Introduction

Science and Technology Studies × Educational Studies: Critical and Creative Perspectives on the Future of STEM Education

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This special issue presents a collection of articles that multiplies Science and Technology Studies (STS) with Educational Studies, in an attempt to think differently about science, technology, engineering, and mathematics (STEM) education. We hope this cross product of the two fields amplifies the philosophical insights from each, stretching scholarship in new directions and across disciplines. While diligently refusing reductive scientisms, we open up this manifold space so as to cultivate discussions of a possible rapprochement between the physical and social sciences (Wilson, 2015). This work responds to the changing theoretical landscape across the humanities or posthumanities, following the ontological turn and the shift to consider more-than-human agencies. This work is thus highly relevant for the field of educational studies and the social foundations of education, providing insights into alternative onto-epistemologies, and tracking the impact of these across education policy, research, and curriculum.

As part of the shifting theoretical terrain, we see philosophers today exploring new mixtures of politics and nature by looking to mathematics (Badiou, 2011; Kirby, 2011; Meillassoux, 2010), the physical sciences (Bennett, 2010; Braidotti, 2013; Coole & Frost, 2010; DeLanda, 2011, 2015) as well as indigenous cosmologies (Avelar, 2013; Chakrabarty, 2009, 2014; Danowski & Viveiros

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de Castro, 2017; Povinelli, 2013) and speculative projects and SF creations[1] (Negarastini, 2008). We note the development of new kinds of realism, such as *agential realism* in Karen Barad (2007) or *speculative realism* in Graham Harman (2010), as well as new forms of materialism, such as *speculative materialism* in Quentin Meillassoux (2010) or *new materialism* in Diana Coole and Frost (2010). Parallel and linked to this work, are examples of ecological perspectives in education research drawing from environmental philosophy and Indigenous Studies to rethink land, place, and people (Bai, 2006, 2009; Bowers, 1997, 2000, 2001, 2016a, 2016b; Martusewicz, 2001, 2006; McKenzie, 2009; Orr, 2004; Tuck, McKenzie, & McCoy, 2014; Williams & Smith, 1999).[2]

We hope this special issue pushes the envelope of educational foundations to further engage with STS, building upon the growing number of critical sessions and papers on STEM at the annual meetings of American Educational Studies Association (AESA; www.educationalstudies.org). Like others in the field of Educational Studies, we are highly sensitive to how STEM policy functions as a form of governance in the production of human capital and global colonialism (Daza, 2013). Originating in the United States, the term STEM is part of a long-established governmental strategy that posits scientific and technological literacy at the center of national prosperity and power. STEM has become a central component of national educational systems, including educational activities across all grade levels—from preschool to postdoctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings. As highlighted by Chesky and Wolfmeyer (2015), STEM "may be the most indicative educational reform discourse of our time and has grown to become one of the primary foci of educational reform" (p. 2).

Critical approaches to STEM education have typically studied how it serves the *control society* through its intrusive discourse, its monopoly on funding, and its gate-keeping status (Pais, 2013). Despite the important insights from this work, showing how STEM education is situated in the socio-political, there is a need to go beyond the agonistics of critique, and reconsider scientific activity as part of the ontological turn. We need to dig deeper into the material and onto-generative power of specific scientific practices and their implications for education research. We need scholars to build robust theorizations that illuminate the distinctive philosophical nature of contemporary sciences. The aim of this special issue is to engage with scholarship that pushes the critical perspective beyond previous limitations and oversimplified binaries between science and culture. The authors in this collection turn to a diverse set of theorists in that endeavor, examining the ways that STEM is mobilized to both destroy and remake the Earth, people, and place. We believe that both critical and creative perspectives are needed, and we suggest that the field of STS offers excellent tools for pursuing this aim. We follow Danowski and Viveiros de Castro (2017) in their effort to adumbrate links between STS scholarship and other theoretical traditions focused on the eco-politics of onto-epistemologies.

