Exploring the Margins of the Field: Rethinking STEM in Education

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Abstract: As a cohort of Learning Sciences doctoral students, we are at the crux of shaping new possibilities for STEM in education. We share key learnings gleaned around critical notions of STEM (science, technology, engineering, mathematics) after participating in a conference that explored marginalized groups and ideas in STEM education. Key ideas we distilled for further deliberation include: 1) How is STEM identified and who is part of it?; 2) Why is critical discourse essential in STEM? and; 3) How do we attend to affect and aesthetic experience in STEM? We argue considering such issues and fostering epistemic fluency will allow STEM to grow and diversify. In presenting our understandings of STEM as it exists, and where we feel it is moving, our learning provokes dialogue about how critical research can impact STEM and educational research.

Keywords: STEM, Critical, Marginalization, Affect

Introduction

We are a multidisciplinary and international cohort of Learning Sciences doctoral students in Western Canada. Here, we discuss current trends and critical issues in STEM (science, technology, engineering, mathematics), how it is taken up in society, who has access to it, what it says about our world, and where STEM is headed. Our participation in a conference on critical and marginalized areas of STEM motivated us to reflect on the norms of STEM in literature, ideas of how to stretch and reconsider STEM, and how we, as emerging scholars, position ourselves relative to STEM and its future. We ground our discussion in established STEM and Learning Sciences literature, and three resonances from the conference: 1) How is STEM identified and who is part of it?; 2) Why is critical discourse essential in STEM? and; 3) How do we attend to affect and aesthetics in STEM? Our intent is to advance ways educators and scholars can rethink how STEM is taught, learned, and experienced.

Background

The term STEM originated in the United States in the 1990s as a strategy to strengthen the political presence of science, technology, engineering, and mathematics practitioners (Moore & Smith, 2014). Historically, STEM has been a mostly Western discourse based on labour productivity, Eurocentric paradigms, economic efficiency, and economic growth (Bhabha, 1985; Smith, 2012). As STEM evolves, there is disagreement of what constitutes STEM, calling for a rethinking of the field and its scope (Bybee, 2013; English, 2016). Scholars advocate for integrating STEM disciplines; however, the lack of a "common operational definition or conceptualization of STEM" (Breiner, Harkness, Johnson & Koehler, 2012, p. 9) and implementation issues in education settings, are a challenge.

Educators have struggled to overcome subject-specific thinking in STEM (Sochacka, Guyotte, & Walther, 2016). Linking art with STEM, to form STEAM, is one way to integrate multiple disciplines and is argued as fundamental for innovation and creativity (Bailey, 2015). The arts, and more broadly, aesthetic experiences can foster opportunities to teach and learn through transforming materials into unique forms and engendering continuity across disciplines and experiences (Farris & Sengupta, 2016). However, gluing more disciplines to the STEM moniker may encourage further compartmentalization rather than holistic integration. At the same time, blending disciplines together may dilute disciplinary ways of knowing and being, causing a "jack of all trades, master of none" effect. This tension needs further exploration. To move beyond the traditional discourse of STEM as separate disciplines motivated by human capital (increased production), scholars need to envision STEM in terms of human capability (holistic lives of personal value) (Sen, 1997).

Critical questions

How is STEM identified and who is part of it?

Identity is inseparable from how researchers, students, and educators shape their beliefs, values, and how they characterize STEM. For example, "fantasy worlds" describe how students and educators position themselves within STEM and how it is defined within various contexts (Holland, Lachicotte, Skinner, & Cain, 1998; Rahm, 2008). In fantasy worlds, identity is shaped in how a person can see themselves and the way others see them. These perceptions are in constant flux and are affected by contexts and environments. Integrating STEM within a person's identity strongly shapes learning experiences (Battiste, 2004; Shanahan, 2009). Unfortunately, learners in many communities are discriminated against because of identity prejudices and beliefs that identity is problematic for learning processes (Montejo, 2010). For instance, traits such as gender, class, and ethnic background are often used to predict success or failure in science careers (Archer, 2011; Wong, 2015). Traditionally, the sciences have promoted Caucasian, privileged, Euro-American men (Baker, 1998). Many factors perpetuate this promotion, including lucrative industry sponsorships welcomed by educational institutions to prepare the next generation of STEM experts and benefit industry. Thus, scholars may be (implicitly) drawn to maintain the systemic inertia of STEM. Attempts to overcome these inequalities need to be addressed more openly. Fortunately, science identities are fluid and educators and students can overcome these traditional notions (Shanahan & Nieswandt, 2011; Wong, 2015). This leads to questions of how someone embodies or rejects STEM as part of their identity (e.g., who gets to be a 'science person'?).

Current Western curriculums commonly give lesser priority to non-dominant perspectives. Fortunately, STEM is evolving to better appreciate marginalized groups and critical perspectives such as indigenous knowledge, decolonization, disabilities, and gender in how STEM is defined (Battiste, 2004; Hwang & Taylor, 2016; Smith, 2012). For example, from an indigenous perspective, there is a mutual interest to integrate Western and indigenous notions of *science*, *technology*, *engineering*, and *mathematics*, even if they go by different names (Hatcher, Bartlett, Marshall, & Marshall, 2009). Identity is becoming the foci of re-thinking and re-designing STEM as past and current inequalities are confronted (Esmonde & Booker, 2017).

