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Three Ontologies of STEM Education? An Apolitical Curricular Trend, Eurocentric Economic Policy, and Discursive Episteme.

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Abstract

In our efforts to foster space for critical work in STEM (Science, Technology, Engineering, and Mathematics) Education, we put forward differing framings for STEM education that interact with one another, emerging and reconstituting themselves as STEM continues. At present, we suggest three intersecting dimensions to this ontology: STEM as apolitical curricular trend, STEM as Eurocentric economic policy, and STEM as discursive episteme. With the goal of interrupting and proposing alternatives, we conclude by pointing to existing spaces where critical work in mathematics and science education already occurs and how STEM education might move forward.



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Introduction

At educational conferences and beginning to take hold in print, there is an emerging diverse discussion to academically critique STEM (Science, Technology, Engineering, and Mathematics) Education and, in many cases, to subvert such policy initiatives and practices with critical educational motives. As examples, there were session panels at each of the 2014, 2015, and 2016 American Educational Studies Association's (AESA) conference meetings that centered on specific critiques and appropriations of the ubiquitous STEM policies and practices and a well-attended working roundtable session at the American Educational Research Association's (AERA) annual meeting in 2017. As well, we are aware of and involved with conversations occurring at critically-oriented content area educational conferences, such as Society for the Social Studies of Science (4S) and Mathematics Education and Society (MES). *Critical Education's* special series "(Re)Considering STEM Education" is an academic venue dedicated to putting these broadly defined critiques and dialogues between scholars into print. In this paper, we offer an initial consideration of these developments as three emerging ontologies while noting that certainly more exist. We take a step back and briefly consider the reality, or becoming, of STEM and STEM education; in so doing we will argue for a multiple ontologies approach in complicating understandings of STEM. Inspired an introductory read of Barad's (2007) agential realism—a reconceptualization of examining objects with attention to human and nonhuman factors in the production of knowledge and how reality is shaped, we have begun to apply such an approach as a philosophical method in determining three STEM ontologies: 1) STEM as apolitical curricular trend, 2) STEM as Eurocentric (i.e., sexist, racist, neoliberal) economic policy, and 3) STEM as discursive episteme. After introducing and explaining these ontologies, we conclude the article with suggesting that both current and future critics of STEM put to use these multiple ontologies, pointing to critical work within STEM education disciplines for influence and further directions.

Agential Realism

To frame our discussion of STEM's existence, we thought it appropriate to apply what the three of us are learning from, through our reading and study of, the physicist/philosopher Karen Barad's notion of agential realism and the manner in which such ideas are being applied to critical educational studies of differing contexts (e.g. Rosiek & Winslow, 2015). By example of agential realism, in *Meeting the Universe Halfway* (2007), Barad describes at length the physics research community's attempts to come to know more about the theory of light. The debate over its true nature, beginning in the 17th century, has argued between its behavior as a wave versus a particle. Barad (2007), in discussing a variety of experiments completed over the years, expresses a preference for Bohr's "philosophy-physics" (p. 97) that entirely destabilizes the classical ontology of scientific knowledge, explaining:

The nature of the observed phenomenon changes with corresponding changes in the apparatus. But this is contrary both to the ontology assumed by classical physics, wherein each entity (e.g., the electron) is either a wave or a particle, independent of experimental circumstances, and to the epistemological assumption that experiments reveal the preexisting determinate nature of the entity being measured. Bohr's conclusion, as we will see, is that classical physics, along with the classical epistemological and ontological assumptions on which it

is based, is fundamentally flawed. (p. 106, emphasis in the original)

In Barad's agential realism, the way an observer comes to think about reality is entirely entangled with the observer themselves. As with other philosophers of science, e.g. Thomas Kuhn (2012/1962) and Paul Feyerabend (2011/1996, 2010/1975), Barad pushes against an onto-epistemology of science grounded in a quest for objective reality. Instead, she proposes that agential realism reinforces the interaction the observer has with the observed, hence a scientist meets the "universe"—or whatever they are learning about - "halfway" (Barad, 2007, p. 39)

