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Critical Scoping Review of Critical Consciousness as a Framework for Precollege Engineering Education

Devon Riter
University of Michigan, driter@umich.edu

James Holly Jr.
University of Michigan, jhollyjr@umich.edu

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Abstract

Engineering's promise to build a better world has been realized differently across the United States, often with lines of social identity determining who becomes an engineer, who benefits from engineering innovations, and who suffers devastating consequences. Many educational scholars have argued that engineering inequities are in part due to deep inequities in precollege engineering education, including the failure to enact pedagogies in which engineering educational spaces can help students recognize oppression and act toward liberation. In this critical scoping review we searched five databases to identify 72 relevant peer-reviewed articles for review. Our findings indicate that research on critical consciousness in precollege engineering education is nascent, with studies primarily utilizing qualitative methods to examine the experiences of K–12 teachers and students in formal and informal precollege engineering classrooms in the United States. Through a constructivist grounded theory approach, we examined a small sample of this scholarship to build on our theoretical understanding of how critical consciousness might be utilized as a framework for precollege engineering education, embedding engineering education within cycles of critical reflection (e.g., discussing with students why engineering is currently a White male-dominated field) and critical action (e.g., helping students design approaches to mitigating disenfranchisement). Specifically, we highlight how critical K–12 engineering educators have been able to (a) navigate institutional critique and support, (b) balance the relational and the technical, (c) reframe who can be an engineer, and (d) reframe what engineers do. This critical scoping review also highlights how critical engineering educators are often constrained by current educational systems and what that practical reality means for advancing critical consciousness as a pedagogical framework in precollege engineering education.

Keywords

critical consciousness, precollege engineering education, equity, justice

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Critical Scoping Review of Critical Consciousness as a Framework for Precollege Engineering Education

Devon Riter, University of Michigan
James Holly Jr., University of Michigan

Abstract Engineering's promise to build a better world has been realized differently across the United States, often with lines of social identity determining who becomes an engineer, who benefits from engineering innovations, and who suffers devastating consequences. Many educational scholars have argued that engineering inequities are in part due to deep inequities in precollege engineering education, including the failure to enact pedagogies in which engineering educational spaces can help students recognize oppression and act toward liberation. In this critical scoping review we searched five databases to identify 72 relevant peer-reviewed articles for review. Our findings indicate that research on critical consciousness in precollege engineering education is nascent, with studies primarily utilizing qualitative methods to examine the experiences of K–12 teachers and students in formal and informal precollege engineering classrooms in the United States. Through a constructivist grounded theory approach, we examined a small sample of this scholarship to build on our theoretical understanding of how critical consciousness might be utilized as a framework for precollege engineering education, embedding engineering education within cycles of critical reflection (e.g., discussing with students why engineering is currently a White male-dominated field) and critical action (e.g., helping students design approaches to mitigating disenfranchisement). Specifically, we highlight how critical K–12 engineering educators have been able to (a) navigate institutional critique and support, (b) balance the relational and the technical, (c) reframe who can be an engineer, and (d) reframe what engineers do. This critical scoping review also

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highlights how critical engineering educators are often constrained by current educational systems and what that practical reality means for advancing critical consciousness as a pedagogical framework in precollege engineering education.

Keywords critical consciousness, precollege engineering education, equity, justice

Engineering is often framed as an increasingly important tool for confronting the greatest challenges facing humanity (National Academy of Engineering, 2008). In fact, for many people it is a commitment to actively building a better world that sets engineering apart from science or, as the old axiom states. "scientists study the world as it is; engineers create the world that never has been" (Von Kármán, quoted in U.S. National Science Foundation, 2012). Yet, engineering's promise to build a better world has been realized differently across the United States, often with lines of social identity determining who becomes an engineer, who benefits from engineering innovations, and who suffers devastating consequences (Kadambi, 2021; Patrick et al., 2023; Perkowitz, 2021; Ross et al., 2021; Smith et al., 2023; Verdín, 2021). A growing number of educational scholars (e.g., Baillie, 2020; Calabrese Barton et al., 2021; Cech, 2014) have argued that inequities in the benefits and harms of engineering are in part due to deep inequities in precollege engineering education and have described how those spaces privilege middle-class White male cultural norms and values.

To create more equitable learning environments, panels of experts have increasingly made recommendations to "restructure engineering education culture and pedagogy to . . . make social impact more central to the study of engineering" (Blue et al., 2005, p. 3). Recently, this focus on the social impact of engineering has meant explicit calls for K–12 design spaces, where youths can learn about engineering as a tool for social justice and have opportunities to engage "engineering to redress injustices and disrupt systemic oppressions" (National Academies of Sciences, Engineering, and Medicine, 2021, p. 23). Often drawing on theorizations of social justice in engineering (e.g., Reynante, 2022; Riley, 2008) and justice-oriented scholarship in math and science education (e.g., Bang & Medin, 2010; Calabrese Barton et al., 2020; Morales-Doyle, 2017), scholars have begun to theorize how we might shift precollege engineering educational spaces to become places for social impact and social justice (Calabrese Barton et al., 2021; Holly, 2021; Madkins & McKinney de Royston, 2019; Tan et al., 2019).

In this scoping review, we examine critical consciousness as a prominent framework for designing engineering educational spaces meant to support equitable social change within and beyond the walls of the engineering classroom. We frame

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critical consciousness as the result of a developmental process that is inherently centered around a type of critical pedagogy in which students and teachers engage in cycles of critical reflection and critical action. We first describe trends in critical consciousness engineering education research to provide context into the cycles of critical reflection (e.g., discussing with students why engineering is currently a White male-dominated field) and critical action (e.g., helping students design approaches to mitigating disenfranchisement) that the reviewed research articles describe as being enacted in various learning environments. We then group these critical pedagogical approaches into themes, exploring and discussing how engaging precollege engineering students in cycles of critical reflection and critical action seems to require that educators (a) navigate institutional critique and support, (b) balance the relational and the technical, (c) reframe who can be an engineer, and (d) reframe what engineers do. This scoping review also highlights how the efforts of critical engineering educators are continually constrained and marginalized by current educational systems. We hope that this study can help researchers better understand some of the challenges and opportunities for enacting different critical pedagogical approaches in precollege engineering environments and offer a guide for future research efforts in this area.

BACKGROUND

Scholarship concerned with how teachers engage students in understanding injustice and acting toward liberation has a long history, which draws heavily on critical theories and the concept of *critical consciousness* (Mejia et al., 2018). Critical consciousness as an educational philosophy is deeply connected to the work and writing of Freire (1970) and other critical scholars (e.g., Fanon, 1967; Ladson-Billings, 1995; hooks, 1994), where the educational goal is "learning to perceive social, political, and economic contradictions, and to take action against the oppressive elements of reality" (Freire, 1970, p. 35, footnote 1). A growing number of scholars support the idea that critical consciousness provides a deeply theorized and promising framework for reimagining and remaking engineering education toward more just ends (e.g., Holly, 2021; Mejia et al., 2018; Trbušić, 2014; Xu et al., 2022).

Critical consciousness has been used for decades as a theoretical framework in education, community psychology, social work, and public health, with different interpretations as to what critical consciousness is (Jemal, 2017). Some scholars define critical consciousness as the developmental process of learning about and acting against oppression (e.g., Diemer et al., 2016; Shin et al., 2016). In this sense, critical consciousness describes the process of reflecting and acting on social justice issues.

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Other scholars define critical consciousness as the outcome of that developmental process (e.g., Mustakova-Possardt, 1998; Gutierrez & Ortega, 1991). In this framing the process of reflecting and acting is called *conscientização*, conscientization, or consciousness-raising, and a person becomes ever more critically conscious by going through that process.

In this review, we position critical consciousness as the outcome of a two-dimensional developmental process, including both (1) *critical reflection*, which involves questioning one's own beliefs and social reality, analyzing history and its impacts on everyday life, and identifying the hidden oppressive interests that shape reality, and (2) *critical action*, which involves taking individual and collective action against oppressive interests and toward liberation. We specify critical consciousness separately from *critical pedagogies*, which we see as the specific tools, methods, and approaches used in critical consciousness-raising efforts (e.g., open discussions, reflective questions, maps of social capital, and readings; Garcia et al., 2009).

Scholars have long noted the wealth of positive outcomes from critical consciousness-raising efforts, especially for marginalized youths (Apple, 2009; Cabrera et al., 2014). These benefits include enhanced motivation and engagement (O'Connor, 1997), resilience (Ginwright, 2010), future career planning (Diemer & Blustein, 2006), civic activism (Watts & Hipolito-Delgado, 2015), increased SAT scores (Seider et al., 2020), higher grade point averages (Dee & Penner, 2017), and attainment of higher-paying and more prestigious occupations (Rapa et al., 2018). However, despite the wealth of positive outcomes for students, relatively few learning spaces take up critical consciousness as an educational framework (Brown et al., 2019). Instead, critical forms of education remain largely misunderstood (Sleeter, 2012) and are increasingly labeled as harmful to K–12 students and in need of being banned (Holly & Masta, 2021; Morgan, 2022).

Simultaneously, the popularity of precollege engineering education continues to grow (Sneider & Ravel, 2021). Bolstered by wide adoption of the Next Generation Science Standards (NGSS Lead States, 2013), engineering design is now a core part of the K–12 science educational standards in at least 40 states (Christian et al., 2021). However, research on precollege engineering education has rarely explored engineering education research as an educational framework (Hynes et al., 2017). Instead, engineering education research has primarily focused on pedagogical practices aimed at disseminating technical knowledge to students and enhancing their desires to join the engineering field (Calabrese Barton & Tan, 2018; Holly, 2021). Certainly, critical pedagogies may motivate students to become engineers and become proficient in the use of traditional technical engineering knowledge. However, from a critical perspective, such outcomes are only equitable if they are a by-product of academic structures "embracing the political struggles of those

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oppressed in classroom settings—in both form and meaning—as acts of justice" (Calabrese Barton & Tan, 2020, p. 433).

In this review we specify *critical consciousness educational frameworks* as theoretical perspectives on teaching and learning, which explicitly engage the history, epistemology, and vocabulary of critical consciousness. For instance, we consider Ladson-Billings's (1995) culturally relevant pedagogy as a critical consciousness educational framework because it specifically takes up critical consciousness as one of its three essential criteria, with extensive descriptions of the educational environments that support the development of student sociopolitical consciousness. Like Ladson-Billings (1995), we recognize that critical consciousness educational frameworks are "not radically different" (p. 162) from educational work that has been going on in activist movements, such as the American Indian Movement (Davis, 2013; McCarty, 1989) and the Black Power movement (Boggs & Kurashige, 2012) for generations. Yet, within this review we limit our conceptions of critical consciousness educational frameworks only to those that explicitly take up the language of critical consciousness. We do this as an analytical approach that is meant to help us explore how the field of precollege engineering education potentially shapes and is reshaped by critical consciousness as an educational framework.