STS

STS emerged in the 1960s and 1970s through a confluence of scholarship on the cultural and material practices of science, exploring philosophical and historical questions about human agency, epistemology, and responsibility for the physical world. Early significant texts in the field, such as Thomas Kuhn's (1962) *The Structure of Scientific Revolutions* and Steve Woolgar and Bruno Latour's (1979) *Laboratory Life: The Construction of Scientific Facts*, emphasized the situated nature of scientific knowledge. Feminist philosophers of science such as Evelyn Fox Keller (1985), Sandra Harding (1986) and Donna Haraway (1985, 1988) developed and expanded the field in

the 1980s. Much of this work used sociological, anthropological, ethnographic, and historical approaches to study scientific and technological practices in diverse geographic sites and historical periods, revealing the ways that science (or knowledge of the natural world) is embedded, embodied, and enacted in particular political conditions. Growing interest in the field in the 1990s led to the development of university graduate programs that used the STS moniker to designate studies in "Science, Technology, and Society."

Latour (2005) has always been an important voice in the STS field, developing actor-network-theory (ANT) as a kind of grounded ethnographic methodology for performing these kinds of studies. His focus on the agency of nonhuman *actants* in scientific activity has been hugely influential, showing how complex systems of interaction and invention enlist and mobilize diverse kinds of agents. More recently, scholars in STS have made significant contributions to the ongoing debate about climate change and the Anthropocene. Latour (2013, 2017) and Stengers (2013a, 2013b), for instance, have differently engaged with the concept of Gaia as a way of confronting the climate crisis. This work aims to rethink politics through ecology, and to reconsider the current shape of human geography (urban and otherwise) as part of the current climate regime. The term *Gaia* and its mythical source troubles Western rational images of science—indeed, Latour adopted Lovelock's term and concept in part for that reason.[3] This broad geological perspective (perhaps as Latour states, this "geostory") demands new ways of thinking about the politics of race and gender, and of place and body. Such an endeavor involves a radical remixing of politics and earth: "This is why we have to choose between a Nature that hides its Politics and a Politics in which the role of Nature is explicit" (Latour, 2017, p. 47).

Haraway (2003, 2016) also continues to be an important voice in STS, directing attention to the "kin" and "companion species" relationships that sustain more-than-human ecologies. She prefers the terms "Capitalocene" and "Chthulucene" to Anthropocene, arguing that these better designate our current geo-political rearrangement of life, Earth, and power (Haraway, 2016). For Haraway, the challenge is to develop new ways of studying complex systems and ecologies of material practice, as a means of understanding the distributed mindedness or "sympoiesis" in creative processes of worlding.

Stengers (2013a, 2013b) is similarly concerned with the planet's anthro-geomorphic and mythic potential to stay with the *becoming* of indigeneity. She contests the political economy of accelerationism, and advocates for deceleration and slow science. Capital seeks out and appropriates science, and so she insists on a "cosmopolitical slowing down" (p. 139) of a more-than-human political process. As Danowski and Viveiros de Castro (2017) summarize: "The possibility that she fears is that the sciences in particular will become again mobilized to legitimize a kind of 'war ecology' … which will hitch contemporary scientific research even more firmly to the energy-devouring machine that moves the planetary economy" (p. 118). Stengers (2015) asks that we develop new sciences that better reckon with our being "earthbound" Terrans (inhabitants of planet Earth), and at the same time realize that the earth is strangely indifferent to human life.

Karen Barad's (2007, 2012) STS work on quantum physics references contemporary scientific developments that go against the grain of past positivisms, advocating for a kind of quantum vitalism that overthrows the distinction between animacy and inanimacy. Barad tracks new ontologies in the actual quantum *experiments* performed by Niels Bohr and others, carefully examining the experimental event for how particular quantum concepts thrive and mutate (de Freitas, 2017). Rather than bemoan the apparatus as that which distorts the real, a perspective that feeds into an "aggrieved postmodern antirealism" (Sheldon, 2016, p. 10), Barad positions herself as a re-

alist and affirms a posthuman ethics. Related work on animal studies (Abram, 1996, 2010) and critical life studies (Weinstein & Colebrook, 2017) have begun to better theorize inhuman and more-than-human agencies.

This special issue of *Educational Studies* mobilizes and advances STS scholarship by turning its gaze toward issues in STEM education. Two articles in this collection take up the ideas of Bruno Latour to interrogate and offer alternative approaches to teaching about nature, agency, and experiment in STEM curriculum. Two articles focus on climate change education and the Anthropocene, drawing on Haraway, Barad, and Stengers. Two other articles explore place and land value, one taking up the question of Indigenous science and another the racial politics of urban STEM schools. An article on gender looks back to early feminist STS scholarship to help trouble current attempts to paint STEM pink. Together, these articles carve out a complex terrain of linked ideas and interventions, raising important questions about the future of STEM education.

