

WHITEY ON THE MOON: RACISM'S MAINTENANCE OF INEQUITY IN INVENTION & INNOVATION

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The problem of Black exclusion within invention is not new, but now is a great time to address this problem in new ways. The invention and innovation community sits within a space of deep tension, as it calls for greater attention on the contributing factors resulting in a lack of racial and ethnic diversity while not fully reckoning with solutions that have already been proposed. In light of recent events, widespread video recordings of Black people being murdered and disproportionate fatalities during a global pandemic due to longstanding health care inequities, this renewed attention is welcomed but met with skeptical optimism. Building on prior discussions of the barriers constraining Black invention and innovation can help us achieve comprehensive and transformative action. We assert that racial equity within invention requires consideration of sociopolitical issues, such as urban divestment and inequitable schooling, as well as a reexamination of our insistence that invention be defined narrowly. One prophetic articulation of this dissonance is Gil Scott-Heron's (1970) poem "Whitey on the Moon," where Scott-Heron artistically critiques the preoccupation of the United States achieving a moon landing while rampant poverty causes daily suffering for so many on Earth. The invention and innovation community replicates this value structure, where some types of technological advancement are esteemed while technology advancement in the service of human suffering is under-supported. Radical change and vision are needed to welcome and support Black people throughout the invention ecosystem. We offer three ways that education can generate more racial diversity and facilitate equitable practice within invention and innovation.

Key words: Racism; Innovation; Invention education; Black inventors

INTRODUCTION

The compounding effects of a global pandemic and high-profile extrajudicial murders have prompted a widespread examination of the function of racism in the modern era (1). The disproportionate fatalities suffered by Black people were staggering though many rendered this plausible given the history of disenfranchisement Black people have endured. These events spurred tremendous anguish, and surprisingly, there was much talk of reflection and introspection at the individual and institutional levels across the nation. As the invention community ponders the contributing factors to the low recognition and representation of Black inventors, we use this momentum of racial analysis to scrutinize the cultural norms and practices that maintain this problem. The narrative of

Black contributions to invention is not entirely grim, but the impediments to our ability to fully embrace the potency of invention remain fundamentally the same as they've always been. The problem of Black exclusion within invention is not new, but now is a great time to address this problem in new ways.

BACKGROUND

The invention and innovation community sits within a space of deep tension, as it calls for greater attention on the contributing factors resulting in a lack of racial and ethnic diversity while not fully reckoning with the solutions that have already been proposed (2-4). In light of recent events — widespread video recordings of Black people being murdered and disproportionate fatalities during a

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global pandemic due to longstanding health care inequities — this renewed attention is welcomed but met with skeptical optimism. This is especially true because these recent tragedies stem from long-standing social, political, and economic factors that have predominantly harmed Black people across institutions of government, education, and industry. When we refer to the invention and innovation community within this paper, we are doing so broadly, meaning essentially anyone who is involved with the creation of new ideas, processes, or products as their central enterprise. This largely includes people who seek patents for their creations, whether made individually or in collaboration, but we also include those whose interest may not be to become the first with a specific market propriety on their creation. Building on prior discussions of the barriers constraining Black invention and innovation can help us achieve comprehensive and transformative action. We assert that racial equity within invention requires consideration of sociopolitical issues, such as urban divestment and inequitable schooling, as well as a reexamination of society's insistence that invention be defined narrowly, most often through the patent process.

The innovation community should reconsider its values as it determines which inventors and/or inventions are noteworthy. In a recent report, the Lemelson Center mentions how Black inventors and their products get overlooked due to constrained perspectives on inventiveness:

Dominant notions of invention, which prioritize novelty, profit, efficiency, and ownership, have too often disregarded the creations of Black inventors who worked from a different set of value propositions and with different means and resources at their disposal — people who created amid extraordinary and at times life-threatening circumstances. (5)

Perhaps the most unjust cultural principle within the realm of invention and innovation is that inventing for profit, competition, and efficiency (i.e., capitalism) is viewed as more admirable than inventing for community, cooperation, and cultural expression. These values are rooted in Europeans' innovative history of chattel slavery, which led to the formation of this nation. In fact, "from the carvel to the cotton gin,

technological innovation has made things worse for [Black people]" (6). We must reckon with not only the process of invention but also the implications of its purposes and products.