Drawing on the dialectical nature of critical consciousness, which simultaneously emphasizes both internal reflection and external action, within this review we look at critical consciousness at both a theoretical level, asking how it is being studied and taken up within the literature, and a practical level, asking how it is being enacted in precollege engineering educational spaces. We believe that examining these dual facets of critical consciousness can help build a deeper conceptual understanding of critical consciousness educational frameworks, along with the challenges and opportunities they may bring. In the opening remarks of a recent special equity-focused issue of the *Journal of Pre-College Engineering Education*, Martin and Wendell (2021) described how "engineering education is in need of a paradigm shift" (p. 42). We agree. We also see critical consciousness as a uniquely powerful framework for conceptualizing how we might redesign the overarching goals and the everyday practices of precollege engineering educational spaces. We hope this review can help support deeper and more critical reflections on precollege engineering education while also fostering critical actions that can collectively transform our field toward ever more just ends.

POSITIONALITY STATEMENTS

We each come to this work with different life experiences, different perspectives, and different forms of expertise. Devon Riter, a doctoral student in educational

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studies, led the review efforts: meeting with reference librarians, conducting literature searches, reading articles, coding articles, analyzing codes, and writing article drafts. James Holly Jr., a professor with expertise in engineering education, provided guidance throughout the literature review process: discussing search terms and approaches, advising coding and analysis processes, and contributing to draft editing and writing efforts.

As researchers who ground our work in critical perspectives of the world, we recognize that everything we do, including conducting a literature review, is inherently impacted by our individual experiences and perspectives, which are themselves impacted by broader systems of power and privilege (Milner, 2007). This reality necessitates that we share our positionalities as a means to make "visible the political and theoretical histories of a particular project" (Ishimaru & Bang, 2022, p. 387) and allow the reader to better appreciate how the claims we make are inextricably grounded in the social science approaches we take, the empirical evidence we present, and the social positions we inhabit.

Devon Riter: Positionality Statement

Part of how I see critical consciousness as an educational framework in precollege engineering education is connected to my positionality as a middle-class White cisgender male who is enrolled in an education PhD program at the University of Michigan. I see my racial, gender, class, and academic identities as privileged within American society and as inherently and unjustly beneficial to me. This core belief and an associated desire to transform educational systems toward justice comes from my experiences as a high school science teacher at a rural tribal school in the midwestern United States. In my first year teaching at the school, I employed the educational strategies I had learned in college. However, many students refused to participate in classroom activities. In an effort to try to figure out what I could do differently, I began reading scholarship from Brayboy (2005) and Lomawaima (1999), which opened my eyes to how my teaching practices didn't acknowledge or value my students' culture or community in any way and instead were acting as tools for assimilation into White middle-class norms and culture. McCarty and Lee's (2014) work helped me realize that I should switch my pedagogical approach so as to take up more community-centered practices that valued the perspectives and expertise of my students and their families. Ladson-Billings's (1995) research also helped me see the importance of supporting students' critical consciousness, providing them with opportunities to recognize and act against injustice in the classroom and beyond.

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James Holly Jr.: Positionality Statement

The aspects of my personal identity that influence my scholarly practice are being a Black man who grew up in a highly impoverished urban Black city and attended both private and public schools during my precollege education. While earning a master's degree in engineering, I noticed that the epistemological foundations of engineering knowledge were in contradiction to the aspirations that motivated me to study engineering. Consequently, I developed my research paradigm by studying Black intellectualism knowledge from the seriously committed Black intellectuals who have the enhancement of Blacks foremost on their minds (West, 1973). Thus, my orientation to this review project is primarily concerned with understanding educational practices that have sought to support precollege educators teaching engineering within urban Black communities. I combined my lived reality within and study of Black scholarship on such contexts, along with my study of engineering education in both precollege and postsecondary contexts to examine the implications of attempts to reckon with oppressive social and educational structures.

METHODS

Our goals for this literature review were not to provide an exhaustive summary of all precollege engineering education research concerned with engaging students to act toward justice. Instead, we took up a methodological approach similar to Tanner and McCloskey (2023) in which we worked "to systematically and transparently identify a purposeful set of research literature on the topic, such that we could analyze that corpus and make claims about it" (p. 10). For us, this meant developing a set of peer-reviewed articles concerned with exploring and describing critical consciousness within precollege engineering educational contexts. We conceptualize critical consciousness as inherently connected to the dynamic interplay between both knowing and doing, which in turn motivated us to explore both the theoretical context of critical consciousness, examining the trends of scholarship on the topic, and the practical context of the concept, including teacher enactment of the framework within precollege engineering educational settings. We eventually developed the following two research questions to guide this literature review:

Question #1. What are the current trends for studying critical consciousness as a framework for precollege engineering education?

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Question #2. How are teachers enacting critical consciousness as an educational framework in precollege engineering educational spaces?

It is important to note that we use the labels "teachers" and "students" throughout this review for the sake of clarity, despite the fact that some articles employ alternative terms such as "adult facilitator" (Archer et al., 2021) and "guide" (Bottoms et al., 2017) to designate the less authoritative power relationships enacted within those educational spaces. We take up an expansive view of what constitutes a teacher, namely a person who takes on the responsibility for supporting and guiding others within any learning environment. Similarly, we use the term "classroom" to describe the variety of both formal and informal educational spaces reviewed in these studies.

To begin the review process, Devon consulted a reference librarian to select five academic databases that would capture the disciplines and types of articles relevant to answering our research questions: ProQuest (combined access to 146 ProQuest databases), Web of Science, Scopus, Engineering Village (Compendex), and PsychInfo (EBSCOhost). Devon then identified the following keywords from our research questions: critical consciousness, precollege, engineering, and education. Devon iteratively combined these initial keywords with relevant synonyms to evaluate their capacity to return articles with abstracts relating to our research questions.

Through this iterative search process we recognized that prominent synonyms for critical consciousness, such as "justice-oriented," "sustainable community," "culturally relevant," and "critical sociotechnical," inevitably returned an overwhelming number of articles for review that often did not deeply engage with what we saw as the historical legacy, epistemology, and vocabulary of critical consciousness. Consequently, we decided to limit our use of synonyms for critical consciousness only to sociopolitical consciousness. This resulted in the following search string:

> anywhere in article ((“critical consciousness” OR “sociopolitical consciousness”) AND (engineer* OR STEM)) AND in abstract((pre-college OR P-12 OR K–12 OR secondary OR elementary OR informal OR “high school” OR “middle school”) AND (STEM OR science OR technology OR engineer* OR math OR design) AND (education* OR pedagog* OR teach* OR learn*)).

Devon conducted the literature search in September and October 2022 and limited the search results to peer-reviewed journals, excluding dissertations and conference papers/proceedings. He then reviewed abstracts from the search results, utilizing the following inclusion criteria:

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- Must pertain to formal or informal precollege educational settings, which may include university K–12 teacher preparation programs.
- Must pertain to some aspect of critical consciousness, which we define as "learning to perceive social, political and economic contradictions, and to take action against the oppressive elements of reality" (Freire, 1970, p. 36)
- Must pertain to some aspect of the "multidimensionality of engineering" (Holly, 2021, p. 158), which positions an engineer as a sociologist, scientist, designer, and doer (Figueiredo, 2008) who uses "a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and accomplish goals" (Purzer et al., 2014, p. 8).

After reviewing abstracts and removing duplicates, 71 articles met our inclusion criteria (Table 1).

Following Arksey and O'Malley's (2005) methodology framework, Devon applied "a common analytical framework to all the primary research reports" (p. 26) to collect standard information, including title, author(s), publication year, methodology, participant educational characteristics, participant race, participant gender, participant socioeconomic status, participant sample size, study educational setting, country/region, study duration, researcher demographics, methods for engaging/developing critical consciousness, study measures, measured performance, and study conclusions. Devon used this charting process to create a basic numerical analysis. We then discussed how we could leverage this analysis to answer research question #1: What are the current trends of studying critical consciousness as a framework for precollege engineering education? In looking across this data and the types of claims it could support, we also began to discuss and build consensus around what we saw as the critical implications of these claims and how those implications might shape our understanding of the broader theoretical context of critical consciousness educational frameworks in precollege engineering education as well as their described enactments in classrooms.

Through this charting process Devon also began noticing a disparity between the ways articles engaged both engineering and critical consciousness. Some articles explicitly labeled the classrooms and curriculum that were studied as *engineering classrooms*, while others highlighted how the math, science, or technology topics studied were synergistic with engineering education. We certainly recognize the multidimensionality of engineering and see important aspects of engineering education happening in nearly every classroom ranging from history classrooms where students might learn about the social context of our engineered word to chemistry classrooms where students may engage the engineering design cycle to troubleshoot a lab. As

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Table 1. List of Reviewed Papers