THE COLLECTED PAPERS

From the nearly 40 abstracts received in response to the call for papers, we selected eight. Altogether, these articles take up the potential of science to contravene Humanist notions of intentionality and agency, and undermine conventional notions of achievement, progress and individuation. In their articles, authors address issues concerning the need for ecological response-ability, the political framing of STEM education, the speculative nature of STEM knowledges, and the complex ways that nature, place, and a people are elicited and encountered through STEM education. The authors put philosophy to work as a pragmatic intervention into the concrete STEM practices that saturate education, and also as a creative platform for tapping and formulating subversive STEM practices that might open up a radically different imaginary.

Blanche Verlie proposes alternative ways of doing climate change education in her article, "Rethinking Climate Education: Climate as Entanglement." Verlie's article is a call to contest some of the dualities commonly assumed by researchers and politicians working with and on climate change, such as human/nature dualism. The author makes use of Karen Barad's concept of entanglement to explore climate knowers as of the climate, and co-emerging with it (instead of being somehow outside the climate, thus separated). This entanglement has important implications for science and climate education; namely, it allows for the conceptualization of a pedagogy that does not presuppose and reinforce the anthropocentrism that uncritical science deficit approaches risk, while working for informed climate *response-ability*. The author concludes by outlining a set of conceptual tools for working towards what she calls "entangled climate pedagogies," which understand the human and the climate as co-emergent.

Tristan Gleason uses theoretical tools from Latour in his article, "Science Education and the Nature of Nature: Bruno Latour's Ontological Politics," which provides an historical account of the STS as a field, and examines how recent development in STS provides an opportunity to problematize the tacit ontological commitments of science education in the United States. Gleason shows how Latour's analysis of scientific practice and its entanglement with nature is an argument about ontology, as well as being a theoretical resource for rethinking environmental education. He briefly discusses the extent to which outdoor education programs illustrate this approach to science, using a case study of a residential outdoor science program that has served public school students across an urban county in the Pacific Northwest for over 50 years.

Also drawing on Latour in an article entitled "Using the Sociology of Associations to Rethink STEM Education," Cory Buxton, Susan Harper, Yolanda Denise Payne and Martha Allexsaht-Snider start from the assumption that educational change typically follows a far more chaotic path than the one imagined by funders and policy-makers. To show the messiness and complexity of education, the authors explore, through vignettes, how ANT provides conceptual tools to think differently about their work on a large, federally funded STEM implementation research project. The deployment of ANT theory to analyze the vignettes allows the authors to focus on the non-human actants in school classrooms.

The article by Greg Lowan-Trudeau, "Indigenous Environmental Education: The Case of Renewable Energy Projects," addresses the topic of the relation between indigenous knowledge and Western scientific knowledge, focusing on the development of renewable energy projects in indigenous communities across Canada. These projects align with the communities' ecological philosophies while also providing increased energy security and self-sufficiency, thus building new hybrid STEM knowledges and practices across cultural divides. The article discusses the challenges of sustaining such projects through adequate education, and discusses socio-critical concerns regarding Indigenous environmental education in the context of capitalist and nationalist agendas, underscoring issues raised by Marcuse's theory of repressive tolerance.

The relation between gender, race, and STEM education is the topic of two of the articles that compose this special issue. Jessica Heybach and Austin Pickup's article, "Whose STEM? Disrupting the Gender Crisis within STEM," uses feminist philosophers of science to critique the way in which research conceptualizes the underrepresentation of women in STEM. The authors suggest that much of the research on gender and STEM education uncritically positions STEM knowledge as a gender-neutral commodity to be equitably distributed across gender lines. They criticize the recasting of STEM as "pink" through the creating of "feminized" environments in which STEM is made more appealing to women and girls. Such a move leads to a washing away of the possibilities that gendered ontologies contribute to scientific knowledge, while leaving gender undertheorized. By drawing upon multiple theoretical perspectives (standpoint theory, new materialism, and decolonial scholarship), the authors manage to challenge the implicit framing of STEM as a purely objective set of disciplines unaffected by their gendered history.