This consideration sparks us, as scholar-activist educators and researchers, to rethink our understanding of the reality of objects, an ontological move away from strict "truths" about things and towards the interconnections—via complex networks of relationships—between all objects of matter and the impact that any observation has on the observer. Furthermore, what the latter might reasonably conclude about the former. The notion of agential realism has extended from the hard sciences towards the social sciences, and certainly within educational studies. One example from critical educational studies comes with Rosiek and Winslow's (2015) application of Barad's agential realism to understanding race:

Consider the contemporary conversations about institutionalized racism that often feel the opposing different ontological framings, such as the need to affirm individual experiences of racial oppression as real and the possible basis of an ethics and politics, the need to highlight the real material structural features of racism that transcend the experiences of individuals, and the need to historicize racism as a discursive process and to avoid reifying the categories of racial difference that are ultimately responsible for the individual and structural manifestations of racial oppression. Each of these framings of racist oppression is compelling and each seems to exclude the possibility of granting a robust salience and realism to the other framings...[Similar to light as particle and wave,] we can say racism is a real personal experience, it is really a structural and material feature of our society, and it is really a discursive phenomenon. There are things that can be learned by studying these different, sometimes contradictory, but nonetheless real manifestations of racism...It is an inheritance of enlightenment settler society foundationalist epistemologies, and the emancipatory theories of social change with which they are associated, that compels us to attempt to synthesize our understanding of racism into a single narrative. (p. xxviii)

Such an approach toward objects, in this case a phenomenon like racism, as having agency requires that we not only take note of the interactions it has with other objects but we also value the interaction as a generative force or a relationship in which both the object and the observer have agency. As Rosiek & Winslow (2015) have done with racism, this means considering individuals, institutions, and structures mostly by scrutinizing existing theoretical contributions not in search of "the grand theory" but instead for the opportunities each might have in explaining particular lived experiences or any other scenario.

All of this is to suggest how we have been inspired to approach STEM education through considering the perspective of Barad's agential realism. In this particular exploration with such a perspective, we posit agential realism as a philosophical method in which we have put forth thought experiments regarding the discussions and other practices that exist in and around STEM education. We asked ourselves, what could this instance be here? How has STEM been framed

by this habit, this teaching practice, this book? As we cautiously embark on such efforts here, we recognize that the ontology of STEM education is a far less theorized domain than other objects, such as racism. Thus we do not have the luxury of drawing upon countless scholarship from a variety of domains to declare the various theories on STEM education's ontology; instead we commence the project by announcing this opportunity continue as a thought experiment. In other words, at this point it we ask: What are some options for describing the ontology of STEM education? Engaged in a study that brings to these questions our influences from postmodernism, ecofeminisms, anarchism, new materialism, and posthumanist philosophical readings and dialogues among other critical scholars. Sharing where we are currently at with this endeavor to dis/entangle the readings, our thoughts, and discussions we propose these options: STEM is an apolitical curricular trend stressing interdisciplinarity, a Eurocentric—sexist, racist, and neoliberal—economic policy with primary interests in corporate profit and assumptions of unlimited growth, and a discursive formation that further entrenches knowledge bound/binaries to powerful effects. In the following sections of this paper we take each of these in turn, briefly, to spark conversations about the multiplicities and theoretical potentialities for engaging in dis/entangling and possible reconfiguration of STEM education.

STEM as Apolitical Curricular Trend

The first ontology, STEM as an apolitical curricular trend, refers to the surface discussion of STEM education presented in most mainstream STEM education publications. These are the contributions that discuss teaching and learning by integrating the four disciplines and depoliticize STEM education by removing it from any social context. Examples of this include the many volumes of STEM teaching handbooks that can be found at online bookstores, such as Johnson, Peters-Burton, and Moore (2015). Their edited volume begins with a superficial discussion of the political motivations for STEM education and largely centers on theorizing an “Integrated STEM Education” with curricular structures motivating teachers to put such integration to work in the classroom. The following are the “distinguishing characteristics” for such a conceptualization of STEM education:

- 1) the content and practices of one of more anchor science and mathematics disciplines define some of the primary learning goals; 2) the integrator is the engineering practices and engineering design of technologies as the context and/or an intentional component of the content to be learned; 3) the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification; 4) the development of 21st century skills is emphasized; 5) the context of instruction requires solving real-world problem or task through teamwork. (p. 23)

Complicating an ontology of STEM as integrated curriculum, these characteristics are not entirely depoliticized. For example, the phrase 21st century skills in this case refers to the “knowledge, skills, and character traits that are deemed necessary to effectively function as citizens, workers, and leaders in the 21st century workplace” (p. 24).

We stress that in the discussions of an integrated STEM curriculum, the push for integrated STEM work often associate with STEM education as human capital, the next ontology to be discussed. However, we pose a possibility that such politicized framing of this integrated curriculum lacks substance. In the spirit of Wedel's (2009) “flexians,” (p. 5) we suggest that

education researchers and educators publish these statements in order to get their points out to the public. Their true contribution to STEM is not the policy objective to develop human capital, but rather the simple understanding that STEM content knowledge should be increased. This presents open doors for critical work as described in the following questions: Can an integrated framing of STEM education curriculum be appropriated and used with framings other than human capital? Can we define 21st century skills differently, such as the knowledge, skills, and character traits that aim to address the ecological and social crises of our time? What conflicts might come about in using the depoliticized STEM curriculum for such different motivations?

The discussion of integrating STEM often suggests that learners will increase their ability in each of the STEM domains through integration. For example, learning elementary mathematics within the context of an engineering a situation, such as designing a playground (Skovsmose, 2011, p. 46), is argued to increase the learner's capacity for understanding the mathematics. Our inclusion of Skovsmose, a critical mathematics education scholar, is deliberate, because the lesson example suggests the manner in which apolitical STEM can be subverted by critical goals for education. The depoliticized interdisciplinary curricular trend of STEM education can be occupied for critical curricular projects as follows: 1) Recognize the policy push for integrated STEM curricular units, often uttered and perceived as apolitical; 2) Develop these interdisciplinary units with goals that also connect the content learning with addressing root causes of social injustices, and environmental catastrophes; 3) Document that learners are increasing their capacities in STEM content areas. In other words, this depoliticized curricular focus is an open door for critical projects, at least for the time being.

STEM as Eurocentric (Sexist, Racist, and Neoliberal) Economic Policy

The next ontological basis for STEM education that we put forth is STEM as a Eurocentric neoliberal economic policy. We use eurocentrism to encompass the racist, Patriarchal, and human centered thinking that emphasizes the autonomous individual and maximization of corporate profit. The depoliticized integrated curricular framework, as above, often pays reference to this reality of STEM education. The same example from Johnson, Peters-Burton, and Moore (2015) motivates their primary curricular contributions, stating:

(T)he key to future prosperity of the U.S. is improving STEM teaching and learning opportunities for our children...anchored by two distinct realities: the jobs of the future are integrally STEM driven and the foundation of STEM knowledge students receive in K-12 has been directly linked to the prosperity of our country. (p. 3)

In such an ontology, the overarching goal for STEM is the development of human capital, or those intangible qualities developed in people that will result in corporate profit.

Neoliberalism is a political and economic restructuring and deregulation rooted in classical liberal economic theory and put aggressively into practice in the 1970s and is well and alive working today centering public policy and social institutions on free market logics (Harvey, 2005). One feature, "accumulation by dispossession" (p. 160), notes that the expansion of capital requires new markets either through imperialism (also known as economic globalization)

or the encroaching on and enclosure of spaces/domains that were once public. Public education is one such space; for example, an urban charter school franchise operating upwards of 200 schools as opposed to the traditional public structures with elected representatives. These franchises may hold non-profit status but function more like for profit private industry in a free market: such schools are often managed by private boards, purchase and rent services from for profit corporations, and contribute to a cornucopia of charter schools that are designed to so-called expand markets and create competition touted as choice for clients (students).