Publication Years	Authors	Titles	Journals
2022	Lenora Crabtree Preethi Titu	What will we teach the teachers? Grappling with racism in a professional development setting	*Cultural Studies of Science Education*
2022	Elena Novak Javed I. Khan	A research-practice partnership approach for co-designing a culturally responsive computer science curriculum for upper elementary students	*TechTrends*
2022	Gregory Lowan-Trudeau Teresa Anne Fowler	Towards a theory of critical energy literacy: The Youth Strike for Climate, renewable energy and beyond	*Australian Journal of Environmental Education*
2022	Felicia Moore Mensah	"Now, I see": Multicultural science curriculum as transformation and social action	*The Urban Review*
2022	V. Dodo Seriki S. McDonald	Structures of becoming: The who, what, and how of holistic science advising	*Science Education*
2022	A. M. Limbere M. Munakata E. J. Klein M. Taylor	Exploring the tensions science teachers navigate as they enact their visions for science teaching: What their feedback can tell us	*International Journal of Science Education*
2022	K. L. Mulvey C. J. Mathews J. Knox A. Joy J. Cerda-Smith	The role of inclusion, discrimination, and belonging for adolescent science, technology, engineering and math engagement in and out of school	*Journal of Research in Science Teaching*
2022	B. Criswell R. Krall S. Ringl	Video analysis and professional noticing in the wild of real science teacher education classes	*Journal of Science Teacher Education*
2021	Kamal Prasad Koirala	Multicultural classroom teaching in Nepal: Perspectives and practices of a secondary level science teacher	*Cultural Studies of Science Education*
2021	Mehtap Kirmaci Cory A. Buxton Martha Allexsaht-Snider	A Latina science teacher becoming a dialogic educator: "I'm okay being hated because somebody has to be strong"	*Cultural Studies of Science Education*
2021	Hye-Eun Chu	Editorial: STEAM Education in the Asia Pacific region	*Asia-Pacific Science Education*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2021	Deoksoon Kim So Lim Kim Mike Barnett	"That makes sense now!": Bicultural middle school students' learning in a culturally relevant science classroom	*International Journal of Multicultural Education*
2021	Emily Anna Dare Khomson Keratithamkul Benny Mart Hiwatig Feng Li	Beyond content: The role of STEM disciplines, real-world problems, 21st century skills, and STEM careers within science teachers' conceptions of integrated STEM education	*Education Sciences*
2021	Jordan Register Michelle Stephan DavidPugalee	Ethical reasoning in mathematics: New directions for didactics in U.S. mathematics education	*Mathematics*
2021	L. D. Huffling H. C. Scott	Using critical environmental agency to engage teachers in local watersheds through water quality citizen science	*Water*
2021	Q. Jin	Supporting indigenous students in science and stem education: A systematic review	*Education Sciences*
2021	T. C. Madkins K. Morton	Disrupting anti-Blackness with young learners in STEM: Strategies for elementary science and mathematics teacher education	*Canadian Journal of Science, Mathematics and Technology Education*
2021	B. Upadhyay E. Atwood B. Tharu	Antiracist pedagogy in a high school science class: A case of a high school science teacher in an Indigenous school	*Journal of Science Teacher Education*
2021	Jessica Thompson Kristen Mawyer Johnson Heather Déana Scipio April Luehmann	C^2AST (critical and cultural approaches to ambitious science teaching): From responsive teaching toward developing culturally and linguistically sustaining science teaching practices	*Science Teacher*
2021*	Louise Archer Spela Godec Angela Calabrese Barton Emily Dawson Ada Mau Uma Patel	Changing the field: A Bourdieusian analysis of educational practices that support equitable outcomes among minoritized youth on two informal science learning programs	*Science Education*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2021*	James Holly Jr.	Equitable pre-college engineering education: Teaching with racism in mind	*Journal of Pre-College Engineering Education Research*
2021	Camillia Matuk Talia Hurwich Amy Spiegel Judy Diamond	How do teachers use comics to promote engagement, equity, and diversity in science classrooms?	*Research in Science Education*
2021	Jahneille A. Cunningham	"We Made Math!": Black parents as a guide for supporting Black children's mathematical identities	*Journal of Urban Mathematics Education*
2020	Danya Marie Serrano Corkin Adem Ekmekci Alice Fisher	Integrating culture, art, geometry, and coding to enhance computer science motivation among underrepresented minoritized high school students	*The Urban Review*
2020*	Keratithamkul Khomson Justine N. Kim Gillian H. Roehrig	Cultural competence or deficit-based view? A qualitative approach to understanding middle school students' experience with culturally framed engineering	*International Journal of STEM Education*
2020*	James S. Holly Jr.	A critical autoethnography of a Black man teaching engineering to Black boys	*Journal of African American Males in Education*
2020	Samantha L. Strachan	An examination of two African American males' decisions to become secondary science teachers	*The High School Journal*
2020	Hannah Kye	Beginning teachers' knowledge-in-practice of multicultural science education	*Journal for Multicultural Education*
2020	Mark Sheron Lateefah Id-Deen Shelley Thomas	Getting to the root of the matter: Pre-service teachers' experiences and positionalities with learning to teach in culturally diverse contexts	*Cultural Studies of Science Education*
2020	Lay-Wah Carolina Ching-Chiang Juan Manuel Fernández-Cárdenas	Analysing dialogue in STEM classrooms in Ecuador: A dual socioeconomic context in a high school	*Journal of New Approaches in Educational Research*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2020*	M. Eisenhart C. D. Allen	Addressing underrepresentation of young women of color in engineering and computing through the lens of sociocultural theory	*Cultural Studies of Science Education*
2020	L. McGuire K. L. Mulvey E. Goff M. J. Irvin M. Winterbottom G. E. Fields A. Hartstone-Rose A. Rutland	STEM gender stereotypes from early childhood through adolescence at informal science centers	*Journal of Applied Developmental Psychology*
2019	Toni Denese Sturdivant Iliana Alanís	Teaching through culture: One teacher's use of culturally relevant practices for African American preschoolers	*Journal for Multicultural Education*
2019	Daniel Morales-Doyle	The aspirin unit: Confronting a hostile political context through chemistry curriculum	*Cultural Studies of Science Education*
2019	Joanna Weidler-Lewis Wendy DuBow Alexis Kaminsky Tim Weston	Supporting women's persistence in computing and technology	*Information and Learning Science*
2019	Alma D. Stevenson Alejandro José Gallard Martínez Katie Lynn Brkich Belinda Bustos Flores Lorena Claeys Wesley Pitts	Latinas' heritage language as a source of resiliency: Impact on academic achievement in STEM fields	*Cultural Studies of Science Education*
2019	Jessica Morales-Chicas Mauricio Castillo Ireri Bernal Paloma Ramos Bianca Guzman	Computing with relevance and purpose: A review of culturally relevant education in computing	*International Journal of Multicultural Education*
2019	Deoksoon Kim Eunhye Cho Stephanie Couch Mike Barnett	Culturally relevan science: Incorporating visualizations and home culture in an invention-oriented middle school science curriculum	*Technology and Innovation*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2019*	T. C. Madkins M. McKinney de Royston	Illuminating political clarity in culturally relevant science instruction	*Science Education*
2019	M. Kirmaci C. A. Buxton M. Allexsaht-Snider	"Being on the other side of the table": A qualitative study of a community-based science learning program with Latinx families	*Urban Education*
2019	P. P. Rodenbough M. C. Manyilizu	Developing and piloting culturally relevant chemistry pedagogy: Computer-based VSEPR and unit cell lesson plans from collaborative exchange in East Africa	*Journal of Chemical Education*
2019*	Natalie S. King Rose M. Pringle	Black girls speak STEM: Counterstories of informal and formal learning experiences	*Journal of Research in Science Teaching*
2019	Hosun Kang Doron Zinger	What do core practices offer in preparing novice science teachers for equitable instruction?	*Science Education*
2018	Carmel Roofe Therese Ferguson	Technical and vocational education and training curricula at the lower secondary level in Jamaica: A preliminary exploration of education for sustainable development content	*Discourse and Communication for Sustainable Education*
2018	T. J. Frank	Teaching our kids: Unpacking an African-American mathematics teacher's understanding of mathematics identity	*Journal for Multicultural Education*
2018	B. Garvin-Hudson T. O. Jackson	A case for culturally relevant science education in the summer for African American youth	*International Journal of Qualitative Studies in Education*
2018	Denise Allan Samantha Vettese Paul Thompson	A study of children's relationship with making and use of CAD in collaborative, informal environments and the implications for institutional learning environments	*Design & Technology Education*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2018*	Simon Jorgenson	Bridges and boundaries to power: How teachers used project-based learning to design a radically inclusive STEM high school	*Critical Education*
2018	Maria Varelas Daniel Morales-Doyle Syeda Raza David Segura Karen Canales Carole Mitchener	Community organizations' programming and the development of community science teachers	*Science Education*
2018	Daniel Morales-Doyle	Students as curriculum critics: Standpoints with respect to relevance, goals, and science	*Journal of Research in Science Teaching*
2018	Nancy Ares Dawn M. Evans Alice M. Harnischfeger	Systemic constraints on students' appropriation of reform oriented curriculum	*Critical Questions in Education*
2018	Latika Raisinghani	Teachers' perspectives on cultural diversity and gendered cultural practices in science and mathematics classrooms	*Alberta Science Education Journal*
2018	Cara M. Djonko-Moore Jacqueline Leonard Quintaniay Holifield Elsa B. Bailey Sultan M. Almughyirah	Using culturally relevant experiential education to enhance urban children's knowledge and engagement in science	*Journal of Experiential Education*
2017	Saliha Kozan David L. Blustein Michael Barnett Catherine Wong Alice Connors-Kellgren James Haley Amie Patchen Chad Olle Matthew A. Diemer Ava Floyd R. P. Benjamin Tan Deborah Wan	Awakening, efficacy, and action: A qualitative inquiry of a social justice-infused, science education program	*Analyses of Social Issues and Public Policy*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2017*	Julie C. Brown	A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K–12 settings: Implications for advancing equitable science teaching and learning	*Journal of Research in Science Teaching*
2017	Qudsia Kalsoom Afifa Khanam Uzma Quraishi	Sustainability consciousness of pre-service teachers in Pakistan	*International Journal of Sustainability in Higher Education*
2017	Idalis Villanueva Marialuisa Di Stefano	Narrative inquiry on the teaching of STEM to blind high school students	*Education Sciences*
2017	D. Gavin Luter Austin M. Mitchell Henry L. Taylor	Critical consciousness and schooling: The impact of the community as a classroom program on academic indicators	*Education Sciences*
2017	Maxine McKinney de Royston Sepehr Vakil Na'ilah Suad Nasir Jarvis Givens Kihana Miraya Ross Alea Holman	"He's more like a 'brother' than a teacher": Politicized caring in a program for African American males	*Teachers College Record*
2017	J. C. Brown K. J. Crippen	The knowledge and practices of high school science teachers in pursuit of cultural responsiveness	*Science Education*
2017*	S. I. Bottoms K. Ciechanowski K. Jones J. de la Hoz A. L. Fonseca	Leveraging the community context of family math and science nights to develop culturally responsive teaching practices	*Teaching and Teacher Education*
2017	Melissa Braaten Manali Sheth	Tensions teaching science for equity: Lessons learned from the case of Ms. Dawson	*Science Education*
2016	Renee Baynes	Teachers' attitudes to including indigenous knowledges in the Australian science curriculum	*The Australian Journal of Indigenous Education*

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Table 1. (*continued*)

Publication Years	Authors	Titles	Journals
2016	Alexandra Schindel Dimick	Exploring the potential and complexity of a critical pedagogy of place in urban science education	*Science Education*
2015	Betsy J. Bannier	Review of Okhee Lee, Cory A. Buxton, James A. Banks (eds.), *Diversity and equity in science education: research, policy, and practice* (Teachers College Press, 2010)	*Cultural Studies of Science Education*
2015	Sara Tolbert	"Because they want to teach you about their culture": Analyzing effective mentoring conversations between culturally responsible mentors and secondary science teachers of indigenous students in mainstream schools	*Journal of Research in Science Teaching*
2014	María S. Rivera Maulucci Bryan A. Brown Salina T. Grey Shayna Sullivan	Urban middle school students' reflections on authentic science inquiry	*Journal of Research in Science Teaching*
2013	A. A. McGlashan A. W. J. Wells	The road less travelled: A pre-service approach towards the technology teaching profession	*International Journal of Technology and Design Education*
2012	Bree Picower	Using their words: Six elements of social justice curriculum design for the elementary classroom	*International Journal of Multicultural Education*
2012	J. C. Laughter A. D. Adams	Culturally relevant science teaching in middle school	*Urban Education*
2009	Jennifer Goldberg Kate Muir Welsh	Community and inquiry: Journey of a science teacher	*Cultural Studies of Science Education*

Note. *Articles that were selected for deeper analytical analysis.

researchers concerned with the vastness of precollege engineering education, we felt it was important to recognize these spaces as valuable engineering educational environments. Through discussions, we ultimately decided that our review and future analysis could benefit from differentiation between articles that explicitly centered engineering design and those that did not. We ultimately made these distinctions

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Table 2. Engineering Scoring Guide

None	Not explicitly concerned with engineering or engineering education and not included in this review.
Limited	Engages the field of engineering and/or engineering education, but discussions of these fields are limited. Student learning is not explicitly centered around preparing engineering students, exploring the engineering design process, building products, or taking up engineering habits of mind.
Extensive	Explicitly discusses multiple aspects of engineering and/or engineering education. Learning environments are centered around preparing engineering students, discussing ideas such as engineering design process, building structures, designing products, or enacting engineering habits of mind.