Moon Travel as a Metaphor for Views on African American Invention

Taxes takin' my whole damn check, Junkies makin' me a nervous wreck, The price of food is goin' up, An' as if all that shit wasn't enough

A rat done bit my sister Nell. (with Whitey on the moon) Her face and arms began to swell. (and Whitey's on the moon)

I can't pay no doctor bill. (but Whitey's on the moon) Ten years from now I'll be payin' still. (while Whitey's on the moon)... Y'know I jus' 'bout had my fill (of Whitey on the moon) I think I'll sen' these doctor bills, Airmail special (to Whitey on the moon)

Gil Scott-Heron 1970

The detrimental inconsistency between dominant White conceptions of invention and innovation versus those that primarily serve the needs of under-resourced communities, as well as the ongoing failure of our society to recognize and celebrate inventions by Blacks, has tremendous moral and intellectual consequences. One prophetic articulation of this dissonance is Gil Scott-Heron's poem "Whitey on the Moon" (7), where Scott-Heron artistically critiques the preoccupation of the United States achieving a moon landing while rampant poverty causes daily suffering for so many on Earth. Scott-Heron acknowledges this anti-Black racism in his poem by contrasting the nation's preoccupation with science and technology while inequities abound in health, housing, and employment. The invention and innovation community replicates this value structure, where some types of technological advancement are esteemed while technology advancement in the service of human suffering often goes unrecognized and is under-supported when it does exist.

We acknowledge this divergence in values — innovation for innovation's sake versus innovation in service of humanity. At the same time, it is contradictory to the field of invention to limit the extent of humans' imagination and ability to create. We,

instead, support our capacity for space exploration and a wider mix of other inventions that also promote human flourishing (8). We seek to declare that the disparity in appreciation of inventions by different races results from racial prejudices on acuity (9,10). For many Black inventors, their deployment of creativity through invention is an expression of their Black vernacular technological creativity, which “is a process of engaging material artifacts as opposed to performing Black-informed expressive or aesthetic representations of technology” (11). In other words, instead of simply adding a culturally infused visual depiction of technology, Black people reconstruct the use and development of technologies themselves. To put it even more simply, we’re not just artists and curators, we are creators. This demonstration of technological agency requires a different way of analyzing technological experiences, as current approaches to assessing innovation cannot fully capture the rich creativity of Black people’s technological savvy and intellectualism in spite of marginalization (11).

Nettrice Gaskins, an Afrofuturist artist and scholar, has extended the work of Fouché to conceptualize techno-vernacular creativity (TVC), “a term that refers to innovations produced by ethnic groups that are often overlooked” (12). Gaskins makes visible the importance of personal resonance, which happens through culturally situated engagement, for creativity to thrive. The implication of her work is that the dominant culture of invention is White, and when non-White people are empowered to center their own perspectives and purposes, they produce novelty. TVC — as a multidisciplinary concept spanning science, technology, engineering, art, and mathematics — also embodies equity in both meaning-making and resource provision. Black youth may lack expensive technological objects, but they are rich in culture and resourcefulness.

The scholarship of Black educators and inventors has shown this unrecognized genius correlates with the domestic terrorism Black people have endured since the established institution of slavery. Racial equity within invention is directly tied to the manifestation of racial equity in the broader society. On one hand, Lisa Cook (13) vividly articulates the ways state-sanctioned violence against Black people across several decades severely limited their ability to invent.

On the other hand, Blacks have been prolific inventors in many ways in order to survive and thrive under harsh conditions. Even as Black people were not provided the same resources, opportunity, and support as White people, Black people are and were still innovators under conditions that required an even greater amount of resourcefulness and ingenuity. This also begs contemplation on what would be possible should Black people receive the same respect, resources, and support to explore our ideas. Such a lens should prompt new questions about contributing factors to the low participation of Black people in the invention community.