Neoliberal economic and political restructuring benefits from the introduction of a false notion of what is referred to as a “post-racial” society—a society free from racism. Such neoliberal beliefs thrive when individuals compete for their own self-interest. Such a logic deems that markets do not see color and, thus, no one of a particular race or ethnicity is given any privilege. Davis (2012) describing this, explained:

Neoliberalism sees the market as the very paradigm of freedom, and democracy emerges as a synonym for capitalism, which has reemerged as the telos of history. In the official narratives of U.S. history, the historical victories of civil rights are dealt with as the final consolidation of democracy in the United States, having relegated racism to the dustbin of history. The path toward the complete elimination of racism is represented in the neoliberalist discourse of "color-blindness" and the assertion that equality can only be achieved when the law, as well as individual subjects, become blind to race. This approach, however, fails to apprehend the material and ideological work that race continues to do. (p. 169)

As Davis asserts, the truth of the matter is that racial advantage still exists despite the veil of market neutrality. Rosiek & Winslow (2015), mentioned earlier, nicely outline such advantage with respect to education.

To signal the import of these and similar contributions, we have denoted this ontology of STEM not just as *neoliberal project* but rather *STEM as a Eurocentric—and more specifically a sexist, racist, human-centered—neoliberal project*. Doing so complicates the forces of the market and entangles class struggles together with cultural domination. In fleshing out this ontology for STEM, we note the following trends: 1) the paramount motivation of STEM education is the production of human capital for corporate profit, 2) racist structural and institutional forces exist in STEM education, as well as racist implicit biases held by individuals of power throughout STEM education, 3) a secondary motivation for STEM education is the neoliberal enclosure on public education via educational business interests. We will take each of these in turn briefly.

As a racist neoliberal project, STEM education redirects public education towards the cultivation of those intangible qualities in humans that will be most usable for corporate profit. The clear neoliberal orientation to STEM education policy comes mostly from its insistence that STEM content is the most important in winning a global economic race and the countless comments about the dominance of STEM industries today. Most of the apolitical curricular materials pay reference to this before they go into their discussions of STEM teaching and learning. Inherent in these policies is the ongoing class struggle: with STEM education policies rooted in the development of human capital, corporate wealth receives taxpayer-funded investment from which the workers fail to gain the full benefit.

Dedicated study in the implicit and structural racism of this neoliberal project has yet to be fully developed. However, initial directions come from work in a related field: critical mathematics education. As an example, Martin (2013) acknowledges the racialized subtext to mathematics education reforms of the 1960s:

The New Math reform project was not an antiracist vessel in the sea of racial discord characterizing that time. With its emphasis on the “best and the brightest,” it was just another mechanism for maintaining White (male) privilege. One chronology of the “prominent persons” involved in the political project of the New Math movement identified mostly White males, from various backgrounds, as the key leaders and decision makers of the movement, a finding that is common for White institutional spaces (p. 326).

As we now understand them, these reforms were just as much a “new math” reform as they were the early features of nascent STEM education policies. The curricular projects emerging at this time through the National Defense Education Act (NDEA) included mathematics, science, and technology. Viewing NDEA and curricular policies at the time as nascent STEM policies, we consider early STEM to be a White institutional space as well.

STEM as Discursive Episteme

The third and final ontological description is STEM as discursive episteme. To propose this ontology we draw upon the poststructural traditions built upon Foucault and others that point towards STEM education's solidification of knowledge boundaries, connotations, and hierarchies that enact power through language. Arribas-Ayllon and Walkerdine (2008) describe Foucault's definition of discourse as follows:

He is not referring to a particular instance of language use – a piece of text, an utterance or linguistic performance – but describing rules, divisions and systems of a particular body of knowledge. In this sense, discourse approximates the concept of 'discipline' in at least two ways: it specifies the kind of institutional partitioning of knowledge such as medicine, science, psychiatry, biology, economics, etc. But it also refers to the *practices* through which certain objects, concepts and strategies are formed. (p. 99)