Table 3. Critical Consciousness Scoring Guide

None	Article not concerned with critical consciousness and not included in review.
Light	Article concerned with how teachers engage students in recognizing and understanding social inequalities.
Deep	Article concerned with how teachers engage students in recognizing and understanding social inequities and how teachers support students in taking critical action to produce sociopolitical change.

by implementing individual article evaluations using a shorthand scoring guide we created (Table 2).

Similarly, we discussed and debated toward consensus on how to classify the multitude of ways articles were engaging with critical consciousness as an educational framework. Some articles explicitly framed critical consciousness as being concerned with both critical reflection and critical action, while other articles seemed primarily concerned only with critical reflection, offering little support or structures for students to act against oppressive elements of society. Consequently, we decided to differentiate between articles that engaged K–12 engineering students in both critical reflection and action and those that focused primarily on critical reflection. To aid in evaluating and classifying each article along this critical consciousness engagement spectrum, we created a shorthand scoring guide (Table 3).

After concluding initial charting of the 71 reviewed articles, we also discussed and debated the best approaches for answering research question #2: How are teachers engaging critical consciousness as an educational framework in precollege engineering educational spaces? We recognized that initial theoretical work in this area might best be served by focusing our deeper analytic efforts within those learning

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environments that explicitly centered the fields of engineering and engineering education. We ultimately decided our initial analysis would best be served by critically analyzing the subset of 10 articles Devon had categorized as both deeply engaging critical consciousness as an educational framework and explicitly engineering-focused learning spaces (see the Table 1 note).

Due to our philosophical alignment with critical theories and critical scholarship, we decided to utilize a constructivist grounded theory approach to analyze these 10 articles. Constructivist grounded theory employs a deeply reflexive methodology to assist researchers in continually questioning themselves, their data, and their analysis. According to Charmaz (2017), "this methodological self-consciousness requires scrutinizing our positions, privileges, and priorities and assessing how they affect our steps during the research process" (p. 35). Devon worked to conduct initial open coding of each of the 10 articles by first reading the articles and then going back through and open-coding passages with reference codes meant to signal how Devon felt the article was helping to answer research question #2.

After open-coding three to four articles, Devon stopped to write reflections, guided by a set of reflective questions such as the following: What does this data mean? How was this data collected? Why am I representing data this way? How is my background potentially impacting the patterns I am seeing? These reflections provided an opportunity for Devon to reexamine the data, rename codes, and continually work to improve the precision and scope of the analysis. Ultimately, we see this type of reflexive iterative analysis as part of a constructivist grounded theory approach and how "researchers can connect the subjective with the collective, and move their analyses to make statements about injustice, inequities, and human rights" (Charmaz, 2017, p. 41).

After finishing coding the 10 articles, Devon grouped open codes into emergent themes, writing out how he saw the open codes potentially answering research question #2. We next met together to discuss and debate toward consensus these emerging themes and their potential associated claims. Afterward, Devon went back to the coded documents, adding in specific quotes and other empirical evidence from the reviewed literature to support each of the emerging claims being made. We then continued to meet regularly to discuss and adjust our final claims and conclusions based on empirical evidence provided by the articles.

Study Limitations

There were several factors that limited the completeness of our search efforts. These included our use of English-language search terms as well as our use of popular academic databases that "tend to have a Western and particularly U.S. bias" (Arksey

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& O'Malley, 2005, p. 25). We also limited this search to articles that specifically used the terms "critical consciousness" and/or "sociopolitical consciousness" in their text. We acknowledge that there are many emerging precollege engineering educational frameworks and perspectives that, while not overtly labeled as such, embody many principles of critical consciousness (e.g., Calabrese Barton & Tan, 2018; McGowan & Bell, 2020; Tan et al., 2019). From our perspective, there are important similarities and differences between these frameworks and what we characterize as critical consciousness educational frameworks, particularly around the language being used and the educational practices and pedagogies being employed. For instance, McGowan and Bell's (2020) critical sociotechnical literacy framework is centered around the development of students' critical sociotechnical literacy. This framework draws heavily on Freireian concepts but does not take up the explicit language of critical reflection and critical action cycles and instead describes a largely linear six-step pedagogical framework. We certainly encourage future review studies to explore and potentially even categorize this broader family of justice-oriented, social change–focused approaches to engineering education. Such an analysis would likely offer insight into the practical challenges of implementing critical consciousness–inspired frameworks in real-world classrooms. This type of analysis could also offer a valuable opportunity for learning across these different frameworks in a way that could help build collective capacity to continually push toward more transformative and equitable forms of precollege engineering education.

FINDINGS

Question #1. *What are the current trends of studying critical consciousness as a framework for precollege engineering education?*

Our charting of articles reveals that research studies examining critical consciousness engineering frameworks overwhelmingly utilized qualitative methods to engage K–12 students and teachers in the United States as study participants, with a majority of this research work happening in formal settings and a modest amount within informal settings (Table 4). This research work is also relatively recent, with the first article published in 2009 and the vast majority of articles being published between 2017 and 2022 (Figure 1).

We classified articles as engaging engineering education and critical consciousness in different categories to explore whether scholars and/or practitioners in these different contexts (i.e., explicit engineering environments vs. implicit engineering environments) might be taking up critical consciousness frameworks differently. Based on historical characterizations of explicit engineering educational spaces as

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Table 4. Overview of Methodology, Participants, Settings, and Geographic Locations

Methodology		Participants		Setting		Geographic Location	
Qualitative	51	K–12 Students	25	Formal	45	United States	51
Mixed methods	5	Teacher candidates	8	Informal	16	Canada	2
Theoretical	6	Teachers	28			Asia	4
Quantitative	4	Parents	2			Africa	1
Literature review	3	Administrators	1			Australia/New Zealand	3
Issue introduction	1					South America	1
Book review	1					Caribbean	1
						Europe	3
Total	71	Total	64	Total	61	Total	66

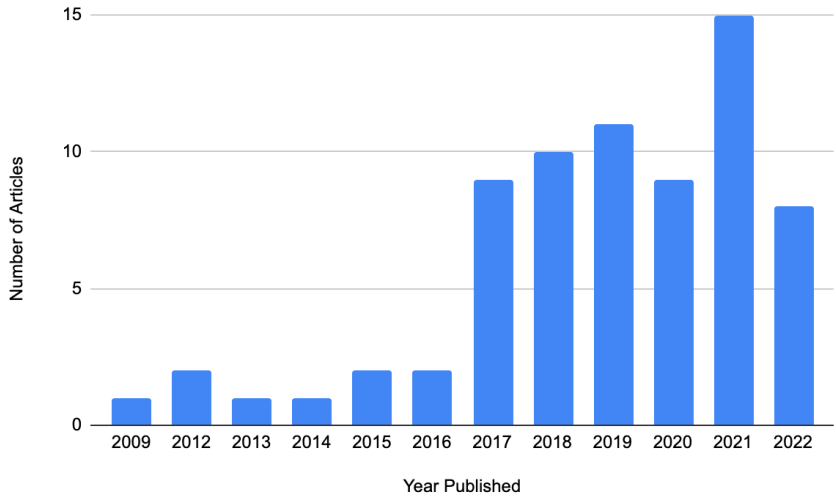

Figure 1. Overview of Publications by Year

potentially uniquely resistant to implementation of critical pedagogies (McGowan & Bell, 2020), we anticipated that learning environments with extensive connections to the engineering field might tend toward more lightly engaging with critical consciousness as an educational framework. However, from the tallied data in Table 5, we see that the ratio of articles engaging critical consciousness deeply versus lightly is nearly exactly the same (2:1) in both the extensive engineering-focused environments and the less explicitly engineering-focused environments.

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Table 5. Levels of Engagement with Engineering and/or Critical Consciousness

	Lightly Engaged Critical Consciousness	Deeply Engaged Critical Consciousness	Total
Limited engagement with the engineering education field	18 articles	38 articles	56 articles (79%) • 32% light CC • 68% deep CC
Extensive engagement with the engineering education field	5 articles	10 articles	15 articles (11%) • 33% light CC • 67% deep CC

Note: CC = critical consciousness.

This analysis provides some initial evidence that scholars studying both explicitly engineering-focused learning environments and those in more implicit engineering educational environments are likely engaging with critical consciousness in similar conceptual ways. The analysis also supports our claim that critical consciousness as a topic continues to be differently understood and utilized within the scholarly literature. Nearly a third of reviewed engineering education articles engaged critical consciousness as an educational framework but did not describe educational practices that included full cycles of critical reflection and critical action. An example of this type of article was Kim and colleagues' (2017) work with seventh grade students and their engagement with invention curriculum designed to incorporate perspective from their home culture. Kim and colleagues discuss the engineering program's use of culturally relevant pedagogies, which included opportunities for students' critical reflections that "explored family histories and cultural backgrounds" (p. 252). Students then used these reflections to engage in design activities and to connect their invention designs to their home cultures.

Although the critical consciousness educational framework described by Kim and colleagues (2019) provided opportunities for students and teachers to critically reflect on normative oppressive views of what types of knowledge are valuable in an invention classroom, there seemed to be no explicit discussion, structures, or guides for individual or collective critical action to address these injustices. From our perspective, deeply engaging critical consciousness as an educational framework also necessitates providing explicit structures or supports for critical action, in which students and teachers can identify and name oppressive elements in society and act to transform them. Students and teachers in Kim and colleagues' study were certainly acting to disrupt the traditional oppressive White heterppatriarchal norms of invention education, but to what extent did they recognize their classroom practices

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as acts against oppression? Did they see traditional invention classrooms as oppressive? Perhaps, but Kim and colleagues' analysis and discussion of the pedagogical approaches being employed did not make answers to those questions clear and so seemed to conceptualize critical consciousness as being concerned primarily with critical reflection and not necessarily requiring cycles of critical action.

Our quantitative analysis also provides additional evidence that a large majority of critical consciousness engineering education frameworks are happening in environments where engineering design is not the primary learning objective (79% of reviewed articles). A representative example of these kinds of studies is Tolbert's (2015) research on mentoring science teachers. This study discusses the importance and potential for facilitators to help science teachers understand how "non-dominant knowledge systems and/or contributions of women and People of Color to mathematics, sciences, and engineering knowledge have been marginalized" (p. 1352). This work highlights the potential for critical consciousness frameworks to act as a guiding construct for teacher professional development, with cycles of critical reflection and critical action supporting teacher critical consciousness building, along with enactments of culturally sustaining pedagogies. This type of scholarship has deep implications for how teacher educators might introduce students to the multidimensionality of engineering. However, Tolbert's article does not go into detail about these engineering educational connections or discuss any direct implications for the field of engineering education.

