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Bridges and Boundaries to Power

How teachers used project-based learning to design a radically inclusive STEM high school

Simon Jorgenson
University of Vermont

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Abstract

This study combines critical and social realist perspectives on STEM education to reconceptualize STEM empowerment and examine the experiences of teachers who used project-based learning to design a radically inclusive STEM high school. The findings and analysis illustrate how teachers used the social and material practices of project-based learning to establish an open and inclusive culture of instruction at the school and how they made sense of the patterns of social and curricular integration and disintegration they experienced during implementation. The study indicates the challenges of using disciplinary integration as a principle for STEM curriculum design and suggests the potential for a more subject-based approach to curriculum justice in the context of inclusive STEM high schools. The study ends with an analysis of STEM empowerment at the school and considers implications for critical educators interested in STEM education for students from power-marginalized groups.

Keywords: STEM Education, STEM Schools, Empowerment, Project-Based Learning



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Introduction

STEM education has emerged as a major social and political movement and the centerpiece of national agendas to build economic competitiveness through a combination of educational reform and workforce development strategies. In spite of STEM's discursive reach and political muscle (Wolfmeyer, Lupinacci, & Chesky, 2017), critical educators still know very little about how teachers are understanding and enacting STEM education in the context of urban schools and classrooms. This lack of empirical knowledge is troubling considering that low-income and minority students are among those most likely to be denied access to powerful STEM knowledge (Wheelahan, 2015; Young & Muller, 2013), high-level STEM curriculum (Weis et al., 2015), and engaging STEM instruction (Battey, 2013; Ladson-Billings, 1997; Lubienski, 2002).

Now is a good time to examine these issues. Based on federal recommendations (President's Council of Advisors on Science and Technology, 2010), states are developing networks of publicly funded specialized STEM high schools. Many of these schools are selective and geared towards the academically elite (Teo & Osborne, 2014; Thomas & Williams, 2010), however, an increasing number are *inclusive* STEM high schools specifically designed to prepare historically underrepresented youth for STEM postsecondary education and careers. Although STEM education remains a nebulous concept, inclusive STEM high schools share a distinct set of design characteristics and typically feature a project-based approach to an advanced STEM curriculum that includes opportunities for students to take classes at higher education institutions and partner with STEM professionals for research and career training purposes (Peters-Burton, Lynch, Behrend, & Means, 2014; Weis et al., 2015). Research indicates that the differences between inclusive STEM high schools are due primarily to contextual factors during the implementation process (National Research Council, 2011; Peters-Burton et al., 2014).

In addition to providing high-quality STEM education for students, today's specialized STEM high schools are mandated to research and develop innovative STEM education practices that inform and improve STEM education in their respective states generally (Teo, 2012; Thomas & Williams, 2010). This mandate has provided teachers who work in inclusive STEM high schools—including the teachers who participated in this study—with an exceptional degree of freedom to experiment and imagine new possibilities for STEM education in urban contexts. As such, inclusive STEM high schools provide an opportunity for teachers to reassume their role as “transformative curriculum leaders” (Gornik, Henderson, & Thomas, 2004) whose curriculum design work empowers students by bridging the boundaries and borderlands between disciplines, institutions, and social-cultural contexts (Arhar & McElfresh, 2004; Giroux, 1992). It remains to be seen, however, what teachers are making of this opportunity and how the STEM education they imagine, envision, and hope for students is framed and shaped by policy constraints, the concrete realities of school and classroom life, and the cultural norms of inclusive STEM high schools themselves. For example, many publicly funded inclusive STEM high schools—in spite of their innovative mandate—are subject to the same state-level accountability demands as any other schools, including student achievements on standardized state tests (Peters-Burton et al., 2014). In their comparative study of four public inclusive STEM high schools, Weis et al. (2015) found that these accountability demands contributed substantially to eroding STEM opportunities for students and the original vision of school designers. Teo and Osborne's (2014) research suggests that publicly funded but *selective* STEM high schools are exempt from external accountabilities of this kind.

By examining the experiences of teachers who used project-based learning to design an urban inclusive STEM high school, this study seeks to provide critical educators with insight into how teachers are reframing and reimagining STEM education to better serve the needs and interests of low-income and minority students. In the article, I use Young's (2013) social realist concept of *powerful knowledge* to reconceptualize STEM empowerment and the notion of an empowering STEM education. I argue that the unique character of STEM knowledge as *powerful knowledge* challenges critical educators to reconsider several taken-for-granted assumptions about the relationship between knowledge, curriculum, power, and pedagogy that may not apply in the context of STEM education, assumptions which a social realist perspective helps to uncover. In addition to reconceptualizing STEM empowerment, my research advances the scholarly literature by providing a more focal and nuanced understanding than Weis et al. (2015) and Peters-Burton et al. (2014) of the role of teachers and project-based learning in the design and implementation of inclusive STEM high schools.

A Critical and Social Realist Framework for Researching STEM Empowerment

How can STEM education empower students from power-marginalized groups? Researching this question in context requires a combination of critical, social realist, and qualitative perspectives on STEM knowledge, pedagogy, and curriculum design. I argue that integrating critical and social realist perspectives is necessary because neither perspective alone is capable of capturing the complexity of STEM empowerment or the complex knowledge work of designing and teaching in an inclusive STEM high school. By situating STEM education at the nexus between critical and social realist theories of empowerment, I also hope to disrupt established notions of what a critical STEM education might entail. My choice of qualitative research methods is meant to signal my position as a researcher, which is that a critical theory of STEM education must account for—and be calibrated to—the lived experiences of practicing teachers, those who work closest to the struggle.

What does an empowering STEM education look like from a critical perspective? First, a critical perspective brings attention to how dominant forms of power have used STEM knowledge to regulate and control both human and natural communities (Kahn, 2010; Kincheloe, 2004). Understanding and resisting this power requires that students study STEM in social and historical contexts, “asking questions of the uses to which it has been put and whose interests it serves” (Kincheloe, 2004, p. 30). From this perspective, STEM education is empowering to the extent that students learn to identify dominant power and critique the role of power in the production and use of STEM knowledge. In the context of inclusive STEM high schools, this work is complicated by the fact that these schools are typically governed in partnership with business/industry, higher education, and the neoliberal state—the very same powers that critical educators are anxious to critique (Foster et al., 2010; Franklin, Bloch, & Popkewitz, 2003; National Research Council, 2011; Office of Science and Technology Policy, 2016).

