issue) argue that machine learning education software differs significantly from previous forms

of computing software. New algorithmic methods are more flexible, revising and modifying the very recipe as they 'learn' from the data sets on which they feed.

In education research, these techniques of Artificial Intelligence (AI) are enabled by the field's reliance on standardization, the potential for vast data sets, and the creation of new data platforms into school governance networks. This ready-made situation lends itself to the aspirations of researchers in computer science, the computing industry, as well as institutional managers with their different but convergent interests; and yet in the same stroke, these pursuits of AI ultimately destabilize those same institutions and disciplinary boundaries (Deleuze, 1992). Rather than treating big data methods as complementary and supportive to educational policy and practices, Gulson and Webb (this issue) posit that what are needed in education research are novel forms of analysis that dig deep into the functional details of machine learning in education research, revealing how new images of reason are embedded in what they term 'computational education policy'. This new paradigm of policy intensifies interactions between people, networks, algorithms and computational capacities. They examine the rationalities of education policy that are part of these networks. Focusing on prediction, transparency and data, the authors argue that 'policy rationalities' within education are providing the channels through which principles of AI can be integrated into education practice.

To that end, it's important to keep focused on how algorithms run on material hardware, and that new kinds of algorithms operate through particular assemblages, reflecting revolutions in nano-material science. One might argue, as the media theorist Friedrich Kittler does, that there is no such thing as software, since close inspection always directs our attention to the material configurations of hardware that *are* in fact the algorithms at work. Certainly, we begin to grasp Kittler's playful but important claim when we turn to new digital microsensors that saturate our built environments, and consider how current research into nano-materials seeks the micro-capacities of atoms to sustain a digital 'bit' (Fabian et al, 2017). The human scale is a small bandwidth in relation to these kinds of developments, and 'passive' sensing devices embedded in various environments – including schools - are now a common way of collecting data from the human body. With these developments, the inherent *technicity* of matter and life is emphasized, since 'sensing' occurs below the time-scale of the human. Brain imaging and other micro-sensing technologies that tap the body in new ways are said to offer access to pre-cognitive engagement. These kinds of biotechnologies are being used with children to track and modify attention, engagement, decision-making, emotional states, motion, performance and creativity - see for instance projects at the MIT Affective Computing Lab.¹

These developments in micro-sensory digital technology support post-phenomenological approaches to studies of embodied learning, and demand new

¹ <http://affect.media.mit.edu/projects.php>

analytic frames that better integrate the qualitative with the quantitative. Quantification of social life at scales below and above the human suggest a strange new world of immersive measure (Hayles, 2017; Manovich, 2013; Ruppert et al, 2013). In the context of education, emotion recognition software and various other micro-sensors are being introduced to help guide teaching and learning (Bahreini et al, 2016). Responding to these developments, and the realization that this data deluge is indicative of a deeply quantitative world, Hansen (2015) suggests we theorize imperceptible “probabilities in the wild”. He argues that micro-sensors are not operating prosthetically (like previous technologies), because they engage with the environment in a more distributed and unconscious way, and thus have no correlate to the usual embodied organs, but instead seem to transcend the very notion of organism, while still, paradoxically, mobilizing embodied forces (Nakamura, 2012). For this reason, the media theorists Galloway and Thacker (2007) call for a new “climatology” of the social, and Hansen (2015) suggests we develop ways of studying the expanded sensory contact that characterizes this digital “worldly sensibility”.

Elizabeth de Freitas (this issue) builds on Hansen’s work to examine how we are in the midst of a re-engineering of human experience, where a proliferation of non-perceptual sensible data feeds-forward into possible ‘embodied’ futures. She explores the question: What will become of social science (in particular sociology and ethnography) in this brave new world? De Freitas examines the concept of research method, identifying five key characteristics. Drawing on the work of Michel Serres (2017), she suggests that floods of data play a pivotal role in what kinds of methods emerge. While many research methods reinforce established social orders – through the desire for origins, the need to exclude, and the establishment of a regime of labour – she argues that floods of data can overturn these old methods, and create conditions for new forms of innovative inquiry to emerge. She suggests that new research methods are innovative if they engage with time or temporality in new ways. De Freitas advocates for methods that queer the temporal logic of old methods that are no longer well suited to the digital data deluge. The entanglement of the qualitative and the quantitative is at the heart of our current methodological crisis in the social sciences. Elsewhere, de Freitas (2016a) has drawn on Deleuze to argue that sociology become a fractal monadology, and that alternative ontologies of number better attend to the *intensive* dimension of quantity – her aim is to bring number into the dynamic fold of new materialisms (2016b).

