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Addressing colonial and militarized themes in STEM education

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In response to longstanding inequities and injustices within STEM, this review addresses the pressing need to decolonize STEM education and redefine the purpose of its disciplinary fields. Focusing on the influence of entrenched power structures, particularly the military-industrial complex, this review examines the relatively under-theorized impact of these forces on shaping the goals and scope of certain bodies of STEM education within UK higher education. The first section offers an overview of militarized STEM education and its connections to the challenges of decolonization. The second section explores strategies and interventions for decolonial pedagogy aimed at challenging discourses and practices that reinforce colonial and militarized narratives within curriculum and teaching. This review highlights how critical pedagogy and Indigenous Knowledge Systems offer educators' methods to cultivate criticality and humanity in their teaching practices. Ultimately, the review attempts to highlight how STEM education can be re-envisioned to serve broader, more emancipatory, and just purposes. Here the review advocates for a transformative educational paradigm that integrates inclusive pedagogical interventions with critical engagement in the ethical and moral dimensions of STEM practice, with the overarching goal of advancing social justice in teaching practices.

KEYWORDS

decolonization, demilitarization, critical pedagogy, indigenous knowledge, decolonizing pedagogy

Our positionality

Sean's work has included supporting activist movements to demilitarize and decolonize educational institutions, with previous roles in advocacy, teaching, and campaigning across higher and further education sectors in the UK. They write about transformative and critical education practices as a means to teach and learn about social justice in the context of institutions in the Global North. In their current role as a Senior Educator Developer at the University of Exeter, Sean focuses on integrating social and environmental justice into the mainstream curricular. Concurrently, as a doctoral student at the University of Sheffield, they are interested in learning and belonging in activist spaces, using autobiographical approaches to reflect on their years spent in grassroots community organizing.

Dr Yusra Siddiqui, the second author, brings a multifaceted perspective shaped by her diverse educational and professional background. Having studied and taught in various countries, including Pakistan, Singapore, and Poland, she has encountered and navigated different educational systems and cultural contexts. This exposure has deepened her understanding of how colonial legacies and Eurocentric frameworks continue to shape STEM education globally. Her commitment to decolonizing STEM curricula is informed by both her lived experiences and her professional journey, as she has been actively involved in curriculum development that

seeks to challenge dominant narratives and create more inclusive, context-sensitive educational practices. Yusra's positionality as an academic from the Global South, now operating within the UK, allows her to critically engage with the intersection of race, gender, and colonial histories in STEM education, advocating for transformative approaches that address systemic inequities and promote diverse ways of knowing.

Unpacking the colonial and militarized foundations of scientific disciplines

Science, Technology, Engineering, and Mathematics (STEM) disciplines are often perceived as inherently factual and objective (Bhambra et al., 2018), yet their historical development reveals that these fields have been deeply shaped by the intentions of their contributors, often rooted in racist and colonial ideologies. For example, scholarship on the decolonization of the sciences has exposed how the concept of racial hierarchy, advanced by figures like Dr. Samuel Morton (1799–1851) under the guise of scientific truth, was used to promote white supremacy (Kolbert, 2018). This pseudo-scientific narrative helped to justify Euro-American colonial conquest, enabling the exploitation of racialized bodies, communities, resources, and lands for the economic and technological expansion of the Global North (Braunold, 2024; Estes, 2019; Gilio-Whitaker, 2019; Lave et al., 2010; Ndlovu-Gatsheni and Chambati, 2013). Decolonisation then compels us to ask whose interests scientific and technological innovations serve, at whose expense they are pursued, and for what purposes, thereby challenging the presumed neutrality of these advancements and practices. It is within this context of power and purpose that this review focuses on the militarization of STEM education, a comparatively under-explored and under-theorized concept that is nonetheless a critical and timely area of inquiry for decolonizing educational practices.