Second, in addition to calling attention to the relationship between dominant power and STEM knowledge, a critical perspective emphasizes the need for STEM pedagogies that position marginalized students as active subjects working to understand the physical and natural world and the social context of their experience. Traditionally, low-income and minority students have been subjected to the opposite, a “pedagogy of poverty” (Haberman, 1991) that is both unimaginative and decontextualized. In response, critical educators in science, mathematics, and

sustainability education have developed a range of inquiry- and project-based pedagogies that privilege youth experience and the codes and practices of family, community, culture, and place (Anderson, 2014; Gruenewald, 2003; Gutstein, 2003; Ladson-Billings, 1997; Leonard & Evans, 2008; Orey & Rosa, 2007; Tal, Krajcik, & Blumenfeld, 2006; Wager & Whyte, 2013; Waxman & Padron, 1995). All of these pedagogies depend on some form of “contextually authentic instruction” for their implementation (Buxton, 2006, p. 713). This often involves taking students outside of school to address real-world issues in collaboration with local community partners and STEM professionals (Bouillion & Gomez, 2001; Buxton, 2006; Fusco, 2001; Wals, Brody, Dillon, & Stevenson, 2014) and/or providing students opportunities to collect real data through the use of portable technologies (Bonney et al., 2014; Tinker & Krajcik, 2001), opportunities which Tate (2001) argues are a “civil right” (p. 1024). From this perspective, STEM empowerment is largely an *instructional* issue, and STEM education is empowering to the extent that teachers can enact context-based instruction that connects real-world issues to the social context of students’ experience. Bybee (2010a) has attempted to narrow STEM education’s focus to instructional contexts associated with a discrete set of sustainability challenges (e.g., climate change, energy efficiency, hazard mitigation) which he calls “STEM-related issues” (p. 32). A more critical approach would invite students to decide for themselves what constitutes a STEM-related issue and what concepts, practices, and resources would help them better understand and address these issues. As Gutstein (2003) notes in regards to critical mathematics education, “a real-life context is not necessarily a meaningful one” (p. 63).

STEM empowerment looks quite different from a social realist perspective, and in ways that have significant implications for how critical educators think about STEM education. Most importantly, social realism opens a theoretical space for critical educators to consider the empowering potential of STEM knowledge itself. Maton and Moore argue (2010):

Social realism attempts to recover knowledge in the service of progress and social justice. The impulse underlying social realist work is towards both the creation of epistemologically more powerful forms of knowledge and establishing the means to enable them to be accessible to everyone. (p. 10)

To accomplish this, social realism theorizes socio-epistemic differences between bodies of knowledge in terms of their structure and purpose and the social relations that sustain them, differences which provide “relatively *objective* non-positivistic criteria” (i.e., realist criteria) for deciding that some bodies of knowledge are “better than others” (Moore, 2013, p. 339). Social realists argue that some knowledge is characterized by its exceptional degree of specialization and differentiation from everyday knowledge and experience. Young (2009, 2013) calls this *powerful knowledge*—a concept which has enlivened recent debate within the sociology of education and curriculum theory (Beck, 2013; Deng, 2015). In regards to curriculum design, Young (2008b) argues that powerful knowledge is context-independent and “cannot, except in special cases, be acquired in homes and communities” (p. 15) but requires school-based curriculum structures that connect teachers and students to universities and other specialized knowledge-based institutions outside of school. Young and Muller (2013) argue that the STEM subjects exemplify the ‘power’ of specialized knowledge because they “offer predictions and explanations beyond any that are possible for those who have to rely only on everyday thinking” (p. 245). From this perspective, STEM is empowering due to the specialized character of STEM *knowledge*, and STEM *education* is empowering to the extent that it provides students access to

the specialized institutions and social networks where this knowledge is produced and acquired (Young, 2013).

Social realist theory drives my primary argument—that the relationship between curriculum, power, and pedagogy is *different* in the context of STEM education than in other contexts that serve marginalized students, contexts that may be more familiar to critical educators than STEM. If one accepts the idea of powerful knowledge and social justice as curriculum principles, then it follows that all students are equally entitled to powerful knowledge through the school curriculum. This means, however, that STEM knowledge may be empowering to students, in terms of its social and epistemological value, irrespective of the powers that produced it (Young, 2013, p. 104). From this perspective, a critical STEM education that focuses exclusively on naming the power interests behind STEM knowledge denies students' cognitive interests and civil right to whatever social opportunities this knowledge might provide. It may be that specialized STEM knowledge is precisely what enables students from marginalized groups to reconstruct society by entering into and deconstructing dominant power systems from within.

Critical educators should find these ideas challenging. The idea that social justice goals can be met through specialized knowledge runs counter to the radical position, which is that academic specialization should be resisted due to its historical association with unequal access to power and knowledge (Young, 2008a, p. 32). These ideas also challenge the belief among many critical educators that empowering marginalized students requires experiential and context-based pedagogies. From a social realist perspective, this approach to STEM education may in fact reproduce the very inequalities it is designed to resist because the knowledge it provides students access to is limited to knowledge that can be acquired through experience alone and within a particular social and cultural context—in other words, *not empowering enough*.

To be clear, I am not arguing that social realism is a more valuable or valid theoretical perspective on STEM education than critical theory or pedagogy. Rather, I am arguing that social realist theory illuminates issues of knowledge and power as they relate to STEM education that critical theory and critical pedagogy are comparatively 'blind' to. What social realism contributes is the idea that STEM empowerment is a social and epistemological matter of redistributing access to specialized knowledge and the specialized locations where it is produced and acquired. This is one important aspect of STEM empowerment—but not the only one. As Zipin, Fataar, and Brennan (2015) have noted, social and educational justice involves much more than simply redistributing access to STEM-based knowledge; it is also an ethical and political matter of recognizing the empowering potential of knowledge produced in diverse and increasingly global social-cultural contexts. What critical theory and critical pedagogy bring to this conversation is a deep appreciation for exactly this kind of knowledge work. For example, Giroux (2011) writes:

Knowledge need not be only indigenous to be empowering. Individuals must also have some distance from the knowledge of their birth, origins, and specificity of place. This suggests appropriating that knowledge that emerges through dispersal, travel, bordercrossings, diaspora, and through global communications. (p. 170)

To close the gap between these different knowledges and contexts, Zipin et al. (2015) argue for a more robust theory of curriculum justice that connects “powerful knowledge *dialectically* with funds of knowledge that carry use-values of diverse social-cultural groups” (p.

32). Here I argue for a similar theory of STEM empowerment that integrates the systematizing powers of specialized STEM knowledge with the life-world knowledge produced and acquired by students through everyday experience. This frames the primary challenge facing teachers as building curricular and pedagogical bridges between the two so that students access powerful STEM knowledge in ways that remain relevant to the social and cultural context of their lives. Social realist theory suggests that different types of boundaries in relation to knowledge, disciplines, and institutions will play a significant role in shaping and influencing this work (Young & Muller, 2010, p. 20).

Research Context, Participants, and Methods

Central STEM High School¹ is an inclusive urban STEM high school serving approximately 900 students. Central's students are predominantly African American, with a very high percentage qualifying for free and reduced lunch. Nearly one quarter are identified as in need of special education and intervention services. In addition to being a state designated STEM school, Central is a state designated site for career and technical education (CTE) and features four STEM-related career pathways in addition to core courses in science, mathematics, English, and social studies. Central is situated in a state recognized for its innovative approach to STEM education policy. State legislation in 2007 set aside funds to establish several new specialized STEM schools and a subcommittee to oversee the process of awarding grants. Those applying for a STEM school grant were asked to provide evidence that the proposed school would feature an integrated and project-based STEM curriculum and collaborative forms of governance to include partners in higher education and business/industry. As such, the state policy signals to teachers and school designers regarding STEM school curriculum, instruction, and governance were very much aligned with the dominant culture of specialized inclusive STEM high schools (National Research Council, 2011; Peters-Burton et al., 2014).