The computational data deluge disorganizes our old social science methods, and demands new ones, but at the same time, it demands a robust bioethics adequate to this new empiricism. This is especially true in education, which is at the forefront of the control society, responding rapidly to technological changes, utopian desires, and more and more explicitly to capitalist flow. We are witnessing this transformation today, as schools become digitally enhanced sensory environments, binding multi-scalar subjects (human and non-human) together in reconfigured modes of existence, while overturning conventional notions of ‘learning’ from an agent-centered perceptual modality to an *unequally* distributed “environmental

sensibility” (Hansen, 2015). This perspective underscores the need to rethink embodiment, and the need to introduce “a more porous and less self-referential conception of embodiment, a conception that understands the body to be a society of microsensibilities themselves directly and atomically susceptible to technical capture.” (Hansen, 2015, p. 193).

Such a dangerous move – abandoning the organism, as we’ve come to identify with it – raises frightening prospects. It’s not simply a matter of talking about systems and autopoiesis, since these are still too married to the dream of a self-maintaining organic image of life (Ruyer, 2016). The data deluge forces us to imagine life quite differently, and to seek the inorganic potentialities and inhuman forces by which a body can “branch out into territories beyond its own self-maintenance” (Colebrook, 2011, p. 26). The extent to which there is any sort of posthuman figure ‘who’ survives this moment is highly debated. What exactly emerges from a data deluge that refuses to abide by the old narratives of emergence? For Hansen (2015), there is a need for us to rethink forms of *presencing* that are not conventionally phenomenological; the ‘present moment’ is more or less animated or intensified *for the human* by an undecidable future. The degree of that intensity depends on our access to worldly technicity, and on our sustaining the undecidability of the future. In other words, we need to rethink technology and media, not as affordances for human achievement, but as somewhat indifferent to human achievement (Gane, 2006). We suggest that such a perspective brings forth a new politics more adequate to the ubiquitous computing environments in which we now dwell: “the scope of the present depends on the degree of precision of technical access.” (Hansen, 2015, p.195). Everything hinges on how well we can live with this “resolutely technical” matter while resisting the ossifying instrumentality that captures and controls it (p. 198).

A related approach to Haraway’s “staying with the trouble” is a program of research called critical data studies (CDS), drawing primarily from scholars in geography and cultural studies (Dalton and Thatcher 2014; Iliadis and Russo, 2016; Kitchin, 2014; Kitchin and Laurialt, 2014). CDS makes data its object of inquiry and applies critical social theory to examine the ways in which data are never objective or neutral but rather are always already relational, situated, contingent, and context. For CDS, data is both produced by and produces the world. What makes this approach different from previous theoretical stances on the primary status of relationality, is its focus on the specific architecture of digital quantitative measures.

Contra the idea that quantitative data are raw, CDS continues to be informed by ideas from Michel Foucault and Ian Hacking, and understands data to be “mutually constituted, bound together in a set of contingent, relational and contextual discursive and material practices and relations” (Kitchin and Laurialt, 2014, p). Thus, following in the footsteps of previous critical theories, CDS seeks to expose the political forces of data and their technologies as well as the ways in which there are complex dialectical relationships between data and society. As a data rich field with many different forms of sociotechnologies, education research must tackle the ‘black

box' of big data methods, and take heed of this call for a program of research in critical data studies.

In order to theoretically examine how data may be always already imbued with sociopolitical relations, Dixon-Román (this issue) leans on black literary feminist Sylvia Wynter's (2007) work on science, blackness, and the human. He works through her concepts of the cosmogonies of the human and the sociogenics of the fictively constructed genres of Man. Cosmogonies, for Wynter, refer to the myths, narratives, and stories of the ontological origin of the human and the way in which this shapes the histor(icit)y of the human, including the later sociogenic codes and formations of Western Man as the exclusive white, male, able-bodied, heterosexual, thereby rendering all other bodies as nonhuman. Wynter (2001) rejects cultural and biological explanations of race while still accounting for the ways in which the fabrications of race, as sociogenic, becomes ontogenic via the flesh. Wynter's principle of cosmogonic/sociogenic causality is her version of a cybernetic theory of inheritance. Dixon-Román examines the ways in which data become haunted by sociopolitical relations of racialization, using Wynter's theories of power, inheritance, and the body. Rather than leaving the data assemblages of education in this dystopic place, however, he then explores the potential for alternative futures by arguing for Wynter's proposed Autopoietic Turn/Overturn praxis of alt-science to reconstitute the human.