For those of us in a current university setting, the divisional practices of STEM discourse are felt in very real ways. Teachers and professors categorize themselves as STEM, Not-STEM (perhaps for the latter, “humanities” or a similar signifier). The division implies our practice, such as whether we seek external funding or are at least perceived as valuable by the institution for such promises. In drawing stark boundaries like these, gray areas that otherwise might exist become lost or more difficult. As an example question, how much of Karen Barad's work, discussed earlier in this article, has been taken up by hard scientists (STEM) versus social scientists (not-STEM)? Our impression is that her contributions are far more celebrated and developed by the latter.

As another consideration of *STEM as discursive episteme*, we offer the conflation of knowledges that comprise STEM and how its message further entrenches “discourses of modernity” (Martusewicz, Edmundson, & Lupinacci, 2015). Taking again the notion a Foucauldian discourse, we argue that the following discursive messages entrenched within

modern society go hand-in-hand with STEM discourse: “individualism, progress, rationalism, anthropocentrism, commodification, and consumerism” (pp. 66-67). STEM education, with its focus to develop those entrepreneurial achievements in science, technology and engineering, dovetails nicely with these goals as it sets apart a content cluster suggested to resonate most with modernity.

As a more specific example, STEM continues a long tradition of conflating science with technology as a mythic path towards progress. Bowers (1993) has found this cultural myth in science textbooks. He writes the textbook authors' efforts to make the connection “between scientific discoveries and the development of new technologies (computers, genetic engineering, telecommunications, etc.), further strengthened through use of appropriate visual images, further promotes the cultural myth that change is linear and progressive in nature” (p. 136). No longer confined to science education textbooks, such myths of modernity like the conflation of science/technology/progress are scaled up via STEM education as discursive episteme. The omnipresent messaging throughout policy, media, curricular materials, and teacher/student life constantly imbues us with a belief in science and technology as the answer to societal and individual needs.

In further illuminating our understanding of three ontologies for STEM, we put together a diagram to put them into conversation. Figure 1 represents each ontology as a circle, with sizes corresponding to significance, arrows denoting pathways of influence, and rupture points pictured as dashed lines. To start, each circle's size corresponds to our understanding of the level of significance it has, with Eurocentric economic policy as further entrenching economic and other social relations between groups of people, curricular trends as impacting the educational system specifically (students and educators and the long lasting effects on students), and discursive episteme as an all encompassing rewrite of knowledge production and internal habits of mind regarding knowledge process and information. In our understanding of STEM history, we place economic policy in the first order chronologically, and the arrows indicate its flows of influence onto education and social thought. As social thought (discursive episteme) becomes further solidified, it also puts pressure on curricular projects, in effect STEM educational practices are thus further divorced from the arts, humanities, and social sciences. The rupture occurs in the educational sphere because the influence of what we might call “critical education” comes to bear on STEM curricular projects. For this reason, we drew the circle with partial dashed lines to indicate potentials for rupture. Consider the possibility that critical education subverts the apolitical curricular trend for STEM education. With the use of dashed arrows, we indicate the potential significance that such a rupture will have to push back on both the discursive episteme and Eurocentric policy as well as enter domains of influence that we might not yet know about. We intend the drawing to both illuminate this discussion and complicate our proposal of these three ontologies for STEM.