Central's district-based partnership received one of five state grants awarded that year. Central's district is regarded as an urban innovator with respect to teacher leadership, so it was not surprising when district administration hired a group of teachers from within the district to lead the school's curriculum design team. All of these teachers were either teaching at Central when they were hired or had taught there previously. They each had experience with project-based learning, co-teaching, student internships, and other pedagogically progressive practices through their previous work at Central. They each received an academic year's paid release from their classroom teaching duties so that they could focus exclusively on curriculum design and leadership. When the grant was awarded, the district had not yet decided where the new STEM program would be situated, although it was clear that an existing school building would be used rather than a new one being built at the time. Many teachers believed that Central, which was scheduled to streamline its academic programs and had already begun a building renovation process, would be the site. This proved to be the case, and when Central STEM High School opened its doors in 2008, its century-old building housed two separate schools—one school being phased out and one school being phased in. After three years, the transition to Central STEM High School was complete.

The participants for this article were seven teachers at the school, including four of the five teachers selected by the district to design the school's curriculum and two teachers from the

¹ A pseudonym

school's CTE program. All of the participants were involved in the process of implementing the designed curriculum. At the time of the study, I was working as a doctoral level assistant at the school and a school-based liaison for the state's STEM education policy network. Due to the nature of this position, I gained unusual access to the gap between the ideals of STEM education policy and the realities of life in the state's specialized STEM schools. The data sources for this article were drawn from a larger qualitative study that compared curriculum and teaching at several of these schools, including Central STEM High School. I interviewed each of the participants once, a semi-structured interview that lasted approximately 90 minutes. Following the examples of Seidman (2006) and Spradley (1979), I created an interview protocol that invited participants to share their life histories and describe their experiences as curriculum designers and teachers at the school. I asked members of the CDT to reflect specifically on how closely the curriculum they had designed matched the curriculum implemented at the school. At the time of the study, the school was in the third year of implementation. Data analysis combined connecting and categorizing strategies (Maxwell & Miller, 2008). Narrative analysis using the Listening Guide (Gilligan, Spencer, Weinberg, & Bertsch, 2003) was conducted to determine central themes, tensions, and metaphors related to the participants' lived experiences. These were treated as codes and applied across the data corpus (Saldaña, 2009) which included additional documents related to the school's curriculum and curriculum design process. My selection and use of evidence was similar to the iterative process described by Eisenhardt (1989), where a researcher moves back and forth between multiple data sources, the research topic/questions, and the extant literature.

The Work Begins: Building an Open and Inclusive Culture

The teachers on the curriculum design team (CDT) recognized the unique nature of their situation of being hired to design the curriculum of a new inclusive STEM high school. They credited a strong teachers' union and building/district tradition of teacher leadership for this. One teacher explained: *"The driving force was the union, which at the time was really promoting teacher leadership, and we came from an environment under [a former principal] in which it was really fostered, in which you give responsibility to your teachers...and they do incredible stuff."* From a critical perspective, this was promising and indicated that the historical power relations between teachers and administrators had been reconfigured, with the help of the local teachers' union, to support teachers' professional judgment about curriculum. Typically, as Kincheloe (2004) notes, in the dominant culture of schooling, "teachers are seen as receivers, rather than producers, of knowledge" (p. 19).

The CDT teachers quickly learned that there were limits to their knowledge and powers. Research suggests that transformative curriculum leadership involves teachers and administrators working closely together within a supportive district context (Gornik et al., 2004). In this respect, the CDT's design year experience was not ideal. Several teachers mentioned that a principal administrator was not assigned to the project until late in the design year. This meant that that the CDT had to make administrative decisions as well as curricular decisions. They found the district to be structured in such a way that teachers had a difficult time getting answers to administrative questions. The absence of an administrator also made their work less focused and efficient. One teacher said: *"A principal could have—and I think should have—worked to set up some boundaries, you know, let's narrow our thinking, and they would have helped shape the work and our thinking."* Social realism helps explain this experience. From a social realist perspective,

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the boundaries between administrators and teachers are not arbitrary or inconsequential because administrators bring specialized professional knowledge to the school and curriculum design process that teachers do not, knowledge that provides contours and constraints to the work (Young & Muller, 2010, p. 18).

Despite these difficulties, the CDT remained committed to their vision for a radically inclusive STEM school that had no admissions requirements or entrance examinations of any kind. As one teacher said: *“We didn’t want to create a school that no kid could get into or be successful at.”* Visits to STEM schools in other parts of the country provided examples of practices to avoid. For example, one teacher shared: *“Even the schools that had no entrance requirements, they had kind of hidden entrance requirements when you have a mandatory 6:00 PM interview to come into the program and both parents have to be there.”* In this case, the CDT recognized that this requirement would exclude students from admission whose parents worked second shift or were hesitant to come to school themselves due to their own negative experiences with schooling. Several of the participants mentioned that none of the STEM schools they visited served a student population similar to their own. This lack of models of radically inclusive STEM high schools is evident in the literature as well. For example, Dozier-Libbey Medical High School and Manor New Technology High School, the inclusive STEM high schools selected as ‘success’ stories by the National Research Council’s *Committee on Highly Successful Schools or Programs in K-12 STEM Education* (National Research Council, 2011), are both strikingly different than Central in terms of student demographics.

	<i>Students</i>	<i>African American</i>	<i>Economically Disadvantaged</i>	<i>Special Needs</i>
Central STEM High School	890	90%	99%	23%
Dozier-Libbey Medical High School	685	19%	45%	7%
Manor New Technology High School	384	22%	54%	2%

Table 1: Demographic differences between Central STEM High School and two models of successful inclusive STEM high schools. Data for Dozier-Libbey Medical High School and Manor New Technology High School from National Research Council (2011, pp. 14, 16).

Without a clear model for STEM education or a radically inclusive STEM high school, the CDT gathered ideas from a range of sources and re-designed these ideas to fit the context. One of the teachers summarized the CDT’s design process as follows: *“We did a lot of research on the net and called people. As much as we could, we tried to get good information about best practices, about what was going on with STEM as we knew it at the time. And from that, we designed what we felt like would fit for kids, you know? [Central] is in the middle of the city. It’s an urban school. It’s kids from all over. The demographics haven’t changed. We probably have more kids on free and reduced lunch than when I first started at [Central], but it’s still the same kind of kids, you know? And so, we wanted to make a school that was still for those kids.”*

Incorporating the Social and Material Practices of Project-Based Learning

For the CDT, project-based learning represented their desire to create a STEM school where students were *active* and *doing* and teachers were busy designing projects to support this activity. As such, the CDT understood STEM education in terms of acting persons. One teacher explained why the CDT judged project-based learning superior to problem-based learning, which had been recommended to them by a university researcher: *“We wanted to design projects that students were working on, many of which have this overarching idea, and solve a problem, but we were about doing projects.”* Observations of other project-based STEM schools introduced the CDT to new social and material practices associated with project-based learning, several of which became critical design components for the team.

Research indicates that not enough attention is paid in urban school settings to comprehensive systems of support for progressive instruction (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000; Wager & Whyte, 2013). What I find striking and significant about Central is the combination of social, material, and relational supports envisioned by the CDT. The CDT appeared especially cognizant of how school buildings themselves, and the physical arrangement of learning environments within schools, support the social configurations between teachers required to sustain project-based instruction (Blumenfeld, Krajcik, Marx, & Soloway, 1994; Roth, McGinn, Woszczyzna, & Boutonne, 1999). One example is glass classroom walls, which the teachers observed at several of the STEM schools they visited during the design year. The CDT valued glass classroom walls primarily for their potential to build and sustain a culture of instructional excellence through teacher-to-teacher accountability. One teacher recalled: *“When I saw these places with the glass, I was like what a dream to be able to look through a place and see what every class is doing in their room, right? And to let every teacher see how hard each other’s classes are working and how much is being done and create that environment in which, you know, there’s a great positive peer pressure to be doing great things.”* Teo and Osborne (2014) argue that these forms of personal and professional accountability are central to how teachers and administrators use power to maintain and project teacher quality in the context of specialized STEM schools and other emerging school types that feature a high level of curriculum autonomy.