Undeniably, space travel excites the imagination of Black people just as it does other Americans. Lisa Alcindor, a Ph.D. candidate and contractor who has worked at the Pentagon, NASA, and Fort Belvoir, uses space travel to showcase racial and gender diversity. She highlights what invention and innovation should look like with her Instagram picture of Mae Jemison. She wants to show people that they are truly limitless and to demonstrate that Black Americans deserve to go to space just as much as anyone else (14). Similarly, Shirley Malcom outlines her reasons for pursuing a career in STEM and promoting equity in STEM in her testimony to the House Science Committee (15).

In her testimony, she explains:

I have personally spent my entire career in positions, as well as in volunteer service, working to address concerns around equity in STEM. I do this partly because of my own pathway, from the Jim Crow South to years as ‘the only,’ in my class or in my major or in my lab group or on faculty or on a board or committee. I was drawn to science after the launch of Sputnik because of the compelling vision and opportunities, even for a little girl from Birmingham, for understanding the world, making a difference in the world, for earning a living and making a life. There are many more people out there, from all backgrounds and experiences, who are drawn to and interested in STEM, who need to see the pathway to turn interest to outcomes. (15)

The framing of the disconnect between Black Americans’ STEM interests and outcomes needs to be reframed to more accurately consider the

multitudinous prohibitions laid in their way.

What an Impact Diversity and Inclusion Could Have!

The world of invention has dazzled us; it has provided us with increased functionality and convenience in managing many of our daily activities while offering new possibilities for what we can do. When we see the contribution of invention to the United States and to the world, it is inspiring. And we must realize that increasing the number and types of inventions and inventors will create a stronger, better society as well as allow the rapidly expanding convergence of technologies to solve more complex problems.

At this point in our history, society's viewpoint of who is smart, who can contribute, and who should get opportunities remains dangerously skewed and shortsighted. For as smart as our innovations and burgeoning economy have demonstrated that we are, we appear to be unable, or unwilling, to do much more than write reports and give lip service to the importance of racial diversity. If the nation can put people on the moon, surely solving for racial diversification should be possible. Freeman Hrabowski shares his hopes around diversity by stating that "this is now a Sputnik moment and that a greater commitment will be made on the part of all of us in society and the scientific community to implement recommendations that have been made for years" (16). At this moment, however, there is a strong lack of purposeful attention around making invention, innovation, and a myriad of opportunities available broadly in our society.

Actualizing the creative potential of our nation requires shifts in our perspectives — not just our policies and practices. Nonetheless, somehow many still cling to the innateness of intelligence, with White males being the most innately intelligent of us all. The people we celebrate and our historical omissions have skewed our vision of who can and should be inventors, scientists, engineers, and the like. The campaigns to counter these notions have not been effective in shifting the perspectives of those with the power to reform the appropriate institutions and expand opportunities and support for those who have been historically excluded. Our national discourse about contemporary inventors and creatives continues to

exhibit a narrow focus on wealthy White men, including Richard Branson, Jeff Bezos, and Elon Musk.

Consider the effect on current and future inventors if the media and education institutions chose, instead, to often highlight the current intellectual contributions of some recent Black inventors: Lonnie Johnson, whose Super Soaker invention gave him the resources to continue his research and innovations on energy technology (17); Ayanna Howard, a human-centered roboticist and currently dean of the College of Engineering at the Ohio State University (18); James West, with more than 250 foreign and U.S. patents centered around the production and design of microphones and techniques for creating polymer foil electrets (19); Mark Dean, who holds three of nine patents for being the co-creator of the IBM personal computer released in 1981 (20); Shirley Jackson, former president of Rensselaer Polytechnic Institute, whose scientific research enabled the creation of telecommunications devices such as solar cells and fiber optic cables (21); or Patricia Bath, who invented the Laserphaco Probe, a device for laser cataract surgery (22). The inventions by these individuals have had a transformative impact on our society, and many of them continue to advance the nation through contributions to higher education leadership, government, and other endeavors. These individuals and many others extend the legacy of Black inventors who innovate despite the constraints of racism (23), and though commendable, we see these accomplishments as motivation for this social structure to be dismantled so that the full potential of all citizens' ingenuity can be realized.