The military-industrial complex exerts a significant but often overlooked influence within certain realms of STEM education, shaping the direction of scientific research and innovation to serve military and political interests. This influence is evident in the strong connections between defense industries and various STEM departments at universities, where collaborations, research agendas, and graduate recruitment are oriented toward military applications (Brzoska, 2006; Joint Economic Data Hub, 2023; Langley, 2005; Stavrianakis, 2006). Engineering departments, in particular, have a track record of being integrated with military-industrial priorities through funding and partnerships. Indeed, research and education in engineering and technology are considered essential to the UK defense sector, as demonstrated by contemporary collaborations between arms manufacturers such as BAE Systems and Lockheed Martin with higher education institutions, focusing on arms-related technological advancements (Beale and Street, 2007; Ajonye, 2024). However, it is not just engineering departments where militarized partnerships are formed. A 2014 report by the Nuclear Information Service highlighted substantial financial commitments made by the Atomic Weapons Establishment to computer science, mathematics, and physical science departments in the UK (Langley, 2005).

It is within this context that recent campus activism in the UK advocating for divestment from arms industry ties represents a new frontier in the broader movement to decolonize the university. Here activist and campaign work has attempted to highlight the connections between the military-industrial interests of the Global North and the priorities of UK higher education, specifically challenging institutions benefiting from military partnerships, particularly those providing equipment to Israel in conflict zones such as Gaza (Corderoy and Stockwell, 2024). Indeed, this issue is especially contentious given the recent escalation of the Israeli-Palestinian conflict, widely regarded as a war of colonial violence and occupation by a Western-aligned Israeli state (Pappé, 2006; Zureik, 2015). Palestinian solidarity has long been central to decolonization efforts, primarily through Boycott, Divestment, and Sanctions (BDS) campaigns on campuses, which parallel earlier movements opposing apartheid in South Africa. These movements underscore the need for a critical examination of how STEM education, whether intentionally or inadvertently, may perpetuate or obscure militarized agendas within higher education, often at the expense of more humanitarian-oriented educational pursuits.

In addition to the humanitarian devastation wrought by war, which has historically served to expand colonial and imperial power and influence (Johnson, 2004; Kiely, 2007), recent discussions have increasingly focused on the intersection of military activities and climate change. These discussions are particularly relevant within campus activist contexts, where intersecting campaigns advocate for the "Decolonization, Decarburization, and Demilitarization" of the curriculum, locating militarization in interconnected networks of exploitation, extraction, and oppression. Indeed, the defense sector is a major contributor to global greenhouse gas emissions, accounting for approximately 5%−6% of the total, with the US being the biggest contributor of military based emissions (Parkinson and Cottrell, 2022). These emissions stem from fuel consumption in operations, the manufacturing of military equipment, and infrastructure development (Crawford, 2019). These impacts disproportionately affect the Global South, where communities often face greater vulnerability to environmental degradation and have fewer resources to manage the consequences of climate change and conflict (Sultana, 2022). The connection between STEM education, military interests, and environmental degradation is further illustrated by the Campaign Against Arms Trade report (Ajonye, 2024) and the Joint Economic Data Hub (2023), which outlines the significant financial ties between UK universities and the arms industry, with STEM departments often at the forefront of these partnerships as previously mentioned. This report, along with accompanying research, highlights the role of STEM education in perpetuating militarism and environmental harm, challenging the notion that STEM disciplines are inherently neutral or apolitical endeavors (Langley, 2005; Stavrianakis, 2006). The following section of this review will explore various interrelated pedagogical interventions that can bridge the gap between theoretical understanding and practical, transformative action, offering strategies to integrate decolonial and demilitarized perspectives into STEM education.

Pedagogical interventions

The decolonization of STEM education requires a shift from just focusing on technical knowledge and skill acquisition to a more holistic framework that adopts critical reflection on the social, cultural, and ethical dimensions of STEM practice, alongside scientific enquiry. In essence, this approach seeks to blend technical knowledge with reflective curricula, enabling learners to understand how knowledge is produced, applied, and used in real-world contexts. Here, educators would look to integrate scientific inquiry with critical thinking frameworks, such as what some scholars describe as a "socio-scientific issues" method, which explores the norms, values, and histories that shape scientific disciplines, while also examining the ideological functions and applications of science and technology in both historical and contemporary contexts (Kahn, 2015; Zeidler, 2016). Aligned with Freirean critical pedagogy and decolonial teaching methods, this perspective emphasizes the cultivation of critical consciousness among learners (Gandolfi, 2023), interrogating the racial and colonial power structures embedded in disciplinary canons and epistemologies. In STEM education, this involves moving beyond what Freire (1972) termed "fragmented knowledge"—curricula that focus solely on scientific processes—toward critically examining how certain technologies and scientific breakthroughs are deployed in the real world, such as in sustaining the military-industrial complex, enabling land dispossession and resource extraction, or expanding invasive and discriminatory surveillance and policing technologies. Additionally, this perspective necessitates a consideration of those most affected by such applications and encourages exploration of alternative, more equitable uses of scientific progress and technological innovation. In short, this pedagogical method views scientific and technical inquiry as intertwined with reflective learning, encouraging learners to critically assess the ethical and practical contexts of how knowledge is applied in the world.