When the CDT teachers learned that district administrators had chosen Central as the site for the new STEM school, Central’s century-old building was already in the process of being renovated. When they learned that glass classroom walls were structurally and financially out of the question, they lobbied successfully to have glass windows added to the classroom doors instead. Other classroom features the CDT believed to be critical components of a project-based STEM school, such as sliding classroom dividers, were deemed too expensive. One teacher explained: *“We had to put on multiple meetings with architects and say, but you don’t understand, we’re trying to bring a STEM school here. We need project space. We need drops for computers. We need outlets. We had to come in and ask for all that stuff. And we could only make so many changes because we were late in the game, and the building was being designed to be your traditional, you know, industrial, run your kids through their classes and get them out. No project-based learning. No technology integration. And we fought hard for that stuff.”* The lack of sliding classroom dividers proved to be a significant constraint to implementing the designed curriculum. For example, the co-taught tenth grade English and social studies course the CDT

envisioned had to be implemented with 60 students gathered together in one large room with no physical means to separate the class into smaller groups, a situation that proved unsustainable.

The CDT designed and implemented other project-based practices as a means to bridge school and community contexts and programmatically enhance STEM opportunities for students. The most significant of these was intersession—a week devoted entirely to community-based STEM projects—which the team observed at a local Montessori high school. Intersession solved a significant problem for the CDT: how to maximize and diversify partner engagement without over-burdening partners with visits to the school. Intersession also fixed community-based partnerships into the school’s institutional fabric and culture of instruction. Central’s intersession program modeled a research-based approach to urban STEM education. The community partnerships teachers developed in the context of intersession served as contextual scaffolds for bridging STEM “as represented in classrooms” and STEM “as represented in communities outside school” (Bouillion & Gomez, 2001, p. 879) and introduced students to new social spaces where STEM was practiced and STEM knowledge produced (Buxton, 2006). The CDT was adamant that students self-select for the intersession projects each year, a decision which empowered students to develop STEM-related identities which were both meaningful and personally relevant (Furman & Barton, 2006).

Breaking Down Walls: Social and Disciplinary Integration

In designing the curriculum for Central STEM High School, the teachers on the school’s curriculum design team focused on disciplinary integration. As one teacher explained, this is what they understood STEM to mean: *“As we first started talking about what STEM was and trying to define it, one of the things we talked about as being the cornerstone was breaking down those traditional walls you find in school, the walls between disciplines.”* Their goal was to have as many interdisciplinary projects as possible on every grade level team. This commitment to curriculum integration is reflected in the core curriculum the CDT designed for the school’s inaugural year. In addition to co-taught classes that integrated English with social studies and English with science, the curriculum included an integrated mathematics and social justice course and an integrated STEM project to anchor each quarter. Each of these anchor projects involved an external partner, either a community organization or business/industry partner. These projects were complemented by project-oriented capstone courses (Dutson, Todd, Magleby, & Sorensen, 1997) in each of the school’s STEM-related career pathways. The CDT envisioned technology class as the place where students would complete the interdisciplinary projects they had been assigned in their core classes and create multi-media artifacts. Project checklists, shared regularly with parents, were seen as a way to organize student work, facilitate communication between home and school, and interrupt the traditional power dynamics between teachers, students, and parents (Elmesky & Tobin, 2005; Wager & Whyte, 2013).

The CDT knew from experience that implementing the ambitious curriculum they had designed would require a deep culture of relational trust and vulnerability. Several teachers mentioned that interdisciplinary projects required teachers to reveal the limits of their content knowledge to one another. Similarly, projects that integrated school partners required teachers to open their classrooms and teaching practice to people who might not understand the realities of urban schooling or the working conditions of their lives. The teachers also knew that

interdisciplinary projects required school structures that allowed teachers to connect with one another during the school day. At Central, this meant that the master schedule needed to include ‘special’ periods (e.g., music, art, physical education) when students were out of their core classes so that teachers could design projects collaboratively. As one teacher explained: *“How can I link the math to a social studies or English class if I don’t have access to the social studies teacher or English teacher during the time that I’m in the building?”*

The participants’ interpretation of STEM education in terms of curriculum integration through interdisciplinary projects is significant. Currently, both the research literature and state policy signals reflect the assumption that STEM education reform requires curriculum integration (Capraro, Capraro, & Morgan, 2013; National Academy of Engineering & National Research Council, 2014; Wang, Moore, Roehrig, & Park, 2011), an assumption that the ‘STEM’ acronym itself works to reify. This assumption is based primarily on the theory that the “grand challenges facing society” are STEM-related (Bybee, 2010b) and so complex that understanding and addressing them requires an interdisciplinary approach. This assumption persists despite the lack of effective instructional models for interdisciplinary K-12 STEM education (Bybee, 2010a; Stohlmann, Moore, McLelland, & Roehrig, 2011), perhaps bolstered by the perceived relationship between curriculum integration and democratic schooling (Beane, 1997) and the belief that interdisciplinary projects develop a specific set skills (e.g., critical thinking, collaboration) required for success in the 21st century post-industrial workplace (Bell, 2010; Boss, 2013; Capraro et al., 2013). When one considers the value of project-based learning to the design culture of inclusive STEM high schools (Peters-Burton et al., 2014), Central’s building tradition of project-based learning, and the state’s mandate that STEM schools feature a project-based and integrated STEM curriculum, it is no surprise that the members of Central’s CDT interpreted STEM education in terms of curriculum integration. From a social realist perspective, however, the CDT’s desire to “weaken the boundaries” (Young & Muller, 2010) between teachers, classrooms, disciplines, and subjects through progressive pedagogy was misguided because these boundaries serve an important curricular role as “conditions for innovation and the production and acquisition of new knowledge” (Young & Muller, 2010, p. 16).

STEM, Social Justice, and Sustainability Projects

In the first year of implementation, Central’s district was awarded a federal grant to support science-focused environmental projects at the school, projects similar to the ‘discipline first’ projects recommended by McPhail (2018) where students apply disciplinary knowledge to interdisciplinary problems and contexts. These projects significantly enhanced Central’s curriculum and identity as a STEM-focused school. The sustainability challenges at the center of the projects (e.g., climate change, energy efficiency, sustainable food production) were STEM-related issues that aligned well with STEM education’s “curricular theory of action” (Bybee, 2010a, p. 33) and professional discourse in the STEM fields (Omenn, 2006). Addressing these issues in the manner described in the proposal required students and teachers to collaborate closely with university researchers, graduate students, public corporations, and community organizations, collaborations that were encoded into the projects during the grant proposal process. Through these projects students learned new technical skills (e.g., how to conduct an energy audit) and were introduced outside of school to the specialized codes, practices, and analytic tools used by local STEM professionals and corporate problem-solvers. Students developed action plans and multi-media presentations to influence household, school, and

community members to more deeply consider the environmental implications of their actions and behaviors. With grant funds, the school purchased backpacks and portable technologies that allowed students to collect data while in the field and create new scientific knowledge to share on the project website. These backpacks allowed students to more actively participate in producing STEM-related knowledge outside of school, thereby disrupting unjust notions of *who* gets to produce specialized powerful knowledge and *how* (Zipin et al., 2015). Other science- and engineering-based environmental projects at the school connected Central's students with graduate students in urban planning and local community garden organizations, projects which Fusco (2001) argues invite students to "create science...performances, tools, and discourses that are extensions of their lives, cultures, and communities" (p. 862).

