Envisioning Beyond Zip Codes and Boundaries: The Systemic Work Needed to Actualize Equitable Science Education for All

Stefanie L. Marshall & William R. Penuel

As part of the Taking Stock of Science Standards Implementation Summit, the first author shared this reflection: Faith was a high schooler from Flint who asked me a question as I served on a panel about careers. She asked me, "How did you know you could do science?" This question indicated to me that Faith's reality had been socially framed so that she did not know that she was a doer of science. My response to Faith was, "I didn't know that I couldn't." Faith is Black like me, and I recognize the privilege of always identifying as a doer of science. I also acknowledge that Faith asked me this question, given my positionality as a Black woman. This experience grounds me to do right by all of our children.

Introduction

There are two underlying meanings to Faith's story, her personal story and a story of her context. Despite knowledge of the water in Flint poisoning the local community, government officials chose to do nothing. That is, those with privilege chose to allow the community of Flint to be poisoned. From the above description, we know that simultaneously, students like Faith had limited science experiences and were socialized to believe that they were not doers of science. Both are crises.

In both water districts and school districts, city boundaries matter. This yields the question, what would it mean for district lines to not matter in the quality of science education a student receives? What would it mean for the boundary of a city, school district, or zip code to not determine the science education a child experiences? What if all children experienced quality science education everywhere? As argued in the recent NASEM meeting to take stock of the implementation of the NGSS, a child's zip code, county, or school district should not determine the quality of their science education experience.

We embrace this aspiration, but policies and boundaries (e.g., zip codes, district lines, neighborhood redlining) have been historically used to systematically marginalize and oppress people of color, and they continue to do so. Redlining prevented both fair housing practices and Black families from living in desirable neighborhoods. When Blacks did move into a community, their white neighbors would move, resulting in some of the most segregated regions in the United States (Sugrue, 2018). Today, home values for Black and Latino communities have been devalued compared to homes in white communities (Perry, Rothwell, & Harshbarger, 2018).

The devaluation of homes decreases local funding through property taxes and yields inequitable school funding. While many states have funding formulas with goals to adjust for such differences, few states successfully achieve this goal. Therefore, we cannot disentangle public policy, schooling, and science education (often discussed as being under-funded) from these man-made boundaries and policies. Boundaries are also relevant to schooling as we consider between school segregation (Reardon & Owens, 2014), in-school segregation (Chambers, 2009), and those who serve as boundary spanners—as they navigate and make sense of multiple discourses between contexts (Akkerman & Bakker, 2011). In addition, individuals

and communities of practice are also constrained by their own beliefs about what science is, can be, and what science can do for our communities. Standards that align to the *Framework for K-12 Science Education* (National Research Council (NRC)*, 2012)*, like the Next Generation Science Standards, have become "standards for some" (through between school and in-school segregation), especially when the standards are not implemented for "all." These broader policy decisions impact classrooms everyday, and we must consider the deliberate actions needed to promote equitable implementation, actions that break down and span the boundaries that separate schools and communities in ways that reproduce racial inequity. We need leaders who will traverse boundaries in light of and despite inequitable ideologies, policies, and practices.

Taking Stock

We are grateful to have shared and learned from the science education community during the *Taking Stock of Science Standards Implementation: A Summit*. As we reflect on the summit, there were **four** overarching themes from the *Landscape of Implementation* and *The Role(s) of Leadership* panels. They are: (1) quality science education is a human right; (2) we must actively work to shift our beliefs and biases to align with equity in practice; (3) a systemic approach is necessary to achieve three-dimensional learning; and (4) community partnerships should be designed to carry out the educational vision of science and STEM. We will now expand upon these themes and what we can do about them individually and collectively as a community.

Quality Science Education is a Human Right

One of the current challenges of science education is that we envision what science could do for all without dismantling the systems framing decision-making by educational leaders. As stated by Philip Bell (professor of education, University of Washington), policies have the potential to "provide openings to local engagement that [are] meaningful for the purposes that are locally held." When we center place-based and land-based education (Bang et al., 2014), we de-center neoliberal ideals currently framing science and STEM education that emphasize the role of science in advancing individual interests (Marshall et al., 2021a). Schools in underserved communities are under much scrutiny to achieve "success" as defined by current federal, state, and local policies rather than the ideals of their community. This scrutiny, evident in accountability systems today across the U.S., has resulted in the prioritization of reading and math and the deprioritization of science (Marx & Harris, 2006; National Academies of Sciences Engineering and Medicine, 2021b). Science is then offered to some, rather than to all, as a product of boundaries we have employed on students.