In addition to better quality inventions, diversity and inclusion expands the quantity of inventions that would be produced in our society. Bell et al. discuss the role of ability versus environment in determining the likelihood of a child becoming an inventor in the modern era. They noted that "children from high-income families are ten times as likely to become inventors as those from below-median income families" (24), which they suggest implies that the racial and economic gaps may be driven by differences in environment rather than abilities to innovate. One significant takeaway of Bell et al.'s investigation is that the extent to which children are exposed to invention has more to do with their potential to become

inventors than natural ability, and they specifically state “childhood environment affects not just the types of innovation that children pursue but also the overall fraction who go into innovation” (24). We highlight this finding to make an explicit connection between shifting the culture of innovation to be welcoming for all people and the benefit to the invention community from having more people engaged in pursuing innovation as a career. The expansion of access and exposure to invention would increase the number of innovators among White women, racial minorities, and people from low-wealth families. The current predominance of framing invention as only for the most intelligent people denies recognition of the barriers for people navigating social disadvantages to express their intelligence and/or for their demonstrations of intelligence to be equally valued. The legacy of exclusivity has left a legion of untapped potential, and it means that, with effort, our society can benefit from the contributions of a much broader cohort of inventors and a greater diversity of inventions.

MAKING CHANGES IN THE PATHWAY TO INVENTION

There are numerous issues with efforts to increase equity, inclusion, and diversity in invention, and these problems are structural, meaning the barriers exist across interconnected institutions. Moreover, the difficulties exist from birth through adulthood. Certainly, money is important to these efforts, but the most important aspect for our society is a mind-shift in attitude and action that requires believing that diversity and inclusion will bring more progress. Currently, organizations, institutions, and policymakers see diversity as a fringe issue that they dedicate time and resources to occasionally. When companies promote their intention to hire more diverse people, instead of actually hiring racially diverse applicants, they allow equity detours — initiatives that provide an illusion of progress but actually sustain inequity (25) — which essentially derails true progress. Similarly, myths of meritocracy preserve rhetoric that proposes companies must lower their standards of excellence to take equitable actions. Ironically, Black candidates are seen as less qualified though we are often asked to do more for equal appreciation, leading to

harmful norms like Black Superwoman Syndrome (26). While there are cadres of well-qualified Black candidates, there is also the reality of an educational system that is absolutely failing lots of people and continually operating as a mechanism of social stratification (27) and a site of suffering for Black students (28). Racism is at the core of these disparaging routines, but we firmly believe that true progress requires a more diverse sandbox.

Radical change and vision are needed to welcome and support Black people throughout the invention ecosystem. We offer three ways that education can generate more racial diversity and facilitate equitable practice within invention and innovation:

1. Celebrating the natural curiosity of children and educating them to promote invention and innovation — allowing our children to explore their creative sides and rewarding them for it
2. Providing a science and technology education, including fields such as engineering, computer science, and synthetic biology, that gives students the tools necessary to help make the world better
3. Teaching people the so-called “soft skills” that allow us to solve complex social and human problems versus learning and focusing on one skill or trade

However, we do not consider education to be a panacea, and we are more concerned with the type of teaching that youth experience rather than promoting education for the sake of education. Given our respective positions, our primary recommendation is focused on reconstructing our perception of what it means to invent and innovate and the importance of highlighting more of what happens in Black and other communities as invention.

Education to Spur Invention and Innovation: Reinforcing the Importance of Sociotechnical Creativity

As we noted earlier with the example of “Whitey on the Moon,” contemporary invention is mostly driven by abstract desires for technological advancement with a presumption that new technology will benefit everyone. Yet, technology is not neutral (29), and the field of invention suffers from a technical/

social dualism that considers the technical aspects of the practice as more important than the social aspects (30). The reality of discrimination and inequity in our society should be acknowledged as we seek to spur invention and innovation, and the value system that has previously been used to acknowledge innovation and invention should be reexamined in an effort to appreciate and reward the technologies that are produced to uplift the underserved rather than those aimed at the dominant social groups.

At the most basic level, we should celebrate and take advantage of the fact that people with different experiences and identities have diverse perspectives that shape the ways we identify problems and approach addressing them. These differences are assets. For example, unsurprisingly, women have been shown to be most likely to engage in designing intentionally for other women (31). When examining the technological development process holistically, it is clear that social dynamics are involved from beginning to end because people must interact during every stage of the process. We call for a value system and educational process with which to implement a principle of sociotechnical creativity, where the use of one's imagination and technical prowess are operating in concert with awareness of social context to produce novel creations.