As was the case with many projects at Central, the school's science-focused environmental projects—and the sustainability challenges at their center—were highly valued as a context for connecting student interests to STEM careers. For example, one of the school's CTE teachers said about sustainable energy and the energy project: *"I want them [students] to get a job in it because I know it's a really hot career right now. Play some type of role in it. If you want to go into healthcare, that's fine. But figure out your niche with sustainable energy. Be the person that innovates something that helps at the hospital, that helps recycle equipment. Start thinking outside the box. Not only what you can do in that career, but what you can do for others within that career."* The curriculum and pedagogy of this particular course invited students to: (1) anticipate occupational fields that would emerge as global climate change initiated a societal transition to sustainable energy; (2) research attributes of specific careers in these fields, (e.g., salary, working conditions, educational requirements); and (3) identify matches between their personal skills/values and the skills/values required for professional success in these careers. In this case, STEM empowerment was viewed through an occupational lens.

Although the curriculum designed by the CDT includes several examples of knowledge relevant to low-income and minority students, one course was specifically designed around critical education principles, a mathematics course which combines ethnomathematics (D'Ambrosio, 1985; Orey & Rosa, 2007) with ideas from Gutstein's (2003) project-based approach to teaching and learning mathematics for social justice. The teacher who designed the course appreciated mathematics deeply and wanted his students to do the same. He noted that mathematics is the only core discipline whose history is not included in its standards. By contrast, the curriculum he developed deeply contextualized mathematics for students through a cross-cultural history of Eurocentric, African, and Asian mathematics models, and although not overtly political, clearly recognized the empowering potential of diverse ethnomathematical knowledge and the need to "confront and then counter" the Eurocentric historiography of mathematics in the mathematics classroom (Joseph, 1987, p. 26). A core idea of the course is that mathematics was invented to solve a particular problem at a particular time. The teacher said: *"I believe there are lots of nuances to mathematics. I believe that there's a lot of hidden beauty. I believe that there are a lot of things in math that are not explored. You never hear about, that there was a violent debate between, you know, that the discovery of calculus almost ended in a dual, with two people trying to kill each other over discoveries. And I think that that's what makes it an interesting discipline, not just the black line, master copy, rote skill that people do."* Here the teacher speaks to one of the primary objectives of Gutstein's (2003) pedagogical approach to social justice—using the teacher's role to decenter their dispositions and orientation towards mathematics as a "rote-learned, decontextualized series of rules and procedures to memorize, regurgitate, and not understand" (p. 46).

When asked how the course addressed social justice, the teacher who designed the course said: *“I want to meet the students where they are, and see what they have, what they're bringing to the plate, and rather than change their viewpoint, enhance it and bring it to like my language. So they know math already. And I think that that's where the social justice piece comes in. I'm taking what they know and I'm just adding the mathematics language to what they're doing.”* Throughout our interview, this teacher made clear that he counted student experiences outside of school as mathematical knowledge worthy of representation in the curriculum and strived in the classroom to pedagogically connect that knowledge to the disciplinary language and practices of mathematics.

Disintegration and Loss of Project Partners

Although a full account of curricular implementation at Central STEM High School is beyond the scope of this paper, it is important to identify how the CDT's original plan was shaped by the realities of school operations during the implementation process. In sum, the data indicate a process and outcomes similar to that found by Weis et al. (2015) in their longitudinal study of inclusive STEM high schools whereby the curricular innovations envisioned by school designers became difficult to sustain as the schools grew more operationally complex.

At Central, the school grew quickly to be larger than anticipated, and the instructional culture established during the design year and first year of operations was compromised as the school hired many new teachers whom the school community did not have the time or resources to fully socialize and enculturate. In addition, integrated STEM projects were disrupted as teachers moved across grade levels to accommodate the changing needs of the school. In this sense, sustaining the school's project-based culture of instruction depended on social stability. The data also provides evidence that Central's teachers may have been differentially invested in project-based learning. For example, one teacher described why they preferred teaching intersession projects at the school.

It [intersession] makes it easier because you don't really have to collaborate with anybody but yourself. So, if there's a math piece, you're teaching the math piece, not the math teacher. You don't have to tell the math teacher what to do. You don't have to talk about it. You don't have to decide about it. You don't have to do anything but teach what students need to know that's math-based for the project. That's in intersession, because you're the teacher of record. You're the only one that they get to see. But during the regular school year, like for the energy project, there were actually pieces that should be facilitated in technology class, pieces that should be facilitated in language arts class, that should be facilitated in the math class, which means that you have to coordinate and collaborate with those teachers who may or may not have the same vested interest in the project that you do.

In addition, despite its innovative mandate, Central STEM High School remained tied to state achievement tests, district assessments, and district curriculum pacing guides in its core courses, and it was clear that student achievements on these assessments would be the primary measure used by outside observers to judge the quality and success of the school. Urban educational research is conclusively clear on the corrosive effects of these “technologies of power” (Kincheloe, 2004, p. 99) on student confidence, teacher morale, professional community,

and classroom teaching (Cuban, 2013; Hargreaves, 2003; Settlage & Meadows, 2002; Spencer, 2012; Weis et al., 2015).

When I asked how teachers of core classes at the school could sustain a project-based approach to instruction under these conditions one teacher responded:

Project-based learning can still be done in a content or core class. A teacher has to be committed to it. They have to really know what they are doing and they have to really make sure that while they're doing the project-based content that they are also hitting their standards and that their kids are moving along, meeting the pacing guide that's assigned by their district. Otherwise, they'll spend eight weeks doing a project and they just won't get to all of what they're supposed to get to.

District policies—not teacher desires—also determined the number of teachers assigned to the school. Larger than expected class sizes, fewer teachers than anticipated, poor acoustics, and the lack of classroom dividers made co-teaching at Central in the manner envisioned by the CDT impossible. When asked how many teachers were still implementing the curriculum the CDT had designed, one teacher said: *“There might be one or two math teachers that are still doing this. There might be a couple science teachers that are still trying to implement. There's some that have gotten frustrated because of certain things happening that they've resorted to more of a traditional approach.”*

The school also experienced a transition in regard to school partners. Several of the school's corporate partners disengaged from the school for reasons beyond the teachers' control, in one case due to business-related conflicts with the district and in another case due to changing corporate priorities related to community outreach and engagement. As they did, students lost connection to the specialized social networks and institutions of each. One of the CDT teachers said: *“I just don't know if they really understood the value that they added to the experience for the kids, you know, for that lifelong memory that kids will have about the work. To me it's a shame.”* What remained elusive was a curriculum where the boundaries and barriers between teachers and specialized STEM partners outside of the school disappeared. One of the school's CTE teachers described what this ideal looked like for her: *“So if...when we are doing the automation and robotics unit. I, it would be, there's no barriers for me to call someone at [large engineering firm]. I don't know a specific contact person. If there's a list provided. OK, this person knows about the Project Lead the Way curriculum, they're available to come in and teach, you know, they know that, OK, if you're teaching automation and robotics, and you are at section 3, they're already up to speed on what is needed and what is taught.”*