Often, policy reports justify calls for reform of science education by appealing to the importance of science to improve national competitiveness (Basile & Lopez, 2015). Framing quality science education as a *civil right* transforms working toward better science education into an ethical imperative to increase the proficiency of Black and Indigenous students, other students of color, emergent multilingual students, girls and genderqueer students, and neurodiverse students. Moreover, it grounds the work of reform "in a longstanding struggle for quality education for all rather than in the cyclical debates of economic competitiveness and enlightened self-interest that typically are coupled with science and science education" (Tate, 2001, p. 1018).

Guaranteeing this right depends on allocation of time and resources. Both research (Banilower et al., 2018) and recent policy reports (National Academies of Sciences, Engineering, and Medicine, 2021a, 2021b) have highlighted the ways that schools allocate too little time for science, particularly in the elementary grades. Further, emergent multilingual learners, children

with learning disabilities and/or learning differences, and children who are perceived to be engaging in challenging behaviors in ways that are racialized are actively *removed* from what opportunities they do have (National Academies of Sciences, Engineering, and Medicine, 2021b, p. 1-6). Some students may also forgo opportunities to engage with opportunities they are provided, because of fear of punishment (Wright et al., 2018). Resources, including curriculum, laboratory equipment, and technologies are also inequitably distributed in American schools, further limiting opportunities for science learning.

Guaranteeing science education as a civil right also depends on the quality of the experiences provided. Here, the *Framework for K-12 Science Education* (National Research Council, 2012) and subsequent reports (National Academies of Sciences, Engineering, and Medicine, 2019b, 2021a, 2021b) provide a clear vision for what equitable learning can and should look like. Learning opportunities should be organized around phenomena and problems that are personally relevant to students (National Academies of Sciences, Engineering, and Medicine, 2019b) and that allow them to investigate questions that pertain to their personal and community concerns (NRC, 2012, p. 278). Students should no longer ask, "What does science have to do with my life," because science is connected to students' experiences in their families and communities (National Academies of Sciences, Engineering, and Medicine, 2021a, p. 23). Science classrooms, further, should be places where students and teachers establish and enact norms for building knowledge together in a way that encourages students to care for one another (Krist & Suárez, 2018; National Academies of Sciences, Engineering, and Medicine, 2021b).

We cannot expect that students who are exposed to such opportunities will experience them in the same way. Several studies in science education and other disciplines point to the ways that students' opportunities for knowledge building in the same classroom are experienced differently, depending on their race, their gender, and the languages they speak (Krumm et al., 2020; Langer-Osuna, 2015; Munter & Haines, 2019). It is not likely that educators can easily convince students of color from communities where science and engineering have caused harm to trust in Eurocentric conceptions of science, without directly naming those harms and inviting students to be part of imagining different ways science and engineering can serve community goals and support justice projects (National Academies of Sciences, Engineering, and Medicine, 2021b).

Addressing inequities of experience requires us to consider how to make science learning environments *dignity-affirming*. Dignity here refers both to an inherent quality of an individual's value, as well as value that is conferred through learning experiences that "recognize and cultivate one's mind, humanity, and potential" (Espinoza et al., 2020, p. 2). Such environments come with "participation rights" (Espinoza et al., 2020, p. 2), that is, with the expectation that students can be seen and heard. Those rights are realized when students have ongoing opportunities to exercise those rights, that is, in science, to participate meaningfully in learning opportunities where they apply science and engineering knowledge to answer questions related to matters of personal and community concern.

Shifting Our Beliefs and Biases and then Act

Superintendent Gudiel Crosthwaite shared with us the steps Lynwood Unified School District (LUSD) in California took to offer quality science education for all students in his district.