The Kern Entrepreneurial Engineering Network (KEEN) and the Lemelson Foundation have put forth frameworks for educational systems more suited for spurring invention, innovation, and entrepreneurship. KEEN has a partnership with engineering schools in colleges and universities to foster curricula and promote a classroom culture that teaches "technical skills while fostering curiosity, connections, and creating value" (32). KEEN's goal is to educate undergraduate engineering students on how to develop the economic and social value of their work.

The Lemelson Foundation calls for "a pedagogical approach focused on problem identification through empathy and collaborative problem solving that results in novel solutions by integrating the process of invention into teaching and learning" (33). This framework includes a list of traits and dispositions that inventors should possess, such as empathy, curiosity, creativity, resourcefulness, calculated risk-taking, resilience, passion, and tolerance

for ambiguity and complexity, and tenets for the implementation of the framework. Both frameworks demonstrate that invention, innovation, and entrepreneurship are central, rather than tangential, skills that can be cultivated.

Notwithstanding, the prevalence of racism requires explicit focus on alleviating the consequences of racial harm experienced by racially marginalized people groups. As previously mentioned, Black Americans have shouldered the burden of many toxic and harmful inventions; therefore, the skills mentioned in these frameworks absent racial consciousness will likely exclude the people most negatively impacted. Inventors have peculiar considerations when addressing the needs of groups that lack resources as a result of intentional disenfranchisement or when trying to mitigate residual effects of social conditions that are centuries old. Indeed, we need new frameworks, but the framing of these approaches cannot afford to be mild when confronting the inequities that provoke their formulation.

We must seriously consider the repercussions of promoting innovation through an invention/entrepreneurship/innovation educational lens without assuring the provision of resources to bring to fruition the ingenuity that is stimulated through these educational initiatives. It bears repeating that the barriers to increased numbers of Black inventors are not the interest, motivation, or education of Black people; rather, it is the social structure that renders us intellectually inferior, withholds resources made available to White people, and offers inconsistent protections. Invention education should transpire with an intention to invest in students from marginalized groups to create novel productions. In addition to financial investments, this requires coaching, explaining patent law, sharing social networks, enhancing protection of intellectual property, and assisting with product development and promotion. We are calling for a responsive and responsible approach to educational initiatives aimed at promoting invention, entrepreneurship, and innovation.

Science and Technology Education: Giving Students the Tools Necessary to Help Make the World Better

Scientific and technological literacy are critical

to developing an informed citizenry that is actively engaged in preserving the well-being of our society and this earth. Science and technology, whether loosely or strictly defined, are all around us and inhabit every aspect of our lives. Thus, the formal classroom is just one setting among many where young people are exposed to the meanings of science and technology and their applications. The future of invention is inextricably linked to young people's ability to understand and influence the natural world, human-made contraptions, and the interplay between the two. Thus, understanding the social and political context of science and technology within our society is essential. Recent reforms in science and technology education in the pre-college domain display efforts to make teaching and learning more equitable; this includes broadening conceptualizations of these fields of study along with expanding the resources made available to educate students about these subjects. The invention community would do well to stay attuned to these curricular enhancements because to actualize the potential for future generations to diversify who invents and what they produce, we must first diversify approaches to knowledge construction and ensure people have the tools to create.

There are scholars investigating methods for teaching technology in ways that affirm Black students' cultural identity and lived experience (34). Fundamental to these efforts are making clear that the mainstream methods of teaching are problematic and, instead, implementing new instructional methods that not only mention the relationship between culture and cognition but consider culture as an asset to learning. The implications for the invention community suggest a similar shift is necessary: More effort is needed to centralize the role of culture in stimulating creative applications of science and technology. This also means the discourse on the functionality of invention may need to be reconceptualized to emphasize its potential to leverage one's imagination to redress what already is as opposed to mainly focusing on creating something new. Without directly addressing the problems Black people navigate to survive, visionary ambitions for a new reality only reproduce established inequities with new facades.