Dixon-Román suggests that research on sociotechnical assemblages in education would benefit from the interrogative and creative work of Afrofuturisms (da Silva 2017; Harney and Moten, 2013; Nelson, 2002; Weheliye, 2014; Wynter, 2007). As a multimodal, multidisciplinary philosophy of science and history, Afrofuturism seeks to critically examine the historical and current conditions of people of color while also seeking to rethink and reimagine alternative futures that emerge from the African diaspora and/or a rethinking of blackness as aligned with good/life/human. With the focus on educational inequities and the marginalizing experiences of students of color, Afrofuturist interventions into the sociotechnical and data assemblages of education would provide a sorely needed different perspective.

To the extent that Afrofuturisms operate through a kind of historical ontology, they align with the work of Halpern (2014), who argues that data is another form of historically and spatially situated vision. Here, vision is understood to be a technology of observation, empiricism, surveillance, and power, operating differently in disciplinary and control societies. In Foucault's disciplinary society, the disciplining of docile bodies was also based on the awareness that one is always being watched and thus comporting to what's expected, while in Deleuze's control society, the subject is less conscious of being watched, yet movement and subjectivity is constantly modulated, producing a false sense of freedom. In education, we can see how 'passive' data mining seems to serve this image of the control society. Research on learning analytics, educational data mining, and computational psychometrics are paving the way for such sociotechnological

practices in education. Following the call from critical data studies, there is a need to interrogate the digital platforms that enable this kind of surveillance.

Ben Williamson (this issue) studies one of the most widely used platforms of educational social media, ClassDojo. Initially an educational technology app, ClassDojo has developed into a commercial platform for tracking students' behaviour data in classrooms, and a social media network for connecting teachers, students and parents. The platform has been designed to influence how school leaders and teachers make decisions, how schools connect with parents, and how teachers act to change students' behaviour. As a result, ClassDojo is forming and shaping the discourses and practices of classrooms and public education. In his contribution to this special issue, Williamson carefully excavates all of the various actors, forces, and entities, both human and nonhuman, that make up the sociotechnical assemblage of ClassDojo. He shows how the technology is allied with the psychology community, working through evaluative mechanisms of concepts such as grit, perseverance, and mind that are set into the platform. He also shows how this platform is well positioned to respond to the US policy demands of ESSA that require states to include at least one non-cognitive measure as an outcome for accountability. Williamson argues that ClassDojo provides evidence of how the business model and political economy governing social media—'platform capitalism'—is being inserted into public education, while reshaping student and teacher subjectivities by the presumptions and worldviews encoded in digital platforms.

John Scott and T. Philip Nichols (this issue) examine another online teaching and learning platform, identifying neoliberal and positivist interests while also pursuing creative deconstructive methods which they term *critical learning analytics*. Learning analytics is a very recently developed field that emerged as an extension of educational data mining, but with a particular focus on informing the transactions of teaching and learning. Learning analytics, in sum, is the collection, analysis, and application of data accumulated to assess the behavior of educational communities. The interest is to optimize both student and faculty performance by employing a host of data analytic methods including predictive modeling, data mining, and interactive visualizations for the real-time analysis of teaching and learning transactions. In order to develop a critical learning analytics, Scott and Nichols conceptualize a learning analytics that attends to 'online distance education' not as a ready-made category, but rather, as an assemblage of technical, designed, and sociocognitive planes. Employing DeLanda's (2006) articulation of assemblage, Scott and Nichols consider how the dynamic, emergent, and power-laden relationships within and across these dimensions constitute and animate the work of online teaching and learning. They ultimately argue that critical learning analytics helps position online learning as an unfolding narrative of quantitative and qualitative entanglement, and in turn underwrites the relations between humans, hardware, learning design, content, and code that, together, comprise the emergent character of online education. This article underscores some of the contradictions in current learning theory, as evidenced in the online data, and points to the need for new

theories of learning in this complex entanglement of subjectivity and digital engagement.