Despite these challenges, it is important to note that teachers of capstone courses in Central's CTE program experienced significant curriculum autonomy throughout the implementation process. Although there were federal and state content standards for CTE, there were no assessments or exams tied to these standards, nor were there any district standards, exams, and curriculum pacing guides. As such, the teachers at the school who most accurately enacted the curriculum originally envisioned by the CDT—a vision which included teachers designing and enacting projects throughout the school year—appeared to be Central's CTE teachers. When asked to describe the capstone course curriculum, one of Central's CTE teachers said: *“My class is all project-based. Most of my units are three or four weeks long and there's little individual grades along the way, like checkpoint kind of grades. But there's really only one big major grade at the end of the project, whether that's a report or that's a demonstration or*

that's a product you built or something, so that's kind of how I have done my curriculum." This teacher said that this arrangement would not have been possible before when they were teaching chemistry, a course required by the state and structured by the district. *"Like in chemistry, I don't think I could, when I taught chemistry I could not pull, I could not, I could not do an extended three-week project and devote three weeks to one project. [Why not?]. Because I'm just, the pacing and sequence and timing of the year, I would run out of time."*

Revisiting STEM Empowerment

In this section, I return to the ideas set forth in the conceptual framework, arguing for the need to combine critical and social realist perspectives on STEM knowledge, pedagogy, and curriculum design when researching empowering STEM education. As I argued earlier, the social realist concept of *powerful knowledge* (Young & Muller, 2013) opens a theoretical space for reconceptualizing STEM empowerment in terms of integrating the specialized STEM knowledge produced in specialized institutions with the life-world knowledge produced, valued, and used by students in diverse social-cultural contexts (Zipin et al., 2015). This reconceptualized notion of STEM empowerment framed the primary challenge facing the teachers who participated in this study as bridging these knowledges and locations through project-based pedagogy and curriculum design.

How empowering was this approach to STEM education? Although a thorough answer to this question would require student interviews and classroom observations—a primary limitation of this study—the data strongly suggest that Central's teachers valued the life-world knowledge of their students and the need to represent this knowledge in the curriculum, which they did by grounding their classroom instruction in relevant social and cultural contexts (Battey, 2013; Leonard & Evans, 2008; Zipin et al., 2015). As such, the data suggest that Central's teachers were able to develop and enact, although to varying degrees, pedagogies and approaches to instruction that this study's framework suggests are empowering to students. The STEM education reported by the participants closely matched what research, theory, and exceptional urban STEM educators suggest as an antidote to the "pedagogy of poverty" described by Haberman (1991). For example, Central's teachers were successful at introducing students to new social locations beyond the school building where they collaborated with community and business/industry partners (Bouillion & Gomez, 2001), practiced science and engineering with urban planners and gardeners (Fusco, 2001), explored STEM identities in different social contexts (Elmesky & Tobin, 2005), and used digital tools to create project artifacts that amplified their voices (Furman & Barton, 2006). The instructional context that appeared least often in the data is one most germane to the interests of critical educators—the sociopolitical context of students' lives—and it was unclear to what extent students were empowered to develop sociopolitical consciousness by using STEM to analyze social injustices like racism, power dynamics within society, and the unequal distribution of resources (Gutstein, 2003). This instructional context may have appeared in Central's many community-based intersessions which were not included in this study.

How powerful was the STEM knowledge included in the curriculum? The data indicate that the curriculum designed by the CDT and implemented by Central's teachers was based primarily on context-based and interdisciplinary knowledge rather than specialized disciplinary knowledge. What appeared to be missing were curricular structures that supported teachers in developing and sustaining collaborations with specialized STEM entities outside of the school,

structures that Young (2008b) argues facilitate the teaching and learning of *powerful knowledge*. The data indicate that at least one, if not more, of the study's participants would have appreciated help with the task of translating specialized STEM knowledge into useful course sequences as well as additional opportunities to acquire specialized knowledge themselves. The significance of the social and curricular disintegration reported by the participants depends on where one stands at the nexus between critical and social realist perspectives on empowerment as it relates to disciplinary knowledge. Disintegration in this case could indicate that Giroux's (1992) pedagogical and political project of "refiguring" the borders and boundaries between disciplines had failed to take root at Central STEM High School, proving once again the dominance of specific forms of knowledge and relations of power. Alternatively, it could indicate that Young and Muller (2010) are correct in claiming "the 'non-arbitrariness' of boundaries between knowledge domains" (p. 15) and the need to place "[b]oundary maintenance...prior to boundary crossing" (p. 16) when thinking about socially just curriculum. Disintegration could also indicate that Central's instructional culture was becoming more subject-focused over time, which from a social realist perspective would indicate a potential *increase* in student access to powerful knowledge. What was problematic from a social realist perspective was the disintegration of projects that included external STEM partners because these projects were the primary curricular bridge between Central STEM High School and specialized social and institutional contexts where powerful STEM knowledge is produced and exchanged. For critical educators, the significance of these bridges depends on whether or not one believes that knowledge acquired in private, corporate, or industrial contexts can be put to political and socially reconstructive purposes.

Two final points in regards to the data as it relates to STEM empowerment. The first point is the extent to which Central's CDT were disempowered themselves. Giroux (1992) argues that "developing and implementing progressive pedagogy" in the manner envisioned by the CDT (e.g., co-teaching, designing integrated projects) requires an "emancipatory authority" (pp. 106-107) to influence the fundamental conditions of their work which Central's CDT did not have. Although they were free to design an innovative project-based STEM curriculum, they did not have the power or the authority to influence the state's high-stakes testing and accountability system which drove the district's curriculum frameworks and assessment policies and worked against the instructional culture they had envisioned and initially enacted at the school. The data indicate that the presence or absence of these external accountabilities is what made teaching core courses, CTE capstone courses, and intersession projects at the school such different experiences.

Considering the data in the context of the innovative culture of inclusive STEM high schools (Peters-Burton et al., 2014) draws our attention *not* to the striking array of innovative practices evident at these schools but to the underlying structures which remain beyond teachers' power to change. Writing from a critical perspective, Pais et al. (2012) argue that these structures become most evident when teachers try to "implement powerful ideas in schools" (p. 32) such as those proposed by Central's CDT. Pais et al. (2012) conclude that change and choice in this context is both deceptive and illusory.

The message we get is that it is fine to change teaching methods, learning strategies and even the curricular content—what can be called, after Marx, the superstructure of schooling—as long as the core features of the system (capitalist schooling based on accreditation, the infrastructure) remains the same. (p. 31)

From this perspective, the curriculum autonomy which Central's CDT experienced initially disguised the durability of the state's exams-based assessment system and the power of state policymakers to decide which state requirements would apply to STEM schools and which would not, decisions that structured the work of implementing and sustaining the CDT's original vision. For example, by mandating that STEM schools adopt a project-based approach to an interdisciplinary curriculum, state policymakers placed teachers of core courses in the deeply problematic position of having to prepare students for standardized and discipline-based assessments through an experiential and context-based approach to an interdisciplinary curriculum.