Question #2. *How are teachers engaging critical consciousness as an educational framework in precollege engineering educational spaces?*

From our critical analysis of the 10 articles that deeply engaged critical consciousness and engineering education, we bring forward four common themes that highlight how some educators are engaging critical consciousness as an educational framework in precollege engineering education: (1) navigating institutional critique and support, (2) balancing the relational and the technical, (3) reframing who can be an engineer, and (4) reframing what engineers do. It is important to note that these themes of critical consciousness enactments in classrooms were developed through descriptions in the scholarly literature, and the claims we make here are claims about the corpus of literature we selected. We believe that our previous analysis describing the trends in this review's set of studies provides important context for these claims, namely that the classroom descriptions we draw from were made in relatively recent articles written by scholars explicitly concerned with U.S. K–12 engineering educational spaces. These scholars also conceived of critical consciousness educational frameworks as entailing both critical reflection and critical action.

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Navigating Institutional Critique and Support

As teachers engage students in critical consciousness frameworks, they often wrestle with the tension of positioning engineering and its technical knowledge base not as something students should blindly join or adopt. Instead, engineering gets seen as another social institution and set of practices built within a broader history of a classist, racist, and heteropatriarchal society. Critical consciousness demands the recognition of these past injustices and a questioning of how different aspects of current systems may inherently serve to reinforce these injustices. From this perspective, teachers and students engaged in critical consciousness engineering education frameworks must be able to critique the engineering and engineering educational systems without completely disavowing them so that they might be able to act to transform them.

The most common critiques taken up by teachers in our literature review were implicit critiques of traditional forms of engineering education, particularly its failure to value the knowledge, skills, and cultures of historically marginalized students. For instance, teachers participating in family math and science nights (Bottoms et al., 2017) and community-based environmental engineering projects (Jorgenson, 2018) each worked to recognize and support the knowledge and values of students' cultures and communities. Yet, the teachers did not explicitly voice to students or others within their communities their own perspectives on how more traditional teacher-centered pedagogies inherently privilege middle-class White male norms and values that result in racist, classist, and sexist outcomes in the classroom.

Similarly, King and Pringle's (2019) analysis of fourth through eighth grade Black girls' experiences in I AM STEM, a community-based informal STEM summer program, provides additional examples of teachers engaging in implicit critiques of engineering education through community-engaged pedagogies. The I AM STEM summer program helped teachers support Black and biracial students in problem-based and experiential learning experiences through themes of sustainability and ecojustice. This learning took place in a community center that was based in the students' community as well as through field trips to engage with partners at local businesses, organizations, and universities. Field trips allowed students to complete engineering activities with different local partners, including members of the National Society of Black Engineers and doctoral students in human-centered computing. King and Pringle emphasized how the structure of this community-based summer program, particularly its use of field trips, ignited the girls' interests in STEM. These pedagogies contain implicit critiques of traditional engineering education, which King and Pringle (2019) describe as "dominated by scripted curriculum requirements, teachers lecturing and students reading the science textbook, completing worksheets, and

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writing notes" (p. 561). However, teachers did not seem to explicitly voice this critique of traditional engineering education to each other or to students.

King and Pringle (2019) go on to describe how as soon as their research project provided the time, space, and structure for program-participating Black girls to reflect on their science learning experiences, those girls began sharing their critiques of traditional science education. King and Pringle argue that such critical reflections demonstrate both the potential and the need "to create opportunities for Black girls to share their stories" and then to use those stories to inform how we "create safe spaces outside of the formal learning environment to introduce Black girls to the world of STEM" (p. 564). This scholarship highlights the high potential to engage community-based pedagogies as a way to critique and act against traditional unjust engineering educational structures. However, King and Pringle's study also emphasizes that without space for teachers and their students to reflect on their learning environments, share stories that name oppressive elements of engineering education, and collaboratively act to shift educational structures toward justice, teachers are likely missing out on "necessary insights to better provide for [student] engagement in STEM" (p. 564).

Within the reviewed articles, few teachers explicitly discussed their critique of engineering or engineering education. One notable exception was Mr. Coles, a Black male middle school engineering teacher working with Black students. Madkins and McKinney de Royston (2019) described Coles as holding highly critical perspectives that shaped nearly every aspect of his classroom ranging from what was on the walls, the guest speakers he invited to the ways he interacted with students. Coles described how he discussed his critical perspectives of U.S. society with his students: "We're always talking about how even a statement like, 'Life ain't fair . . .. it's [racism] just embedded in the system, it's just the system. . . . It has to be recognized'" (p. 1336).

Coles's critique of racist systems in the United States, including its engineering and engineering educational systems, did not mean that Coles rejected all aspects of these systems outright. Instead, he navigated between critique and support of different aspects of the engineering and engineering educational systems. For instance, he expressed his support for engineering's use of systematic prototype testing and written analysis, telling students that "as engineers, '[they] must explain' and 'put their ideas on paper' because it is necessary to document their 'creative' processes when engaging in engineering design challenges" (Madkins & McKinney de Royston, 2019, p. 1337). However, Coles also emphasized the importance of adapting these practices to the cultural norms and values of his students, telling his Black students that they would need to leverage "hood skills" (p. 1336) and the creative utilization of what they had available to complete their prototype testing.

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Several articles described the importance of critical reflection for helping teachers develop their critical consciousness and navigate the complexities of disrupting and supporting different aspects of engineering (e.g., Archer et al., 2021; Bottoms et al., 2017; Holly, 2020; Khomson et al., 2020). Holly's (2020) autoethnography of a Black man teaching engineering to Black boys specifically described what this process might look like for an engineering educator:

> To me, this meant reflecting on my own experience in learning about engineering, as well as the impact of my presence in the community. This involved reviewing how the engineering community describes itself and its contribution to society, analyzing the past and present quality of Black male experiences in engineering, investigating whether engineering can enrich the lives of Black males (and if so, how), and contemplating what Black males can contribute to the engineering community, amongst other musings. (Holly, 2020, p. 35)

This reflective process led Holly to voice his critique of current engineering and engineering educational systems through questions to his students about why the number of Black males in engineering is so low, asking "Do Black males like engineering? Are they incapable of making it through? Or is something else causing their underrepresentation?" (Holly, 2020, p. 34). This type of critical reflection provided space for Holly and his students to recognize and name which systemic structures in society are primarily at fault for the low representation of Black males in engineering. It also provided a starting point for discussing and debating how Black males might navigate those systemic structures, when and where to push back on them, and which aspects to reject and which to adopt or adapt. This type of open critically reflective practice in which students and teachers work together to discuss how to navigate different aspects of institutional critique and institutional support seems to be core to deeply engaging critical consciousness in precollege engineering education.

Balancing the Relational and the Technical

The critically conscious engineering educators discussed in the reviewed articles all emphasized the importance of relationship building in the classroom and the need to shift engineering education toward more relational modes grounded in feelings of trust and support between students and teachers rather than authority and power. Jorgenson (2018) described this core goal as the need to build "a deep culture of relational trust and vulnerability" (p. 26), while Brown (2017) described it as the creation of a "collectivist, 'family-like' environment" (p. 1161) and Archer and colleagues (2020) labeled it as a "loving/caring pedagogy" (p. 191). This emphasis on

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relationship building is in line with traditions of culturally relevant pedagogy and a focus on equitable and reciprocal social relations in the classroom (Ladson-Billings, 1995). However, specifically within the context of precollege engineering education, the extent to which relationship building was emphasized seemed to exist along a spectrum, and teachers often framed relationship building in competition for time, resources, and energy with the technical aspects of engineering education.

The reviewed articles continually described connections between relationship building in precollege engineering education and asset-based perspectives of individuals, particularly asset-based perspectives of Black youths and other marginalized students who have been traditionally labeled as intellectually incapable within engineering learning environments. Asset-based perspectives were something Brown (2017) described as a "must" (p. 1169) for advancing equity in engineering classrooms. Bottoms and colleagues' (2017) study of science teacher candidates similarly made recommendations for teacher training programs to support candidates' efforts to understand and value the sociopolitical realities, cultural norms, and ways of knowing of the students they work with and the communities they engage. Archer and colleagues' (2021) work with marginalized youths in two informal science learning programs described how teachers' asset-based perspectives of youths are also inherently tied to their willingness to share power with youths. Archer and colleagues' study described Madison, a facilitator who took a less critically conscious approach to engineering education and utilized "a recipe style activity with instructions for building and flying paper airplanes" (p. 187). The authors describe how this pedagogical approach restricted the power of youths' decision-making and ultimately resulted in students finding the project inauthentic and boring. They contrasted this pedagogy with a second facilitator, Cole, who provided more choice and autonomy to student participants. The authors argue that Cole's decision to provide more power to students was inherently connected to his asset-based perspectives of those youths and his emphasis on loving and caring relationships.

Across the reviewed literature, critically conscious engineering educators often worked toward relational goals and power sharing through the use of conversation. For example, Coles, the critically conscious Black middle school engineering teacher at the center of Madkins and McKinney de Royston's (2019) study, described his pedagogical use of conversation:

> We're all having these conversations about who you are, where, what you are, who you are, and where you come from. Like we're always talking about knowing, you know, your history. Every teachable moment you can, teachers will stop a lesson to just have the conversation. I know I'm REAL good for that. (Madkins and McKinney de Royston, 2019, p. 1336)

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Coles's conversational approach also provided a means for him to share with students where he comes from and what his experiences with engineering and engineering education have been. Madkins and McKinney de Royston (2019) note that Coles's shared racial background with his Black students also likely enhanced his capacity to quickly build trusting relationships with the Black youths in his classroom, as he continually drew connections between his own lived experiences and the lives of his Black students.

The use of conversation seems to be a key tool for understanding and valuing student perspectives, while building relational trust with and among students represents a shift in engineering classroom norms away from depersonalized technical interactions and toward open sharing of personal experiences and political perspectives from outside the classroom. For Eisenhart and Allen (2020) this also necessitates opening up space for discussions of race, class, gender, and sexual orientation that can push against traditional norms of who belongs in engineering education and what topics are appropriate to discuss in that context. Eisenhart and Allen go on to describe how their pedagogical commitment to regular open conversations meant focusing just as much of their time and energy on supporting social relationships and understanding in their after-school program as on developing student technical engineering knowledge. In practice this meant engaging in many informal conversations with the young women of color in the program about the multiple opportunities and obstacles those women might face if they pursued a career in engineering.

Holly's (2020) autoethnography of teaching Black boys engineering also discussed the potential to expand the spaces in which conversation and coalition building pedagogies might take place:

> I saw the youngsters at church, in the grocery store, out walking, and so on. Sometimes we simply greeted each other, and at times we had extended conversations, occasionally participating in activities together (like sitting together at an athletic event, playing basketball, etc.) (Holly, 2020, p. 31)

For Holly, connecting with and caring for students meant at times being physically present where young people hang out as well as adapting classroom practices to make more room for collaborative conversations. "We had numerous discussions because I wanted to know what the boys genuinely thought and felt. So, I delayed or discarded the course's planned aspects to allow for more conversation between myself and the boys" (Holly, 2020, p. 35).