The articles in this special issue explore the risks and pitfalls of the computational turn, while also pointing to the ways in which scholars might pursue important lines of flight and innovation in such a milieu. The future of educational research is at stake, as policy makers dive into the data deluge without adequate theoretical reflection on how the very notion of the 'social' is transformed at this historical moment. And yet we cannot rest easy with a critique of poor policy, as we continue to resist the inadequate God's-eye-view approaches to the data deluge (see de Freitas (this issue) for Bruno Latour's attempts to pursue an alternative approach that works *immanently* from within the problems in which we dwell). In every case, it seems that such lines of flight must sustain a critical perspective while at the same time think more creatively about alternative paths. We cannot simply point to the incompleteness or indeterminacy of our research methods, or to the desire for control mobilized in current education policy, but must actively imagine and engender other paths. These alternatives must take up the computational capacity of our current data deluge *artfully and speculatively* (Parisi, 2013) so as to intensify ways of being together that are not serving an instrumental set of logics in educational governance. The articles in this collection suggest in different ways how that 'future of the future' may well be more-than-human.

References

- Anderson, C. (2008). The end of theory: The data deluge makes the scientific method obsolete. *Wired Magazine*. <http://www.wired.com/2008/06/pb-theory/>
- Barad, K. (2006). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham, NC: Duke University Press.
- Bahreini, K., Nadolski, R. & Westera, W. (2016). Towards real-time speech emotion recognition for affective e-learning. *Education and information technologies*, 21 (5), 1367-1386.
- Clough, P.T. (2016). Rethinking race, quantification and measure. *Cultural Studies-Critical Methodologies*, 16(4). doi: 10.1177/1532708616655760
- da Silva, D. F. (2017). 1 (life) ÷ 0 (blackness) = ∞ - ∞ or ∞ / ∞: On Matter Beyond the Equation of Value. *e-flux* 79: 1-11.
- Dalton, C., and Thatcher, J. (2014). What does a critical data studies look like, and why do we care? *Society & Space*. Available at: <http://societyandspace.org/2014/05/12/what-does-a-critical-data-studies-look-like-and-why-do-we-care-craig-dalton-and-jim-thatcher/> (last accessed May 19, 2017).
- de Freitas, E. (2016a). Calculating matter and recombinant subjects: The infinitesimal and the fractal fold. *Cultural Studies- Critical Methodologies*, 16(5), 462-470.
- de Freitas, E. (2016b). The new empiricism of the fractal fold: Rethinking monadology in digital times. *Cultural Studies- Critical Methodologies*,

16(2), 224-234.

- de Freitas, E., Dixon-Román, E., Lather, P. (2016). Alternative ontologies of number: Rethinking the quantitative in computational culture. *Cultural Studies-Critical Methodologies*, 16(4), 431-434.
- DeLanda, M. (2006). *A new philosophy of society: Assemblage theory and social complexity*. New York, NY: Continuum.
- Deleuze, G. (1992). Postscript on the societies of control. *October*, 59, 3-7. doi:10.2307/778828.
- Deleuze, G. (1994). *Difference and repetition* (P. Patton, Trans.). New York, NY: Columbia University Press.
- Deleuze, G. & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia*. (Trans. B. Massumi). Minneapolis: University of Minneapolis Press.
- Derrida, J. (1970). *Of grammatology* (G. C. Spivak, Trans.). Baltimore, MD: Johns Hopkins University Press.
- Dixon-Román, E. (2016). Algo-Ritmo: More-Than-Human Performative Acts and the Racializing Assemblages of Algorithmic Architectures. *Cultural Studies-Critical Methodologies*, 16(4), 482-490.
- Fabian D. Natterer, F.D., Yang, K., Paul, W., Willke, P., Choi, T., Greber, T., Heinrich, A.J, Lutz, C.P. (2017). Reading and writing single-atom magnets. *Nature*, 2017; 543 (7644): 226 DOI: [10.1038/nature21371](https://doi.org/10.1038/nature21371)
- Foucault, M. (1972). *The archaeology of knowledge: And the discourse on language* (S. Smith, Trans.). New York, NY: Vintage Books.
- Galloway, A. & Thacker, E. (2007). *The exploit: A theory of networks*. Minneapolis: University of Minnesota Press.
- Gane, N. (2005). Radical post-humanism: Friedrich Kittler and the primacy of technology. *Theory, Culture & Society*, 22(3), 25-41.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. Book in preparation for MIT Press. URL <http://goodfeli.github.io/dlbook/>.
- Halpern, O (2014) *Beautiful Data: A History of Vision and Reason Since 1945*. Durham: Duke University Press.
- Hansen, M. (2015). *Feed-forward: On the future of twenty-first-century media*. Chicago: University of Chicago Press.
- Harney, S., and Moten, F. (2013). *The Undercommons: Fugitive Planning & Black Study*. Minor Compositions.
- Hayles, K. M. (2017) *Unthought: The Power of the Cognitive Nonconscious*. Chicago: University of Chicago Press.
- IBM. (2016). *Personalised education: From curriculum to career with cognitive systems*. Portsmouth: IBM Corporation.
- Iliadis, A., and Russo, F. (2016). Critical data studies: An introduction. *Big Data & Society*, 1-7.
- Kirby, V. (2011). *Quantum anthropologies: Life at large*. Durham, NC: Duke University Press.
- Kitchen, R. (2014). *The data revolution: Big data, open data, data infrastructures and their consequences*. New York: Sage Publications Inc.
- Kitchin, R., and Lauriault, T. P. (2014). *Towards critical data studies: Charting and*