This practice of critical pedagogy extends beyond the spatial confines of the classroom. Critical pedagogy embodies what Giroux (2011) describes as a "border crossing" attitude—an approach that not only engages with but also seeks to enact transformative change in contexts beyond the formal curriculum. For instance, the Palestinian solidarity encampments have globally become sites of learning and consciousness-raising through teach-ins and experiments in collective democratic organizing. Similarly, emerging movements such as the Peoples' and Climate Assemblies on campuses, along with related campaigns such as "Another University is Possible," have focused on the intertwined issues of Decolonizing, Decarbonizing, and Demilitarizing universities. The Assembly movement, in particular, offers students, staff, and the local community a platform to explore utopian alternatives for the university, alternatives that are not rooted in human and planetary violence and exploitation. The Assembly model seeks to dissolve traditional distinctions between students and teachers, advocating for a more democratic and non-hierarchical learning processes, mirroring approaches found in anarchist and pre-figurative activist spaces (Fians, 2022; Graeber, 2013). Expanding and participating in these more radical democratic spaces may provide a pathway for educators to integrate a political and activist dimension into their teaching and research practices. This approach is particularly relevant for STEM educators, who often face additional constraints due to the demand to prioritize technical curricular content over more critical discourse and practice (Krug and Shaw, 2016). Additionally, assemblies offer opportunities to engage with colleagues outside of STEM, thereby bridging subject and disciplinary silos and potentially enabling greater opportunities for interdisciplinary collaboration.

Building on the importance of critical pedagogic approaches to STEM, another key pedagogical intervention involves integrating diverse voices and methodologies into a decolonised STEM curriculum (Akinbosede, 2020). For example, there could also be room to investigate and incorporate less common but widely used problem-solving techniques from different nations and cultures. Two key advantages of teaching alternate problem-solving methods are: students realize that STEM disciplines are not Eurocentric but rather have a diverse background and that there are multiple approaches to solving an issue, which appeals to their various learning styles (Nhemachena et al., 2020). This opens the possibility for STEM topics to be challenged by such creative ways. Diversifying STEM education with non-Eurocentric approaches fosters a more critical and ethical perspective among students as they become more critical of the dominant paradigms that prioritize militarization and the development of defense technologies. This critical mindset enables learners to question the ethical implications of their work and the potential for STEM knowledge to be co-opted by military interests. Moreover, Medin and Bang (2014) emphasize that Native science offers alternative approaches to understanding and interacting with the natural world, which prioritize harmony and balance over exploitation and control.

Chinenye Nwokocha and Legg-Jack (2024) have suggested that integration of indigenous knowledge systems (IKS) into STEM fields can result in enriching their education and provide substantial advantages for various stakeholders, including indigenous communities, academia, the government, and industry. The preservation of indigenous communities' traditional cultural heritage and identity is beneficial, and key players in the education industry may expect increased scientific research that is characterized by unique viewpoints, creative solutions, and sustainable practices. Incorporating IKS into STEM subjects, moving away from Western-oriented Eurocentric paradigm could significantly transform global educational practices (Mitra and Das, 2024), enabling some students to see themselves reflected in the content, fostering new ways of thinking, and helping them recognize any biases they might hold about other knowledge systems (Paquin, 2023). Thus, indigenous-inspired pedagogical innovations have been acknowledged as essential to revitalizing STEM education. Localized learning experiences grounded in IKS provide a pedagogical approach that is culturally sensitive. These experiences help students develop a sense of belonging and connection to place while enriching and diversifying the STEM curriculum. As a result, STEM education becomes more deeply aligned with the cultural backgrounds and lived experiences of a diverse range of students, offering a curriculum that resonates with a plurality of identities and perspectives. This approach challenges the traditional expectation that students

must assimilate into Euro-centric or Euro-American standards and understandings. Instead, it validates and integrates diverse ways of knowing, allowing students to engage with STEM content in a manner that is authentic to their own cultural narratives, thereby fostering a more inclusive and representative educational environment.