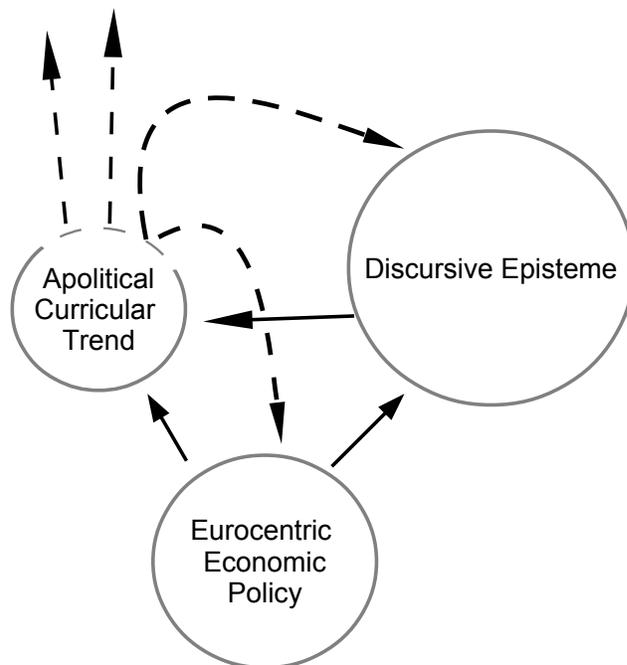


Figure 1: Interaction of Three Ontologies

Conclusion: Motivations, Suggestions, and Inspirations

With these ontologies for STEM, we are simply proposing initial options, ripe for deeper empirical and theoretical discussions. There may be further options for STEM ontology or clarification/redefinition of those we have proposed. All of these we put forth as opportunities to further theorize as well as to frame empirical inquiries into STEM. Considering once again Barad's agential realism, we can frame a STEM research project with one of these ontologies and come to know more about the theory. We also find that a stated commitment to which STEM ontology is active in STEM projects will aim to politicize STEM argumentation more readily.

Thus, we have both laid out the landscape for the object at hand and motivated approaches to a critical reframing and interruption of STEM. We find it especially important to consider STEM as a new cluster of content knowledges and critical STEM approaches must focus on this cluster. A reframing or critique of mathematics, for example, does not pass the muster for a critique of STEM, unless it puts the role of mathematics into conversation with its function in STEM. That said, the STEM interruption we seek must draw on critical work in mathematics and science education that exists in abundance. To conclude the article, we point some example arenas for influence and inspiration; this acts as brainstorming work for an emerging project that deeply critiques STEM education.

Starting with mathematics, there is a strong tradition regarding critical work. For one, there is a subfield that many align with titled Critical Mathematics Education (CME). Mentioned earlier, Ole Skovsmose is one of its major contributors. His (1994) book *Towards a critical philosophy of mathematics education* lays an excellent framework for thinking philosophically about the aims and means mathematics education ought to recognize and serve, which for him is always political in nature. Another strand of mathematics education worth a careful critique are

those works centering on race in mathematics education. Danny Martin, also mentioned earlier in this article, is an excellent scholar to look into. For those looking to get an introductory lay of these fields, one article that discusses both trajectories is written by Larnell, Bullock, and Jett (2016). Journals in which one might find work in mathematics that will inspire critical STEM work include *For the Learning of Mathematics*, *Journal of Urban Mathematics Education*, and *The Mathematics Enthusiast*.

Moving to science, there are similar discussions in place although these focus in other areas. Although in some ways less explicit than in mathematics, there is attention to race and equity in science education. Examples of this kind of work include advances made in applying culturally relevant pedagogy to science teaching (e.g. Laughter & Adams, 2012). Another critical trend in the science education research community is its push for the inclusion of socioscientific issues (SSI) in science curricula. More politicized efforts along these lines come from the developments in integrating science education with the social studies of science (e.g. Weinstein, 2008). A final critical trend in science education are the developments with respect to ecological catastrophe. It appears to us that critical work in science education does not have venues that more readily publish this work; critical science appears in a variety of mainstream science education journals. That said, one journal of note is *Cultural Studies of Science Education*.

For us, one exciting occurrence with STEM policy initiatives is the forced discussions that critical mathematics scholars will now have with critical science scholars. Informally, these have already begun to happen in circles and we have enjoyed noting particular trends and areas in which each domain can be enriched by embracing STEM dialogue. For example, mathematics and STEM have much to learn from science education's emphases on environmental catastrophe whereas science and STEM could do very well with increased understanding of race that mathematics seems to have embraced more directly. All of this is to say that we propose an embrace of STEM at the very least to bring together critical arenas and, as suggested earlier, in the development of critical curricular projects.

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