The differing extents to which instructors shifted or even discarded some aspects of the traditional technical engineering curriculum in place of conversations with students about life, political perspectives, and hopes for the future seem to reflect

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both the critical perspectives educators hold about the value of relational versus technical knowledge and the multitude of spaces these educators taught in and the value those systems put on the different forms of knowledge. Madkins and McKinney de Royston (2019) noted that Coles's changes to classroom norms and his ability to stop the engineering lesson to have deeper discussions were likely impacted by the fact that he was both a classroom teacher and a school vice principal, providing him with unique administrative power and pedagogical freedom. Similarly, Holly (2020), Eisenhart and Allen (2020), and King and Pringle (2019) all noted that the changes they each implemented toward emphasizing relationship building over technical engineering knowledge exploration were likely more possible because they were operating in out of school spaces, which gave them more flexibility than most formal learning environments.

Reframing Who Can Be an Engineer

Educators who are bringing critically conscious frameworks to precollege engineering classrooms are continually working to help students dispel their own false narratives about who can be an engineer and what types of cultural norms those engineers embrace. For Eisenhart and Allen (2020) this meant bringing in adult women of color as mentors to help guide youths' design projects in their after-school program. Eisenhart and Allen believed that these mentors could create a space in which young women of color could hear personal stories about engineering from other women of color and potentially build a deeper understanding of what their future as an engineer might look like, both the challenges and the opportunities.

Other critical educators also took up pedagogical practices centered around sharing counternarratives of engineers and engineering. Archer and colleagues (2021) describe the impact of an after-school program showing students a YouTube video of a Black female engineer explaining how she became an engineer and why she enjoys her career, with one of the youths participants stating "that was good to see because it's usually predominantly a White career," and it is "really empowering to little girls like us, it makes me feel better" (p. 190). In his out-of-school program, Holly (2020) also showed Black male youths examples of Black male engineers to help break down stereotypes of how engineers look, what careers they exist in, and what educational backgrounds they have. This set up an exercise in which youths created an engineering figurine based on their own identity, hobbies, and values.

Madkins and McKinney de Royston (2019) also discussed the capacity for Black instructors to model counterstories of who engineers are and what they do, dispelling the false narrative that Black students are not smart enough to be engineers while also pushing against the idea that White cultural norms must be adopted in order for Black

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youths to become engineers. Madkins and McKinney de Royston use Mr. Coles, a Black male middle school engineering teacher, as an example of such an approach. They highlight his use of language outside of White norms, such as "Y'all just don't know!" or "going to church" (p. 1335), as he discussed the engineering process and shared one of his own engineering products. Coles's decision to model a counterstory of who can be an engineer and what engineering looks like seems deeply connected to his own personal experiences in engineering and his political clarity around what it means to be a critically conscious precollege engineering teacher.

As critical educators such as Coles highlight both the challenges and opportunities of a career in engineering, they model a perspective that is simultaneously critical of the field of engineering and inspired by the people who have chosen to become engineers. Eisenhart and Allen (2020) discuss this tension between their hopes for the young women of color in their program to pursue an engineering career to transform the field toward more equity-oriented ends and the reality that if these young women do pursue a career in engineering they are likely to encounter an environment that is actively hostile to people like them. Eisenhart and Allen reflect on these efforts:

> We did not want the women to blindly accept existing traditions and structures of engineering in these fields. We wanted to encourage them with exciting, cutting-edge, gender- and race-relevant activities while also supporting them to recognize obstacles they could face, be critical toward the obstacles, and consider how they might be handled. Once exposed to engineering and computing, we intended to honor their decisions and choices, whether for or against pursuing these fields. (Eisenhart & Allen, 2020, p. 813)

Eisenhart and Allen's reflection emphasizes yet again how critical educators in this review pushed against the false narratives that only White middle-class men can be engineers.

Yet, how educators acted against this oppressive stereotype seemed to vary depending on how those educators navigated the tension of being a critically conscious engineering educator themselves. For instance, Madkins and McKinney de Royston (2019) described Coles's efforts to model direct approaches to countering stereotypes of Black people in engineering, emphasizing the reality that Black youths do not need to change who they are to become engineers but also that they must recognize the master narrative of Black folks in engineering. He would tell his Black students, "God forbid if you're not 100% stereotypical" and "you [as African Americans] will be judged on anything you do" (p. 1334). Madkins and McKinney de Royston go on to describe how Coles's belief in the academic and engineering potential of his Black students underpinned his efforts to directly challenge the youths to disrupt these

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stereotypes. Other critical educators, such as Holly (2020), seemed to spend less time emphasizing the need for Black youths to challenge stereotypes and more time emphasizing the potential for Black youths to become engineers outside traditional engineering career pathways. Holly discussed not wanting to make Black youths feel as if it is their responsibility to diversify the engineering profession. Instead, it is about helping youths understand two important truths about engineering: the truth that the field of engineering is unjust and unwelcoming of people who do not conform to middle-class White male norms and the truth that marginalized youths can become engineers and should deeply consider doing so.

Reframing What Engineers Do

Brown (2017) notes that published examples of critical pedagogical approaches in engineering classrooms are rare. The handful of critically conscious precollege engineering educators reviewed in this study all worked to support marginalized students to reframe what engineering looks like and who can be an engineer. Some critical educators worked toward these goals by creating separate spaces for marginalized youths to engage in engineering education activities. For instance, King and Pringle's (2019) analysis of the I AM STEM program describes how the program offered students weekly field trips and instruction in robotics through a race-conscious framework, an effort meant to create spaces free of microaggressions that would allow "Black girls to discuss and even confront racism and sexism or power structures that seek to impede their progress in STEM" (p. 562). Similarly, Bottoms and colleagues (2017) describe the potential for family math and science nights to create unique spaces where youths can use different languages across relationships to engage in engineering activities such as designing an airplane or a catapult and the implications this has for how youths might make sense of their engineering learning.

Other critical educators focused on adapting traditional engineering design processes to recognize and value the backgrounds and cultural norms of marginalized youths, shifting power to those youths to make decisions about all aspects of the design process ranging from the problems engaged to the designs proposed and tested. For instance, Eisenhart and Allen's (2020) study of the Female Recruits Explore Engineering (FREE) after-school program emphasized how the program allowed young women of color to choose the engineering projects they wished to engage in, ultimately supporting youths in creating "sunglasses that can melt snow, playgrounds for disabled children, 'hi-lo' shoes that easily convert from heels to flats, clothing that lights up and spells out a name or message, a money reader for the blind" (p. 812). Eisenhart and Allen's work described how these projects built participants' interest in engineering but did not change external engineering pathways, which they

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ultimately found excluded nearly all the women of color participants in FREE from pursuing an engineering career.

Eisenhart and Allen's (2020) description of youths designing playgrounds for disabled children and a money reader for the blind demonstrates how precollege engineering educators might position the engineering design process as a potential tool to take on issues of social justice, including disability rights. However, Eisenhart and Allen did not discuss the specifics for how teachers engaged with youths to develop, negotiate, and select these topics within the engineering educational space or how adults supported youths in understanding the ways in which issues such as ableism, racism, classism, and other sociopolitical factors might impact their projects and shape their project designs.

Holly's (2020) autoethnographic work delved into the challenges and tensions associated with supporting youths in developing engineering projects that address issues of social justice:

> In my experience, youth are aware of the sociopolitical factors that shape their everyday lives, but usually need help deciphering the implications of the realities they recognize. Black youth perceive subtle and overt prejudices, and poor youth know what is beyond their means; even so, they lack the power, infrastructure, and opportunities to alter their fates. (Holly, 2020, p. 30)

Holly (2020) described his use of discussion prompts as a pedagogical approach to foster conversations that helped surface students' political perspectives and moved students from ambiguous language around social challenges to naming specific issues in their community and the people making decisions within those contexts. This process allowed Holly to support young Black men in utilizing engineering habits of mind to develop potential solutions to community issues.

The ways in which teachers in the reviewed articles sought to use engineering to act against oppression seemed to be connected to how they navigated different aspects of critique and support for engineering and engineering education. Some, such as Mr. Coles from Madkins and McKinney de Royston's (2019) study, focused much of their time and political goals on acting against oppressive false notions of Black youths in engineering. Madkins and McKinney de Royston describe the multitude of ways Coles positioned his students as capable engineers, such as drawing connections between engineering practices and the "hood skills" (p. 1336) possessed and valued by the Black youths in his classroom. On the other hand, Holly's (2020) engineering education efforts seemed to focus more explicitly on adapting engineering practices to reframing engineering as a tool capable of supporting specific or tangible forms of sociopolitical change beyond the walls of the classroom. Holly describes

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how his pedagogical approach sought to scaffold Black youths' sense-making around the critical issues that impacted their everyday lives so as to ultimately help youths design problem-solving policies and potential solutions to these issues.

It seems likely that the variety of pedagogical choices and political goals of different educators in this review were shaped both by how those educators navigated the core tensions of being a critically conscious engineering educator and by the boundaries of the system in which they were teaching. Time and again, critically conscious teachers recognized the systemic bounds in which their classrooms operated, such as time, available resources, and expectations of supervisors/funders. These teachers continually reflected on and worked to negotiate what they could do within these boundaries. Jorgenson's (2018) discussion of teachers' attempts to build a radically inclusive STEM school highlights the multitude of systemic forces impacting pedagogical choices within this formal schooling environment, including state achievement tests, district assessments, district curriculum pacing guides, large class sizes, poor classroom acoustics, and lack of classroom dividers. Each of these factors seemed to undermine teacher morale, sense of autonomy, and professional communities, ultimately leading most teachers to take up more traditional classroom approaches.

Although out-of-school spaces generally provided educators with more flexibility and autonomy, they also established limits on the time frame in which teachers could engage in pedagogical activities. For example, Holly (2021) mentioned in designing an after-school engineering program that "I realized I cannot reasonably do all that I want to do. At that point I began to hone-in on what I can teach the students given the duration of the course" (p. 162). Holly's reflections on having limited time with youths to enact an equity-centered engineering education program seem to be connected to broader systemic financial barriers to supporting youths in using engineering tools and approaches to act against oppression. None of the reviewed articles specifically discussed the amount of money or financial resources utilized in their educational programming, but one can assume that the lack of time Holly experienced in his program is connected to the poor classroom acoustics and large class sizes experienced by teachers in Jorgenson's (2018) study. More time, better facilities, and smaller class sizes would likely all require greater financial resources committed to these educators and their classrooms.

DISCUSSION

From a critical consciousness perspective, equitable engineering classrooms always support students and teachers in working through cycles of critical reflection and

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critical action. This review highlights the potential for teachers to use cycles of critical reflection and critical action to develop and enact new pedagogical approaches that support liberatory forms of precollege engineering education. However, it also surfaces many of the challenges and tensions that limit the capacity for teachers to engage critical consciousness as a framework in precollege engineering education.