A second key point that emerges from the data concerns the relationship between curriculum integration and empowerment in the context of inclusive STEM high schools. Although the CDT understood STEM education to mean breaking down the traditional walls between disciplines, the data indicate that interdisciplinary projects were difficult for teachers to put into practice. Whereas there are many practical reasons why the social and material boundaries between teachers and classrooms proved difficult to break at Central, the theoretical explanation I find most plausible is that these boundaries are epistemologically grounded *in addition to* being socially and materially constructed. With this in mind, and drawing on the work of McPhail (2018) and Young and Muller (2010), I suggest that critical educators and designers of inclusive STEM high schools question the idea that empowering students from marginalized groups requires curriculum integration and seriously consider the warrants for a discipline-based approach to STEM empowerment whereby teachers and students apply disciplinary concepts to interdisciplinary problems through critical and context-based pedagogies, projects similar to the science-focused environmental projects found at Central STEM High School and recommended by science education research (Blumenfeld et al., 2000). Relatedly, I suggest that critical educators resist the seductive pull of project-based learning conceptualized as a tool for STEM integration (Capraro et al., 2013) and/or 21st century skill building (Bell, 2010) and reconceptualize projects as a subject-focused method for teaching *powerful knowledge*. This more traditional approach to project-based learning, which originated in European schools of architecture and engineering in the 1700s (Knoll, 1997), requires students to demonstrate their mastery of the knowledge and practices of a specific discipline or profession by completing a sequence of design challenges that culminate in a capstone project undertaken in collaboration with industry partners and/or juried by a professional audience (Dutson et al., 1997), projects similar to those found in Central's CTE capstone courses which remained autonomous from state and district management policies throughout the duration of the study.

Conclusion

This study has illuminated the complexities of designing and implementing a radically inclusive STEM high school for students from power-marginalized groups. The study has demonstrated the challenges of sustaining a project-based culture of STEM instruction on the principle of curriculum integration as well as the opportunities afforded by a more subject-focused approach to STEM projects. Although external accountabilities constrained the implementation of empowering curriculum and progressive pedagogies at Central STEM High School, innovations such as intersession and capstone projects in CTE courses provide reasons for critical educators to be optimistic that leverage points and opportunities to intervene do exist. Given how central STEM partnerships are to STEM education discourse and policy, and to the

teachers who participated in this study, it is worth considering how critical educators might enter into these partnerships to advance their politics of understanding, perhaps serving as liaisons who work in the borderlands between critically minded teachers and STEM professionals in business, industry, and higher education. The purpose of these travels would be to provide students from power-marginalized groups with greater access to the specialized codes and practices that undergird and rationalize dominant STEM power, codes, and practices that students can use to produce a more powerfully critical STEM at the intersections of STEM, social justice, and sustainability.

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References

- Anderson, C. R. (2014). Place matters: Mathematics education reform in urban schools. *Journal of Urban Mathematics Education*, 7(1), 7-18.
- Arhar, J. M., & McElfresh, R. (2004). Blurring the borderlands: Imagining new relationships. In R. Gaztambide-Fernández & J. T. Sears (Eds.), *Curriculum work as a public moral enterprise* (pp. 15-27). Lanham, MD: Rowman and Littlefield.
- Battey, D. (2013). "Good" mathematics teaching for students of color and those in poverty: The importance of relational interactions within instruction. *Educational Studies in Mathematics*, 82(1), 125-144.
- Beane, J. A. (1997). *Curriculum integration: Designing the core of democratic education*. New York: Teachers College Press.
- Beck, J. (2013). Powerful knowledge, esoteric knowledge, curriculum knowledge. *Cambridge Journal of Education*, 43(2), 177-193.
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *Clearing House*, 83(2), 39-43.
- Blumenfeld, P. C., Fishman, B. J., Krajcik, J., & Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist*, 35(3), 149-164.
- Blumenfeld, P. C., Krajcik, J. S., Marx, R. W., & Soloway, E. (1994). Lessons learned: How collaboration helped middle grade science teachers learn project-based instruction. *Elementary School Journal*, 94(5), 539-551.
- Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next steps for citizen science. *Science*, 343(6178), 1436-1437.
- Boss, S. (2013). *PBL for 21st century success: Teaching critical thinking, collaboration, communication, and creativity*. Novato, CA: Buck Institute for Education.

- Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school-community partnerships as contextual scaffolds. *Journal of Research in Science Teaching*, 38(8), 878-898.
- Buxton, C. A. (2006). Creating contextually authentic science in a "low performing" urban elementary school. *Journal of Research in Science Teaching*, 43(7), 695-721.
- Bybee, R. W. (2010a). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30-35.
- Bybee, R. W. (2010b). What is STEM education? *Science*, 329(5995), 996.
- Capraro, R. M., Capraro, M. M., & Morgan, J. R. (Eds.). (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2nd ed.). Rotterdam: Sense Publishers.
- Cuban, L. (2013). *Inside the black box of classroom practice: Change without reform in American education*. Cambridge, MA: Harvard University Press.
- D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the Learning of Mathematics*, 5(1), 44-48.
- Deng, Z. (2015). Michael Young, knowledge and curriculum: An international dialogue. *Journal of Curriculum Studies*, 47(6), 723-732.
- Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A review of literature on teaching design through project-oriented capstone courses. *Journal of Engineering Education*, 86(1), 17-28.
- Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, 14(4), 532-550.
- Elmesky, R., & Tobin, K. (2005). Expanding our understandings of urban science education by expanding the roles of students as researchers. *Journal of Research in Science Teaching*, 42(7), 807-828.
- Foster, K. M., Bergin, K. B., McKenna, A. F., Millard, D. L., Perez, L. C., Prival, J. T., . . . Hamos, J. E. (2010). Partnerships for STEM education. *Science*, 329(5994), 906-907.
- Franklin, B. M., Bloch, M. N., & Popkewitz, T. S. (2003). *Educational partnerships and the state: The paradoxes of governing schools, children, and families*. New York: Palgrave Macmillan.
- Furman, M., & Barton, A. C. (2006). Capturing urban student voices in the creation of a science mini-documentary. *Journal of Research in Science Teaching*, 43(7), 667-694.
- Fusco, D. (2001). Creating relevant science through urban planning and gardening. *Journal of Research in Science Teaching*, 38(8), 860-877.
- Gilligan, C., Spencer, R., Weinberg, M. K., & Bertsch, T. (2003). On the *Listening Guide*: A voice-centered relational model. In P. M. Camic, J. E. Rhodes, & L. Yardley (Eds.), *Qualitative research in psychology: Expanding perspectives in methodology and design* (pp. 157-172). Washington, DC: American Psychological Association.
- Giroux, H. A. (1992). *Border crossings: Cultural workers and the politics of education*. New York: Routledge.