To illustrate the viability of this integrated approach, the Multiple Ways of Knowing (M-Know) model is offered (Chinenye Nwokocha and Legg-Jack, 2024). The M-Know model represents a transformative approach to STEM education that seeks to integrate, complement, interrogate, and consolidate diverse knowledge systems within the traditional framework of Westernized higher education. The M-Know model reshapes the classroom by co-creating courses with faculty, students, and community leaders to ensure diverse perspectives are reflected in the curriculum. Teaching methods would include storytelling, experiential learning, and collaborative projects, complementing traditional lectures. This fosters a space for open dialogue, where students are encouraged to share their cultural narratives and engage in peer learning (Battiste, 2013). In this model, teachers act as facilitators, guiding discussions and connecting various knowledge systems. They are expected to be culturally responsive, valuing the diverse perspectives students bring. By incorporating storytelling and personal narratives into the curriculum, the M-Know model cultivates empathy among students as they learn to see the world through the eyes of others (Regan, 2010). This emotional connection is crucial in decolonizing education, as it challenges the often impersonal, detached nature of traditional STEM disciplines and centers human experiences and relationships (Smith, 2012).

Through this framework, students play an active role, contributing their own knowledge and experiences, leading discussions, and conducting research that reflects the diversity of their identities and experiences. This active participation helps students develop emotional competency by fostering a deeper understanding of themselves and their peers. Engaging with diverse perspectives and knowledge systems encourages students to reflect on their own biases and assumptions, promoting self-awareness and emotional intelligence (Boler and Zembylas, 2003). These skills are essential for building solidarity with others, particularly in decolonizing efforts, where understanding and respecting different ways of knowing are key. Educators in the M-Know model would come from diverse backgrounds, including Indigenous knowledge keepers and community leaders. Courses might be co-taught by Western-trained scientists and Indigenous elders, offering a balanced, comprehensive education (Ermine, 2007). This collaboration not only enriches the curriculum but also models solidarity and mutual respect between different knowledge systems, encouraging students to adopt similar attitudes in their own lives (Kimmerer, 2013).

Faculty retraining is crucial for implementing the M-Know model. Educators would undergo cultural competence training, learn new approaches to curriculum development, and receive ongoing support through professional development and resources for integrating diverse knowledge systems. This training emphasizes the importance of emotional intelligence and empathy in teaching, equipping educators to better connect with their students and create an inclusive, supportive learning environment (Gay, 2010). By fostering these connections, the M-Know model promotes a more holistic, human-centered approach to education, which is essential for decolonizing work and building a more just and equitable society. It reorients us toward the preservation and emancipation of human and non-human life, rather than perpetuating discourses of competition, dominance, or innovation for its own sake, regardless of the impact or harm it may cause.

Conclusion

Decolonizing STEM is not just an academic exercise but a moral imperative. This approach calls on educators and students to explore and interrogate entrenched power structures and reframe the purposes of scientific and technological innovation toward greater humanitarian means. The review has shown how critical pedagogy can play an important role in developing reflective STEM teaching practices that question the values, norms, attitudes, and purposes underpinning the application of STEM in the contemporary world. Furthermore, the review has highlighted how incorporating principles from Indigenous Knowledge Systems (IKS) may enable educators to work with students in examining the ideological foundations of STEM, while community-based learning can foster a more inclusive and diverse learning environment. These strategies may further enable students to engage with STEM in ways that resonate with their cultural identities and lived experiences, rather than assimilating to Euro-American norms and ideologies. It is crucial to recognize that the interventions and strategies referred to in the review exist within a broader context of activism challenging the intersecting forces of capitalism, imperialism, and militarization on our campuses—forces responsible for significant humanitarian and ecological crises worldwide. Moreover, this work takes place in a climate where protest and resistance are increasingly criminalized, and where practices of securitization and surveillance serve to dilute and pacify social justice efforts on our campuses. Understanding the context in which critical and social justice curricula and teaching are developed and implemented is essential for advancing the transformative potential of a decolonized education, especially if our educational experiences are to inspire action and resistance.

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