- unpacking data assemblages and their work. *The Programmable City Working Paper 2*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2474112 (last accessed May 19, 2017)
- Latour, B. (2012). The whole is always bigger than its parts: A digital test of Gabrielle Tarde's monads. *The British Journal of Sociology*, 63, 590-615.
- Lyotard, J.-F. (1980). *The postmodern condition: A report on knowledge* (G. Bennington & B. Massumi, Trans.). Minneapolis: University of Minnesota Press.
- Manovich, L. (2013). *Software takes command*. New York, NY: Bloomsbury Academic.
- Nakamura, L. (2012). Queer female of color: The highest difficulty setting there is? Gaming rhetoric as gender capital. *Ada: A journal of gender, new media and technology*, #1. <http://adanewmedia.org/2012/11/issue1-nakamura/>
- Nelson, A. (ed.) (2002). *Afrofuturism: A Special Issue of Social Text*. Durham, NC: Duke University Press.
- Parisi, L. (2013). *Contagious architecture: Computation, aesthetics and space*. Cambridge, MA: MIT Press.
- Rabinow, P. (1996). *Essays on the anthropology of reason*. Princeton, N.J.: Princeton University Press.
- Ruppert, E., Law, J. & Savage, M. (2013). Reassembling social science methods: The challenge of digital devices. *Theory, Culture and Society*, 30(4), 22-46.
- Ruyer, R. (2016). *Neofinalism*. Trans. Alyosha Edlebi. Minneapolis: University of Minnesota Press.
- Sellar, S., and Thompson, G. (2016). The Becoming-Statistic: Information Ontologies and Computerized Adaptive Testing in Education. *Cultural Studies-Critical Methodologies*, 16(4), 491-501.
- Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., van den Driessche, G., Hassabis, D. (2016). Mastering the game of Go with deep neural networks and tree search. *Nature*, 529(7587), 484-489. doi:10.1038/nature16961
- Thacker, E. (2009). Swarming: Number versus animal. In M. Poster & D. Savat (Eds). *Deleuze and new technology*. Edinburgh: Edinburgh University Press. 161-184.
- Webb, P. T., & Gulson, K. N. (2015). *Policy, geophilosophy, education*. Rotterdam: Sense Publishers.
- Weheliye, A.G. (2014). *Habeas Viscus: Racializing assemblages, biopolitics, and black feminist theories of the human*. Duke University Press.
- Wynter, S. (2001). Towards the sociogenic principle: Fanon, Identity, the Puzzle of Conscious Experience, and What it is like to be Black. in A. Gomez-Moriana and M. Duran-Cogan (eds.). *National Identities and Sociopolitical Changes in Latin America*. New York: Routledge.
- Wynter, S. (2007). Human Being as Noun? Or Being Human as Praxis? Towards the Autopoietic Turn/Overtturn: A Manifesto.