In looking across the reviewed literature, we see a trend that educational initiatives and research efforts at the intersection of critical consciousness and precollege engineering education are increasing. However, there is also a recurring trend in studies across both explicit and more implicit engineering educational environments, with a third of those studies and the educational frameworks they explore not fully taking up both critical reflection and critical action. Quantifying this trend has challenged us to critically reflect not only on why there is a discrepancy in how people take up critical consciousness as an educational framework but also on the systemic challenges that may limit both practitioners' and researchers' full engagement with critical consciousness. What might be the most prominent barriers to critical reflection and critical action in the precollege engineering education classroom? How are students, teachers, and researchers pushing against these barriers? We hope that additional research and more systematic literature reviews might explore these questions and shed additional light on how we might critically act to ensure that trends in critical consciousness engineering education continue to expand into not only more spaces within the engineering education landscape but also deeper and more meaningful types of reflections on inequity and actions toward justice everywhere.

The themes we identified from this review for how teachers are taking up a critical consciousness framework in precollege education are all connected to pushing against what we see as engineering's overemphasis on action without regard for critical reflection. If engineers continue to take actions that reshape our world in increasingly powerful ways devoid of critical reflections, those actions will only serve to deepen social inequities. Instead, what is needed is an emphasis in engineering and engineering education on critical reflection. This includes critical reflection on the oppressive power structures that have shaped precollege engineering education practices, elevating the cultural norms and values of whiteness and heteropatriarchy (Xu et al., 2022). This critical reflection also requires recognizing and naming the violence and dehumanization that this unjust history has caused, particularly to historically marginalized students and their communities, and demands critical actions that work toward creating radically new social structures (Bang & Vossoughi, 2016).

Attempts to bring critical reflection and, in turn, critical action to the precollege engineering educational system face a myriad of practical challenges. Most notably,

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time and resources must be reallocated from the goal of developing student technical engineering knowledge to the goal of developing student critical consciousness. Understanding how to most effectively and efficiently leverage time and resources within precollege engineering education toward the goals of critical consciousness building will likely provide important research opportunities for future scholars. We encourage researchers to continue to ask questions such as the following: How might cycles of critical reflection and critical action be supported and evaluated within and beyond the precollege engineering classroom? What specific obstacles put the highest practical limits on enacting critically conscious precollege engineering education frameworks? What are the inherent alignments and misalignments between critical consciousness and engineering?

We also can't help but acknowledge the potential role that engineering and technology can play within the design of new educational tools and platforms that themselves might help to facilitate the enactment of critically conscious educational frameworks in precollege engineering education and beyond. With this reality in mind, critical scholars may well want to ask questions such as the following: What role might social scientists play in collaborating with engineers to build new tools to support teachers' enactment of critical consciousness frameworks in K–12 engineering classrooms? How might educational scholars engage in collaborative cycles of critical reflection and critical action to understand the injustices that educational tools and technological platforms currently support in K–12 engineering classrooms, and how might we critically act to redesign them toward more just ends?

This review highlights some of the general themes for how educators are bringing critical reflection into the precollege engineering curriculum by (a) navigating institutional critique and support, (b) balancing the relational and the technical, (c) reframing who can be an engineer, and/or (d) reframing what engineers do. Importantly, all of these thematic areas highlight both the need and the potential for teachers and the classroom pedagogies they employ to help change the old axiom that "scientists study the world as it is; engineers create the world that has never been" to something more like "engineers, scientists, and others work together to critically reflect on the world as it is so they can leverage their expertise to create the world that has never been."

Conclusion

The studies reviewed in this article highlight the transformative potential of critical consciousness as a framework for building more equitable forms of precollege engineering education. However, they also demonstrate the complexities involved in

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employing critical consciousness frameworks in precollege engineering educational settings. Teachers must be able to navigate the tensions involved in critiquing and supporting different aspects of the traditional engineering and engineering educational institutions. Critical reflection and critical action are essential for navigating these tensions and building out critical pedagogies that are capable of building the critical consciousness of students and teachers. As this consciousness grows, educators can increasingly become better positioned to recognize and value students' funds of knowledge, cultural norms, and political goals. Through an emphasis on student relationships, educators can work with youths to help each other, their families, and their communities reimagine who engineers are and what engineers do. The potential for engineering as a field to take on the biggest challenges facing humanity and its capacity to help create a more just world will likely depend on the structures, time, supports, and resources dedicated to expanding critical consciousness educational frameworks in precollege engineering. The political environment in which such changes must take place is highly contested, and researchers must consider not only how to build on our theories of critical consciousness in engineering education but also what knowledge and tools are needed to practically bring those theoretical perspectives to bear for more teachers and students.

AUTHOR BIOS

Devon Riter is a doctoral candidate in the School of Education at the University of Michigan specializing in science education. He is deeply committed to leveraging his scholarly work toward understanding and addressing issues of educational equity in science classrooms and beyond.

Dr. James Holly Jr. is an assistant professor of mechanical engineering at the University of Michigan. His scholarship focuses on the ways disciplinary knowledge (e.g., mechanical engineering) reinforce racialized power and on preparing precollege engineering educators to identify and counteract racial inequity.

REFERENCES

Apple, M. W., Au, W., & Gandin, L. A. (2009). Mapping critical education. In M. W. Apple, W. Au, & L. A. Gandin (Eds.), *The Routledge international handbook of critical education* (pp. 3–19). Routledge.

https://doi.org/10.7771/2157-9288.1406

Archer, L., Godec, S., Calabrese Barton, A., Dawson, E., Mau, A., & Patel, U. (2021). Changing the field: A Bourdieusian analysis of educational practices that support equitable outcomes among minoritized youth on two informal science learning programs. *Science Education, 105*(1), 166–203. Portico. https://doi.org/10.1002/sce.21602

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19–32. https://doi.or/10.1080/1364557032000119616

Baillie, C. (2020). Engineering and social justice. In D. Michelfelder & N. Doorn (Eds.), *The Routledge handbook of the philosophy of engineering* (pp. 674–686). Routledge. https://doi.org/10.4324/9781315276502-59

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education, 94*(6), 1008–1026. https://doi.org/10.1002/sce.20392

Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction, 34*(3), 173–193. https://doi.org/10.1080/07370008.2016.1181879

Blue, C. E., Blevins, L. G., Carriere, P., Gabriele, G., Kemnitzer, S., Rao, V., & Ulsoy, G. (2005). The Engineering workforce: Current state, issues, and recommendations. Final report to the assistant director of engineering. *National Science Foundation.*

Boggs, G. L., & Kurashige, S. (2012). *The next American revolution: Sustainable activism for the twenty-first century*. University of California Press. https://doi.org/10.1525/9780520953390

Bottoms, S. I., Ciechanowski, K., Jones, K., de la Hoz, J., & Fonseca, A. L. (2017). Leveraging the community context of family math and science nights to develop culturally responsive teaching practices. *Teaching and Teacher Education, 61*, 1–15. https://doi.org/10.1016/j.tate.2016.09.006

Brayboy, B. M. J. (2005). Toward a tribal critical race theory in education. *Urban Review, 37*(5), 425–446. https://doi.org/10.1007/s11256-005-0018-y

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K–12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching, 54*(9), 1143–1173. https://doi.org/10.1002/tea.21401

Brown, B. A., Boda, P., Lemmi, C., & Monroe, X. (2019). Moving culturally relevant pedagogy from theory to practice: Exploring teachers' application of culturally relevant education in science and mathematics. *Urban Education, 54*(6), 775–803. https://doi.org/10.1177/0042085918794802

Cabrera, N. L., Milem, J. F., Jaquette, O., & Marx, R. W. (2014). Missing the (student achievement) forest for all the (political) trees: Empiricism and the Mexican American studies controversy in Tucson. *American Educational Research Journal, 51*, 1084–1118. https://doi.org/ 10.3102/0002832145 53

https://doi.org/10.7771/2157-9288.1406

Calabrese Barton, A., Schenkel, K., & Tan, E. (2021). The ingenuity of everyday practice: A framework for justice-centered identity work in engineering in the middle grades. *Journal of Pre-College Engineering Education Research, 11*(1), Article 6. https://doi.org/10.7771/2157-9288.1278

Calabrese Barton, A., & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Educational Research Journal, 55*(4), 761–800. https://doi.org/10.3102/0002831218758668

Calabrese Barton, A., & Tan, E. (2020). Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher, 49*(6), 433–440. https://doi.org/10.3102/0013189x20927363

Calabrese Barton, A., Tan, E., & Birmingham, D. J. (2020). Rethinking high-leverage practices in justice-oriented ways. *Journal of Teacher Education, 71*(4), 477–494. https://doi.org/10.1177/0022487119900209

Cech, E. A. (2014). Culture of disengagement in engineering education? *Science, Technology, & Human Values, 39*(1), 42–72. https://doi.org/10.1177/0162243913504305

Charmaz, K. (2017). The power of constructivist grounded theory for critical inquiry. *Qualitative Inquiry, 23*(1), 34–45. https://doi.org/10.1177/1077800416657105

Christian, K. B., Kelly, A. M., & Bugallo, M. F. (2021). NGSS-based teacher professional development to implement engineering practices in STEM instruction. *International Journal of STEM Education, 8*, 1–18. https://doi.org/10.1186/s40594-021-00284-1

Davis, J. L. (2013). *Survival schools: The American Indian movement and community education in the Twin Cities*. University of Minnesota Press. https://doi.org/10.5749/minnesota/9780816674282.001.0001

Dee, T. S., & Penner, E. K. (2017). The causal effects of cultural relevance: Evidence from an ethnic studies curriculum. *American Educational Research Journal, 54*, 127–166. https://doi.org/10.3102/0002831216677002

Diemer, M. A., & Blustein, D. L. (2006). Critical consciousness and career development among urban youth. *Journal of Vocational Behavior, 68*, 220–232. https://doi.org/10.1016/j.jvb.2005.07.001

Diemer, M. A., Rapa, L. J., Voight, A. M., & McWhirter, E. H. (2016). Critical consciousness: A developmental approach to addressing marginalization and oppression. *Child Development Perspectives, 10*(4), 216–221. https://doi.org/10.1111/cdep.12193

Eisenhart, M., & Allen, C. D. (2020). Addressing underrepresentation of young women of color in engineering and computing through the lens of sociocultural theory. *Cultural Studies of Science Education, 15*(3), 793–824. https://doi.org/10.1007/s11422-020-09976-6

Fanon, F. (1967). *Black skin, white masks.* Grove.

Figueiredo, A. D. (2008). Toward an epistemology of engineering. In D. Goldberg & N. McCarthy (Eds.), *Proceedings workshop on philosophy and engineering* (WPE 2008) (pp. 94–95). Royal Engineering Academy.

Freire, P. (1970). *Pedagogy of the oppressed* (M. Ramos, Trans.). Continuum. (Original work published 1968)

Garcia, M., Kosutic, I., McDowell, T., & Anderson, S. A. (2009). Raising critical consciousness in family therapy supervision. *Journal of Feminist Family Therapy, 21*, 18–38. https://doi.org/10.1080/08952830802683673

Ginwright, S. A. (2010). *Black youth rising: Activism and radical healing in urban America*. Teachers College Press.