Erika Bullock's article, "Only STEM Can Save Us? Examining Race, Place, and STEM Education as Property," examines the recent repurposing of failing urban schools as STEM-intensive academies, which is part of the school choice movement and tied directly to gentrification processes. By building on critical race theory, the author shows how these new schools are functioning to reclaim urban space and displace the communities they were meant to serve. In her case study of Memphis, this process of institutionalization of STEM education has further entrenched educational inequity across racial divides. Bullock shows how initiatives to introduce STEM-rich schools to urban communities can become a vehicle for the spread of Whiteness, and she calls on Lefebvre's proposal for a "right to the city" as a way to reclaim urban spaces for diverse peoples. Bullock's article expands our understanding of how the economic draw and incredible affluence of contemporary cities—under the new climate regime—makes such efforts highly racialized. As cities become sites where immaterial labor flourishes, people living in poverty are expelled to far-flung satellite locations. In the case of Memphis, the global policy of reform STEM education serves to speed up this redrawing of geographic boundaries and repopulating of local environments.

The article by Benjamin Allen, "Exploring the Role of Ideology in Interdisciplinary Science Education Policy," recovers the works of Althusser on ideology and science in order to develop a timely critique of the notion of interdisciplinarity that underpins policy calls for STEM research today. Allen critically examines the historical development of STEM interdisciplinarity, arguing that it is driven in large part by corporate interest in the entrepreneurial potential of postsecondary students. Allen uses Althusser to characterize the relationship between science and ideology, and provides an example of how recent policy efforts destabilize STEM disciplines, serving capitalist infringements into basic research and development.

Finally, climate change provides the background for David Rousell, Amy Cutter-Mackenzie, and Jasmyne Foster's article, entitled "Children of an Earth to Come: Speculative Fiction, Geophilosophy, and Climate Change Education Research." Their STEM education proposal responds to the rapidly changing conditions of the Anthropocene epoch. The authors offer an alternative empirical approach to data, by developing the genre of speculative fiction (drawing on the work of Margaret Atwood, Gilles Deleuze and Felix Guattari, and Steven Shaviro, among many others) as a creative research practice that enables children and young people to imagine and populate future worlds in response to the challenges of the Anthropocene. STEM is thus redeployed speculatively in such efforts—drawing on the tradition of SF—to rethink the future earth. They draw on a participatory research project undertaken in an Australian context, studying the way 135 children and young people relate affectively and creatively with climate change, involving artworks, essays, videos, photographs, poems, and fictional works collected over 3 years. The article focuses on one student's contributions, analyzing how her speculative graphic novel reveals her engagement with climate science.

Altogether, these collected article form a rich mosaic of educational studies of STEM policy and practice. In their attempt to offer alternative onto-epistemologies and reconsider the force and significance of contemporary science, they break with Modernist dualisms (culture/nature, masculine/feminine, human/non-human, science/culture and science/humanities) while also problematizing the stalemate claims of Postmodernist subjectivisms (truth is relative). And yet at the same time, this special issue continues to track the pervasive effects of differencing (e.g., racializing, gendering), scientism and ideology in STEM education policy, and points to the need to be both creative and critical as we turn to new theoretical paradigms. The fact that most of the authors are early career researchers makes this special issue a kind of incubator of future STEM education research, and underscores the inventive and ambitious nature of this collection of articles. We look forward to continuing this conversation at AESA and in the pages of *Educational Studies*.

NOTES

1. We use SF in reference to Haraway's (2016) explanation of "SF: science fiction, speculative fabulation, string figures, speculative feminism, science fact, so far" (p. 2). Haraway asserts that SF creations can include both words and visual pictures, a method of tracing threads of string figures, being those figures, and illuminating patterns and pathways for "the cultivating of multispecies justice" (p. 3). In this sense, SF is both practice and process.
2. In many ways, these developments are already influencing researchers in education. We wanted to include in the notes of this introduction some of the research triggering an unprecedented turn to ontology and the more-than-human (and inhuman) in various sub-

fields: mathematics education (de Freitas & Sinclair, 2013, 2014), science education (Bazzul & Kayumova, 2016; Fenwick & Edwards, 2010; Sørensen, 2011), art education (Rotas & Springgay, 2013), early-childhood education (Lenz-Taguchi, 2015), or research methodology (Daza & Huckaby, 2014; Mazzei & Jackson, 2012).

3. Latour (2017, p. 86) cites Serres (1974), who suggests "There is no pure myth other than [that of] science purified of any myth" (Hermes III: La traduction, p. 259). We note that the mythic Gaia is a smart *trickster*, much like Eshu in West Africa, Krishna in India, and Coyote in North America, each of whom "makes this world" (Hyde, 1998).

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