Solving Problems: Employing Realistic Contexts to Stimulate Critical Thinking

Admittedly, the rhetoric of advocating for innovation as a solution to solve complex problems is limiting, as it neglects the joy that can be experienced from simply seeing one's imagination made tangible. We believe that invention should be both a vehicle for simply imagining as well as a vehicle for solving problems. And we believe that more diverse inventions can increase innovation in the pursuit of both objectives. However, we wish to highlight the inspiration that comes from using one's imagination to resolve an issue of real concern and perplexity, particularly when the issue afflicts more than one's self. The fast-paced ways in which the convergence of several technologies and bodies of knowledge (35) can help us solve these key problems implores a deviation from celebrating technological advances for the sake of these advances to a more problem-based focus. This pedagogical approach has spread in recent years after it was demonstrated that students retain their learning at higher levels and are more engaged in the learning process when solving problems of interest to them (36). By problems of interest, we are referring to social inequities that influence the lived experiences of these students. Ladson-Billings' (37) conception of culturally relevant pedagogy insists that centering such issues is not just an instructional gimmick; rather, the connection between experience and class content enhances cognition and efficacy. Another benefit of problem-based learning is making space for students to be more involved in determining the direction of their learning, and this can happen by allowing students to choose problems they find relevant. The flexibility of this learning approach can be more difficult to manage in traditional school settings, but guiding students through applying classroom content to out-of-classroom contexts helps students adapt to interdisciplinarity and ambiguity as well as pushes them to think critically within concrete constraints.

CONCLUSION

The role of Black Americans who have advanced the nation's development through invention has been largely reduced to lists — lists that record the first Black person to reach a particular achievement or lists

that record notable products created by Black people to illustrate we have made some contribution to this country. While these accomplishments and creations are commendable, there remain many unresolved issues regarding the history of Black ingenuity that have become diluted by such lists. These decontextualized, or superficially curated, portrayals can actually function to reinforce deficit-oriented perspectives about why there are relatively few Black inventors today: If Benjamin Montgomery could innovate and gain wealth while enslaved, surely a Black child with access to free public schooling and without legalized oppression should be able to innovate to a much greater extent. Or, youth are left to presume these Black individuals had extraordinary natural abilities that propelled them to greater achievements than the common Black person within this society. Whatever the takeaways, people (Black and non-Black alike) are left with a corrupted viewpoint of what factors contribute to success as an inventor. We reject such abstract presentations, asserting instead that context matters; and in a society with endemic racism, race matters more. The mechanisms of racial exclusion permeating the invention ecosystem must be uprooted at every level for true diversity and inclusion to be established within the culture.

As a society, we continue to see intelligence in a limited way. People who invent autonomous vehicles are intelligent, but people who invent new ways to cope with harsh conditions are not. People who have every advantage available and produce successful innovations are intelligent, but the people who work behind the scenes to contribute to said innovations without recognition are not. Therefore, we often neglect to celebrate the everyday ingenuity and resourcefulness the invention community claims to covet. Specifically, society at large continues to devalue the uniqueness of Blackness, or what Amiri Baraka (38) called “Black creation — creation powered by the Black ethos brings very special results.” Black scholars, activists, and artists have long advocated for the acumen of Black people to be given its proper esteem, and we see this disregarding of Black contributions as fundamental to the low representation and constrained participation of Black people in the invention ecosystem. We support calls for more efforts to expand support mechanisms, but

we recommend these initiatives be race-conscious and cognizant of the centuries-old social relations that created and continue to sustain a hierarchical system based on racial identity in this country. We need innovative approaches and intentionality in welcoming different perspectives, which lead to increased and better inventions, if we are to increase racial diversity within the invention community.