Gutierrez, L. M., & Ortega, R. (1991). Developing methods to empower Latinos: The importance of groups. *Social Work with Groups, 14*(2), 23–43. https://doi.org/10.1300/j009v14n02_03

Holly, J. S., Jr. (2020). A critical autoethnography of a Black man teaching engineering to Black boys. *Journal of African American Males in Education, 11*(2), 25–42.

Holly, J., Jr. (2021). Equitable pre-college engineering education: Teaching with racism in mind. *Journal of Pre-College Engineering Education Research, 11*(1), 155–171. https://doi.org/10.7771/2157-9288.1282

Holly, J., & Masta, S. (2021). Making whiteness visible: The promise of critical race theory in engineering education. *Journal of Engineering Education, 110*(4), 798–802. https://doi.org/10.1002/jee.20432

hooks, b. (1994). *Teaching to transgress: Education as the practice of freedom*. Routledge.

Hynes, M. M., Mathis, C., Purzer, S., Rynearson, A., & Siverling, E. (2017). Systematic review of research in P–12 engineering education from 2000–2015. *International Journal of Engineering Education, 33*(1), 453–462.

Ishimaru, A. M., & Bang, M. (2022). Solidarity-driven codesign. In Peurach, D. J., Russell, J. L., Cohen-Vogel, L., & Penuel, W. (Eds.), *The foundational handbook on improvement research in education* (pp. 383–402). Rowman & Littlefield.

Jemal, A. (2017). Critical consciousness: A critique and critical analysis of the literature. *Urban Review, 49*(4), 602–626. https://doi.org/10.1007/s11256-017-0411-3

Jorgenson, S. (2018). Bridges and boundaries to power: How teachers used project-based learning to design a radically inclusive STEM high school. *Critical Education, 9*(16), 17–39. https://doi.org/10.14288/ce.v9i16.186274

Kadambi, A. (2021). Achieving fairness in medical devices. *Science, 372*(6537), 30–31. https://doi.org/10.1126/science.abe9195

Khomson, K., Kim, J. N., & Roehrig, G. H. (2020). Cultural competence or deficit-based view? A qualitative approach to understanding middle school students' experience with culturally framed engineering. *International Journal of STEM Education, 7*(1). https://doi.org/10.1186/s40594-020-00224-5

Kim, D., Cho, E., Couch, S., & Barnett, M. (2019). Culturally relevant science: Incorporating visualizations and home culture in an invention-oriented middle school science curriculum. *Technology and Innovation, 20*(3), 251–266. https://doi.org/10.21300/20.3.2019.251

King, N. S., & Pringle, R. M. (2019). Black girls speak STEM: Counterstories of informal and formal learning experiences. *Journal of Research in Science Teaching, 56*(5), 539–569. https://doi.org/10.1002/tea.21513

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice, 34*(3), 159–165. https://doi.org/10.1080/00405849509543675

Lomawaima, K. T. (1999). The unnatural history of American Indian education. In K. G. Swisher & J. W. Tippeconnic III (Eds.), *Next steps: Research and practice to advance Indian education* (pp. 3–31). ERIC Publications.

Madkins, T., & McKinney de Royston, M. (2019). Illuminating political clarity in culturally relevant science instruction. *Science Education, 103*(6), 1319–1346. https://doi.org/10.1002/sce.21542

Martin, L., & Wendell, K. B. (2021). Reflections on asset-based pre-college engineering education to promote equity: An introduction to the special issue. *Journal of Pre-College Engineering Education Research, 11*(1), Article 3. https://doi.org/10.7771/2157-9288.1325

McCarty, T. (1989). School as community: The Rough Rock demonstration. *Harvard Educational Review, 59*(4), 484–504. https://doi.org/10.17763/haer.59.4.rq43050082176960

McCarty, T., & Lee, T. (2014). Critical culturally sustaining/revitalizing pedagogy and Indigenous education sovereignty. *Harvard Educational Review, 84*(1), 101–124. https://doi.org/10.17763/haer.84.1.q83746nl5pj34216

McGowan, V. C., & Bell, P. (2020). Engineering education as the development of critical sociotechnical literacy. *Science & Education, 29*(4), 981–1005. https://doi.org/10.1007/s11191-020-00151-5

Mejia, J. A., Revelo, R. A., Villanueva, I., & Mejia, J. (2018). Critical theoretical frameworks in engineering education: An anti-deficit and liberative approach. *Education Sciences, 8*(4). https://doi.org/10.3390/educsci8040158

Milner, H. R. (2007). Race, culture, and researcher positionality: Working through dangers seen, unseen, and unforeseen. *Educational Researcher, 36*(7), 388–400. https://doi.org/10.3102/0013189X07309471

Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education, 101*(6), 1034–1060. https://doi.org/10.1002/sce.21305

Morgan, H. (2022). Resisting the movement to ban critical race theory from schools. *Clearing House: A Journal of Educational Strategies, Issues and Ideas, 95*(1), 35–41. https://doi.org/10.1080/00098655.2021.2025023

Mustakova-Possardt, E. (1998). Critical consciousness: An alternative pathway for positive personal and social development. *Journal of Adult Development, 5*, 13–30. https://doi.org/10.1023/a:1023064913072

https://doi.org/10.7771/2157-9288.1406

National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. National Academies Press. https://doi.org/10.17226/12187

National Academies of Sciences, Engineering, and Medicine. (2021). *Science and engineering in preschool through elementary grades: The brilliance of children and the strengths of educators.* National Academies Press. https://doi.org/10.17226/26215

NGSS Lead States. (2013). *Next generation science standards: For states by states*. National Academy Press. https://www.nap.edu/catalog/18290

O'Connor, C. (1997). Dispositions toward (collective) struggle and educational resilience in the inner city: A case analysis of six African American high school students. *American Educational Research Journal, 34*, 593–629. https://doi.org/10.3102/00028312034004593

Patrick, A., Andrews, M., Riegle-Crumb, C., Kendall, M. R., Bachman, J., & Subbian, V. (2023). Sense of belonging in engineering and identity centrality among undergraduate students at Hispanic-Serving Institutions. *Journal of Engineering Education, 112*(2), 316–336. https://doi.org/10.1002/jee.20510

Perkowitz, S. (2021). The bias in the machine: Facial recognition technology and racial disparities. *MIT Case Studies in Social and Ethical Responsibilities of Computing, Winter 2021*. https://doi.org/10.21428/2c646de5.62272586

Purzer, Ş., Strobel, J., & Cardella, M. E. (Eds.). (2014). *Engineering in pre-college settings: Synthesizing research, policy, and practices.* Purdue University Press. https://doi.org/10.2307/j.ctt6wq7bh.4

Rapa, L. J., Diemer, M. A., & Banales, J. (2018). Critical action as a pathway to social mobility among marginalized youth. *Developmental Psychology, 54*, 127–137. https://doi.org/10.1037/dev0000414

Reynante, B. (2022). Learning to design for social justice in community-engaged engineering. *Journal of Engineering Education, 111*(2), 338–356. https://doi.org/10.1002/jee.20444

Riley, D. (2008). Engineering and social justice. *Synthesis Lectures on Engineers, Technology, & Society*, 47–106. https://doi.org/10.1007/978-3-031-79940-2_3

Ross, M. S., Huff, J. L., & Godwin, A. (2021). Resilient engineering identity development critical to prolonged engagement of Black women in engineering. *Journal of Engineering Education, 110*(1), 92–113. https://doi.org/10.1002/jee.20374

Seider, S., Clark, S., & Graves, D. (2020). The development of critical consciousness and its relation to academic achievement in adolescents of color. *Child Development, 91*(2). https://doi.org/10.1111/cdev.13262

Shin, R. Q., Ezeofor, I., Smith, L. C., Welch, J. C., & Goldrich, K. M. (2016). The development and validation of the contemporary critical consciousness measure. *Journal of Counseling Psychology, 63*(2), 210–223. https://doi.org/10.1037/cou0000137

Sleeter, C. E. (2012). Confronting the marginalization of culturally responsive pedagogy. *Urban Education, 47*(3), 562–584. https://doi.org/10.1177/0042085911431472

https://doi.org/10.7771/2157-9288.1406

Smith, K. C., Poleacovschi, C., Feinstein, S., & Luster-Teasley, S. (2023). Ethnicity, race, and gender in engineering education: The nuanced experiences of male and female Latinx engineering undergraduates targeted by microaggressions. *Psychological Reports, 126*(5), 2345–2382. https://doi.org/10.1177/00332941221075766

Sneider, C. I., & Ravel, M. K. (2021). Insights from two decades of P–12 engineering education research. *Journal of Pre-College Engineering Education Research, 11*(2), Article 5. https://doi.org/10.7771/2157-9288.1277

Tan, E., Calabrese Barton, A., & Benavides, A. (2019). Engineering for sustainable communities: Epistemic tools in support of equitable and consequential middle school engineering. *Science Education, 103*(4), 1011–1046. https://doi.org/10.1002/sce.21515

Tanner, S. J., & McCloskey, A. (2023). Improv theater and whiteness in education: A systematic literature review. *Review of Educational Research, 93*(1), 3–36. https://doi.org/10.3102/00346543221076885

Tolbert, S. (2015). "Because they want to teach you about their culture": Analyzing effective mentoring conversations between culturally responsible mentors and secondary science teachers of indigenous students in mainstream schools. *Journal of Research in Science Teaching, 52*(10), 1325–1361. https://doi.org/10.1002/tea.21240

Trbušić, H. (2014). Engineering in the community: Critical consciousness and engineering education. *Interdisciplinary Description of Complex Systems, 12*(2), 108–118. https://doi.org/10.7906/indecs.12.2.1

Verdín, D. (2021). The power of interest: Minoritized women's interest in engineering fosters persistence beliefs beyond belongingness and engineering identity. *International Journal of STEM Education, 8*(1), Article 33. https://doi.org/10.1186/s40594-021-00292-1

U.S. National Science Foundation. (2012). *National Medal of Science 50th Anniversary: Theodore von Karman*. https://www.nsf.gov/news/special_reports/medalofscience50/vonkarman.jsp

Watts, R. J., & Hipolito-Delgado, C. (2015). Thinking ourselves to liberation? Advancing sociopolitical action in critical consciousness. *Urban Review, 47*, 847–867. https://doi.org/10.1007/s11256-015-0341-x

West, C. (1973, April 17). Black intellectualism. *Harvard Crimson*. https://www.thecrimson.com/article/1973/4/17/black-intellectualism-pbbblack-culture-may-indeed/

Xu, G., Benavides, A., Calabrese-Barton, A., Tan, E., Bliesener, S., DiFrancesco, G., & Barton, S. C. (2022). Critical consciousness in engineering for sustainable communities: A justice-oriented approach connecting schools and communities. *Connected Science Learning, 4*(1), Article 12318669. https://doi.org/10.1080/24758779.2022.12318669

https://doi.org/10.7771/2157-9288.1406