"All people need STEM understanding in order to make sound decisions for themselves, their families, and their communities" (Marrero, Gunning, & Germain-Williams, 2014, p. 2). In providing varied access to STEM learning opportunities, not only do students "reshape their ways of thinking about what science is, how it gets done, and who might pursue it" (Rham & Moore, 2016, p. 771), they create moments for students to develop and question their own identities as scientists and STEM contributors. This can lead to STEM learning that builds on the lived experiences of participants within their communities, while promoting public action in solving societal problems (Adams & Gupta, 2013; Rham & Moore, 2016).

Why is critical discourse essential in STEM?

STEM is interdisciplinary but (often) not inclusionary. STEM has traditionally turned a blind eye to issues of equity, access, and cultural diversity (Esmonde & Booker, 2017; Takeuchi, 2016). It has privileged Eurocentric ways of knowing, where scientists are objective owners of knowledge who share what they know, devoid of cultures and contexts (M. C. Shanahan, personal communication, September 28, 2017). However, cultural practices are intertwined with STEM and accounting for diversity and critical discourse are becoming educational imperatives (Strong, Adams, Bellino, Pieroni, Stoops, & Das, 2016). Incorporating multiple ways of knowing, showcasing ways to navigate diverse ways of knowing, and establishing epistemological fluency are ongoing challenges for STEM educators.

Unfortunately, marginalized groups and ideas are often treated as a complication and there is resistance in upsetting carefully crafted ways of teaching, learning, and knowing STEM (Bang & Medin, 2010). We argue diversity is crucial for advancing the field and not a problem to overcome. Like identity, heterogeneity in people and perspectives is inseparable from teaching and learning (Rosebery, Ogonowski, DiSchino, & Warren, 2010). For example, virtual avatars with customizable sex, gender, and appearance challenge the traditional heteronormativity of STEM, giving a space and a place for identities to be rethought about how biology is taught and learned (Shanahan, 2009). Gender fluidity also opens avenues to integrate affective dimensions of STEM (McWilliams, 2016). For example, how does gender, desire, and emotion change sex education? How do biology curricula address social relationships as understood in other species? If the next great scientists are to make sense of the world, STEM educators cannot ignore deviations to heteronormativity nor ignore how ingrained heteronormativity is in everyday repertoires of teaching and learning practices (Sumara & Davis, 1999). Broadly, STEM educators need to consider how disciplinary norms can evolve toward greater inclusion, equity, and access.

How do we attend to affect and aesthetic in STEM?

A pervasive, but glossed over, component of teaching and learning is aesthetic and affect. Emotions have a strong connection to the design of learning environments (e.g., digital games), and to students' thinking and actions (Kim & Kim, 2010). Emotions are also situated and distributed among people, places, and knowledge. For example, professional game developers strive to balance levels of challenge, reward, advancement, and enjoyment to keep players enthralled for hours, days, and months. Engagement is key for learning; therefore, in the world of coding, game-based learning, and digital experiences, not only does emotion matter for design, it is also part of the learning process. Moreover, playing a game is only the start. Critique and interpretation of a game is where students can get at the heart of its content, ideas, and perspectives. For digital environments and code to mean something, they have to connect with the world around it. As people experience virtual, physical, and augmented environments, emotions are the threads that weave these experiences together and support learning transfer across contexts.

STEM also needs to integrate values and ethics in how it is taught and learned. For example, when an engineer designs a militarized drone, how can educators prepare engineers to grapple with the moral and ethical issues of how their work can save or end the lives of people they may never know (Philip, Gupta, Elby, & Turpen, 2017)? Design embodies sociocultural norms and identities. It represents an aesthetic of what counts as legitimate repertoires of practice, priorities of teaching and learning, and individual ideologies. Students and educators of STEM need ways to navigate the beliefs and values of others and how they strengthen, pull, and knit the fabric of STEM in education.

Future directions

As emerging scholars in the Learning Sciences, and future educators in STEM, we remain sensitive to the field's development and our role in addressing critical issues in STEM research and learning. We anticipate disciplines outside of STEM will benefit from similar critical discussions in current and future research. By exploring common interests such as curriculum development, educational leadership, or lifelong learning in STEM, researchers foster a shared goal of understanding the mechanisms of learning. We believe critical research showcases the potential integrative power of STEM, while addressing the diverse needs and perspectives of learners found in classrooms. Considering that, we question if a focus on critical research can push the compartmentalization and stratification that exists within STEM to the margins, opening up possibilities for integrated research beyond STEM as it exists today. Could this critical focus be the end of STEM as we know it? We are excited to be part of a fluid, developing field, that questions established beliefs, pushes and shifts boundaries, and promotes diverse, holistic, and powerful ways of knowing.

Conclusion

Exploring critical ideas has expanded our STEM epistemologies and our personal ontologies of what it means to be a STEM scholar. We came to STEM through the traditional routes, so we try to reconcile our biases for rethinking the field, while acknowledging our skewed perspectives associated with a Western education model. We are also aware of the thorny relationships between critical change and the fiscal realities associated with implicit or explicit exclusion to retain these privileges. We argue for STEM and the Learning Sciences to grow and advance, scholars, educators, and students need to consider how STEM is defined, who it includes, and how it can attend to affect. Engaging in these issues has influenced our academic pursuits by heightening our awareness of the complexities of teaching and learning across disciplines, epistemological perspectives, and research approaches. By having a shared trajectory for STEM, future researchers can address significant problems, expand the field, and have a positive impact on students' lives and their communities.

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