REFERENCES

1. Ross J. 2020 forced Americans to confront the reality of racism. In 2021, many looked away. *Time*. 2021 Dec 29 [accessed 2022 Feb 16]. <https://time.com/6128657/2021-american-racism/>.
2. Fechner H, Shapanka MS. Closing diversity gaps in innovation: gender, race, and income disparities in patenting and commercialization of inventions. *Technol Innov*. 2018;19(4):727–734.
3. Perry AM. *Know your price: valuing Black lives and property in America's Black cities*. Washington (DC): Brookings Institution Press; 2020.
4. Rothwell J, Perry AM, Andrews M. *The Black innovators who elevated the United States: reassessing the golden age of invention*. Washington (DC): Brookings Institution; 2020 [accessed 2022 Jan 11]. <https://www.brookings.edu/research/the-black-innovators-who-elevated-the-united-states-reassessing-the-golden-age-of-invention/>.
5. Lemelson Center for the Study of Invention and Innovation. *Black inventors and innovators: new perspectives*. Washington (DC): Smithsonian Institution; c2022 [accessed 2022 Mar 2]. <https://invention.si.edu/black-inventors-and-innovators-new-perspectives>.
6. Walton A. Technology versus African Americans. *The Atlantic Monthly*. 1999;283(1):14-18. [accessed 2022 Feb 20]. <https://www.theatlantic.com/magazine/archive/1999/01/technology-versus-african-americans/377392/>.
7. Scott-Heron G. *Whitey on the moon* [vinyl LP]. New York (NY): Flying Dutchman/RCA; 1970.
8. Prescod-Weinstein C. What Richard Branson and his critics both get wrong about equal access to space. *Washington Post*. 2021 July 14. [accessed 2022 Mar 2]. <https://www>.

- washingtonpost.com/opinions/2021/07/14/equal-access-space-night-sky-branson/.
9. Croizet JC. The pernicious relationship between merit assessment and discrimination in education. In: Adams G, Biernat M, Branscombe NR, Crandall CS, Wrightsman LS, editors. *Commemorating Brown: the social psychology of racism and discrimination*. Washington (DC): American Psychological Association; 2008. p. 153–172.
 10. Croizet JC. The racism of intelligence: how mental testing practices have constituted an institutionalized form of group domination. In: Bobo LD, Crooms-Robinson L, Darling-Hammond L, Dawson MC, Gates HL, Jaynes G, Steele C, editors. *Handbook of African American citizenship, 1865-present*. New York (NY): Oxford University Press; 2011. p. 89–109.
 11. Fouché R. Say it loud, i'm Black and i'm proud: African Americans, American artifactual culture, and Black vernacular technological creativity. *Am Q*. 2006;58(3):639–661. [accessed 2021 Jan 14]. <https://www.jstor.org/stable/40068387>.
 12. Gaskins NR. *Techno-vernacular creativity and innovation: culturally relevant making inside and outside of the classroom*. Cambridge (MA): MIT Press; 2021.
 13. Cook LD. Violence and economic activity: evidence from African American patents, 1870-1940. *J Econ Growth*. 2014;19(2):221–257. [accessed 2021 Nov 29]. <https://www.jstor.org/stable/44113425>.
 14. Vargas T. She hopes to change what people think an astronaut looks like. *Washington Post*. 2021 Aug 28. [accessed 2022 Mar 2]. https://www.washingtonpost.com/local/black-woman-change-astronaut-image/2021/08/28/d6b5ccd4-078c-11ec-a266-7c7fe02fa374_story.html.
 15. Malcolm S. Attracting a diverse STEM workforce. 2019 May 9 [accessed 2022 Mar 2]. <https://www.ars.usda.gov/ARSUserFiles/3559/Dr.%20Malcom%20Testimony.pdf>. Written testimony before the Committee on Science, Space and Technology.
 16. Suran M. News feature: keeping Black students in STEM. *Proc. Natl. Acad. Sci. U.S.A.* 2021;118(23). [accessed 2021 Nov 21]. <https://www.pnas.org/content/118/23/e2108401118>.
 17. Silverman L. Meet the guy who accidentally invented the super soaker while working for NASA. Brooklyn (NY): All That's Interesting. [updated 2022 Feb 1; accessed 2022 Mar 10]. <https://allthatsinteresting.com/lonnie-johnson>.
 18. Wessling B. Ayanna Howard elected to NAI class of fellows. *The Robot Report*. Cleveland (OH): WTWH Media, LLC; c2022 [accessed 2022 Mar 2]. <https://www.therobotreport.com/ayanna-howard-elected-to-nai-class-of-fellows/>.
 19. Simpson JC. Sound reasoning. *Johns Hopkins Magazine*. Baltimore (MD): Johns Hopkins University. 2003 [accessed Mar 22]. <https://pages.jh.edu/jhumag/0903web/west.html>.
 20. Prael A. *Biography of Mark Dean, computer pioneer*. New York (NY): ThoughtCo. 2019 Feb 26 [accessed Mar 3]. <https://www.thoughtco.com/mark-dean-biography-4588102>.
 21. Schaffer A. The remarkable career of Shirley Ann Jackson. *MIT Technol Rev*. 2017 Dec 19 [accessed 2022 Mar 3]. <https://www.technologyreview.com/2017/12/19/146775/the-remarkable-career-of-shirley-ann-jackson/>.
 22. Jeong M. What do we know about Dr. Patricia Bath, the inventor of laserphaco? *Medical News Today*. Brighton (UK): Healthline Media UK Ltd.; c2004-2022. [accessed 2022 Mar 2]. <https://www.medicalnewstoday.com/articles/dr-patricia-bath-the-expert-who-revolutionized-cataract-surgery>.
 23. Johnson S. 2017 Feb 15. America's always had Black inventors – even when the patent system explicitly excluded them. *The Conversation*. Waltham (MA): The Conversation US, Inc.; c2010-2022. [accessed 2022 Aug 15]. <https://theconversation.com/americas-always-had-black-inventors-even-when-the-patent-system-explicitly-excluded-them-72619>.
 24. Bell A, Chetty R, Jaravel X, Petkova N, Van Reenen J. Who becomes an inventor in America? The importance of exposure to innovation. *Q J Econ*. 2019;134(2):647–713.
 25. Gorski P. Avoiding racial equity detours. *Educ Leadership*. 2019;76(7):56–61.
 26. Ward T. Black superwoman syndrome: what