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- Giroux, H. A. (1997). *Pedagogy and the politics of hope: Theory, culture, and schooling*. Boulder, CO: Westview Press.
- Giroux, H. A. (2011). *On critical pedagogy*. New York: Continuum.
- Gornik, R., Henderson, J., & Thomas, M. D. (2004). Transformative curriculum leadership: Inspiring democratic inquiry artistry. In R. Gaztambide-Fernández & J. T. Sears (Eds.), *Curriculum work as a public moral enterprise* (pp. 59-72). Lanham, MD: Rowman & Littlefield.
- Gruenewald, D. A. (2003). The best of both worlds: A critical pedagogy of place. *Educational Researcher*, 32(4), 3-12.
- Gutstein, E. (2003). Teaching and learning mathematics for social justice in an urban, Latino school. *Journal for Research in Mathematics Education*, 34(1), 37-73.
- Haberman, K. (1991). The pedagogy of poverty versus good teaching. *Phi Delta Kappan*, 73(4), 290-294.
- Hargreaves, A. (2003). *Teaching in the knowledge society: Education in the age of insecurity*. New York: Teachers College Press.
- Joseph, G. G. (1987). Foundations of Eurocentrism in mathematics. *Race and Class*, 28(3), 13-28.
- Kahn, R. (2010). *Critical pedagogy, ecoliteracy, and planetary crisis*. New York: Peter Lang.
- Kincheloe, J. L. (2004). *Critical pedagogy primer*. New York: Peter Lang.
- Knoll, M. (1997). The project method: Its vocational education origin and international development. *Journal of Industrial Teacher Education*, 34(3), 59-80.
- Ladson-Billings, G. (1997). It doesn't add up: African American students' mathematics achievement. *Journal for Research in Mathematics Education*, 28(6), 697-708.
- Leonard, J., & Evans, B. R. (2008). Math links: Building learning communities in urban settings. *Journal of Urban Mathematics Education*, 1(1), 60-83.
- Lubienski, S. T. (2002). A closer look at black-white mathematics achievement gaps: Intersections of race and SES in NAEP achievement and instructional practices data. *Journal of Negro Education*, 71(4), 269-287.
- Maton, K., & Moore, R. (2010). Introduction: Coalitions of the mind. In K. Maton & R. Moore (Eds.), *Social realism, knowledge and the sociology of education: Coalitions of the mind*. (pp. 1-13). New York: Continuum.
- Maxwell, J. A., & Miller, B. A. (2008). Categorizing and connecting strategies in qualitative data analysis. In S. Hesse-Biber & P. Leavy (Eds.), *Handbook of emergent methods* (pp. 461-477). New York: Guilford.
- McPhail, G. (2018). Curriculum integration in the senior secondary school: A case study in a national assessment context. *Journal of Curriculum Studies*, 50(1), 56-76.
- Moore, R. (2013). Social realism and the problem of the problem of knowledge in the sociology of education. *British Journal of Sociology of Education*, 34(3), 333-353.

- National Academy of Engineering & National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.
- National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.
- Office of Science and Technology Policy. (2016). *Progress report on coordinating federal science, technology, engineering, and mathematics (STEM) education*. Washington, DC: Office of Science and Technology Policy.
- Omenn, G. S. (2006). Grand challenges and great opportunities in science, technology, and public policy. *Science*, 314(5806), 1696-1704.
- Orey, D., & Rosa, M. (2007). Cultural assertions and challenges towards pedagogical action of an ethnomathematics program. *For the Learning of Mathematics*, 27(1), 10-16.
- Pais, A., Ferndandes, E., Matos, J. F., & Alves, A. S. (2012). Recovering the meaning of "critique" in critical mathematics education. *For the Learning of Mathematics*, 32(1), 28-33.
- Peters-Burton, E. E., Lynch, S. J., Behrend, T. S., & Means, B. B. (2014). Inclusive STEM high school design: 10 critical components. *Theory into Practice*, 53(1), 64-71.
- President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future*. Washington, DC: Office of Science and Technology Policy.
- Roth, W.-M., McGinn, M. K., Woszczyzna, C., & Boutonne, S. (1999). Differential participation during science conversations: The interaction of focal artifacts. *Journal of the Learning Sciences*, 8(3/4), 293-347.
- Saldaña, J. (2009). *The coding manual for qualitative researchers*. Los Angeles, CA: Sage.
- Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (3rd ed.). New York: Teachers College Press.
- Settlage, J., & Meadows, L. (2002). Standards-based reform and its unintended consequences: Implications for science education within America's urban schools. *Journal of Research in Science Teaching*, 39(2), 114-127.
- Spencer, J. A. (2012). Views from the black of the math classroom. *Dissent*, 59(1), 76-80.
- Spradley, J. P. (1979). *The ethnographic interview*. New York: Holt, Rinehart, and Winston.
- Stohlmann, M., Moore, T. J., McLelland, J., & Roehrig, G. H. (2011). Impressions of a middle grades STEM integration program. *Middle School Journal*, 43(1), 32-40.
- Tal, T., Krajcik, J. S., & Blumenfeld, P. C. (2006). Urban schools' teachers enacting project-based science. *Journal of Research in Science Teaching*, 43(7), 722-745.
- Tate, W. (2001). Science education as a civil right: Urban schools and opportunity-to-learn considerations. *Journal of Research in Science Teaching*, 38(9), 1015-1028.

- Teo, T. W. (2012). Building Potemkin schools: Science curriculum reform in a STEM school. *Journal of Curriculum Studies*, 44(5), 659-678.
- Teo, T. W., & Osborne, M. (2014). Understanding accountability from a microanalysis of power dynamics in a specialized STEM school. *Critical Studies in Education*, 55(2), 229-245.
- Thomas, J., & Williams, C. (2010). The history of specialized STEM schools and the formation and role of the NCSSSMST. *Roeper Review*, 32(1), 17-24.
- Tinker, R. F., & Krajcik, J. (Eds.). (2001). *Portable technologies: Science learning in context*. New York: Kluwer Academic/Plenum Publishers.
- Wager, A. A., & Whyte, K. (2013). Young children's mathematics: Whose home practices are privileged? *Journal of Urban Mathematics Education*, 6(1), 81-95.
- Wals, A. E. J., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science*, 344(6184), 583-584.
- Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, 1(2), 1-13.
- Waxman, H. C., & Padron, Y. N. (1995). Improving the quality of classroom instruction for students at risk of failure in urban schools. *Peabody Journal of Education*, 70(2), 44-65.
- Weis, L., Eisenhart, M., Cippolone, K., Stich, A. E., Nikischer, A. B., Hanson, J., . . . Dominguez, R. (2015). The guise of STEM education reform: Opportunity structures and outcomes in inclusive STEM-focused high schools. *American Educational Research Journal*, 52(6), 1024-1059.
- Wheelahlan, L. (2015). Not just skills: What a focus on knowledge means for vocational education. *Journal of Curriculum Studies*, 47(6), 750-762.
- Wolfmeyer, M., Lupinacci, J., & Chesky, N. (2017). Three ontologies of STEM education: An apolitical curricular trend, Eurocentric economic policy, and discursive episteme. *Critical Education*, 8(15), 68-81.
- Young, M. (2008a). *Bringing knowledge back in: From social constructivism to social realism in the sociology of education*. London: Routledge.
- Young, M. (2008b). From constructivism to realism in the sociology of the curriculum. *Review of Research in Education*, 32(1), 1-28.
- Young, M. (2009). Education, globalisation and the 'voice of knowledge'. *Journal of Education and Work*, 22(3), 193-204.
- Young, M. (2013). Overcoming the crisis in curriculum theory: A knowledge-based approach. *Journal of Curriculum Studies*, 45(2), 101-118.
- Young, M., & Muller, J. (2010). Three educational scenarios for the future: Lessons from the sociology of knowledge. *European Journal of Education*, 45(1), 11-27.
- Young, M., & Muller, J. (2013). On the powers of powerful knowledge. *Review of Education*, 1(3), 229-259.

Zipin, L., Fataar, A., & Brennan, M. (2015). Can social realism do social justice? Debating the warrants for curriculum knowledge selection. *Education as Change*, 19(2), 9-36.

Author

Simon Jorgenson is an Assistant Professor in the Department of Education at the University of Vermont. A former classroom teacher and outdoor educator, he currently teaches undergraduate social studies, science, and sustainability education courses with an emphasis on place-based and experiential approaches to instruction. His research focuses on the convergence between STEM and environmental education.

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