- it is and how organizations can better support their Black female leaders. Washington (DC): Bellwether; c2022. [accessed 2022 Mar 2]. <https://aheadoftheheard.org/black-superwoman-syndrome-what-it-is-and-how-organizations-can-better-support-their-black-female-leaders/>.
27. Sadovnik AR, Semel SF. Education and inequality: historical and sociological approaches to schooling and social stratification. *Paedagog Hist.* 2010;46(1-2):1–13.
 28. Dumas MJ. “Losing an arm”: schooling as a site of black suffering. *Race Ethn Educ.* 2013;17(1):1–29.
 29. Benjamin R. *Race after technology: abolitionist tools for the new Jim code.* Medford (MA): Polity Press; 2019
 30. Cech EA. Ideological wage inequalities? The technical/social dualism and the gender wage gap in engineering. *Soc Forces.* 2013;91(4):1147–1182.
 31. National Science Teaching Association. *Nature of science.* Arlington (VA): NSTA; c2022. [accessed 2022 July 23]. <https://www.nsta.org/nstas-official-positions/nature-science>.
 32. The Kern Entrepreneurial Engineering Network. 2022. *The framework for entrepreneurially minded learning.* Engineering unleashed. Waukesha (WI): Kern Family Foundation; c2022. [accessed 2022 October 5]. <https://engineeringunleashed.com/framework>.
 33. InventEd. *A framework for invention education.* Portland (OR): The Lemelson Foundation; 2020. [accessed 2022 Mar 2]. <https://inventioneducation.org/framework-for-invention-education/#:~:text=Summary%3A%20The%20Invention%20Education%20Framework>.
 34. Bennett AG. Ethnocomputational creativity in STEAM education: a cultural framework for generative justice. *Teknokultura.* 2016;13(2):587–612.
 35. Diamandis PH, Kotler S. *The future is faster than you think : how converging technologies are transforming business, industries, and our lives.* New York (NY): Simon & Schuster; 2020.
 36. Allen DE, Donham RS, Bernhardt SA. *Problem-based learning.* *New Dir Teach Learn.* 2011;128:21–29.
 37. Ladson-Billings G. *Culturally relevant pedagogy: asking a different question.* New York (NY): Teachers College Press; 2021.
 38. Baraka IA. *Technology & Ethos.* Soulsista. [accessed 2022 Mar 2]. <http://www.soulsista.com/titanic/baraka.html>. Originally published in 1970 by Random House.