1. **Examine the data**. LUSD has 12,000 students: 94 percent Latino, 5 percent African American, and largely a historically underserved community. In 2010, 55 percent of students had access to biology, the only college-required science course offered.
2. **Community conversations.** Teachers, students, and community members had conversations. Dr. Crosthwaite stated, [We] asked ourselves what is it that we want to do, what is it that we believe in?" The answer: "We believe in kids."
3. **Act.** After recognizing the limited science opportunities for their students in the district, they saw the need to offer rigorous courses.

Recognizing these gaps is insufficient; we must do the self-work to interrogate our personal biases and prejudices that may have impacted our decision-making. In essence, we must spend time unlearning to learn how to support the needs of all of our students. Then, once we believe all students deserve a quality science education, we can consider, are your decisions affording equitable science instruction? Where is the evidence that equitable science instruction is being offered?

4. **Examine Biases, and Act Again.** Dr. Gudiel Crosthwaite stated, "And that's when all the buts came. But those kids don't have the GPA. But they don't meet their prerequisites. But they need a letter of recommendation. And so, we had all these 'buts' that were getting in the way that prevented kids from fulfilling their own expectations. Because the system was pushing them down and holding them back."

By "the system," Dr. Crosthwaite recognized that educators were making inequitable decisions. The systems, policies, and beliefs were getting in the way of implementing equitable science. Therefore, shifting our beliefs and understandings by recognizing our biases and racist beliefs will enable us to recognize inequities to be dismantled.

As we consider the path to more equitable science education, we must first believe that *all students deserve quality science instruction.* Said another way, if your data demonstrates there are inequities in science, different decisions must be made that indicate a central belief that all students deserve quality science instruction. It is essential to consider that people make decisions within organizations. People make decisions based on their positionality, understandings, and how they make sense of additional information they receive—also known as sensemaking (Evans, 2007; Weick, 1995). Therefore, we must consider the lens by which we make our decisions, specifically for science. To help us examine our biases, we need powerful conceptual tools, lenses, that allow us to see the harm caused by schools (anti-blackness) and the persistence of racism (Critical Race Theory).

Anti-blackness is a global phenomenon that has framed our ways of knowing and being in the world through our collective socialization. To actively counter anti-blackness, we can use frameworks (or a lens) that allows us to see how we have potentially accepted the marginalization of Black students from science opportunities. Critical Race Theory (CRT) offers such a lens. CRT was first developed out of critical legal studies and coined by Kimberlé Crenshaw (Crenshaw, 2010; Ladson-Billings, 1998). Derrick Bell, Crenshaw, and other lawyers of color recognized that Critical Legal Studies did not include racism in its critique of society and reinforced a meritocratic and colorblind approach to the law. CRT centers the experiences of Black people by offering a framework to attend to and account for how racism is reproduced in society—reproductions of racism manifest in gerrymandering, redlining, and even in science education. Unfortunately, deficit thinking of children and their communities by policymakers

and educators often frames policymakers' and educators' daily decisions. It is, therefore, necessary to actively *see racism* so that we can actively dismantle it.

One of the important conditions for addressing systemic racism in education is developing what Patterson Williams and colleagues (2020) call an "inner witness to notice for equity." Noticing is an active process of attending to classroom interactions, making sense of what's observed, and deciding how to respond (van Es & Sherin, 2002). Noticing *for equity* entails attending to inequitable interactions, interpreting them in light of systemic processes, and acting to disrupt inequity (Erickson, 2011; Patterson Williams et al., 2020; van Es et al., 2017). It requires attention, too, to the ways racially minoritized students are positioned in classrooms, whether from a deficit lens or as sensemakers who can contribute to knowledge building in the classroom (Louie, 2018). Science leaders' noticing is particularly important, because leaders often are in positions of authority to provide feedback to educators on harmful interactions, and to create conditions for more equitable interactions to emerge.

Recent research has examined how science leaders notice for equity (Ceperich et al., 2022), and there is much needed growth in our field. In winter 2020, researchers surveyed some 650 science leaders from 33 states, and on the survey, leaders indicated what they noticed in a vignette that presented the experiences of three Black elementary school-age girls as they engage in an engineering design challenge and ultimately decide to combine their ideas rather than debate them out of fear of getting in trouble. The vignette was drawn from Wright et al. (2018). We found the majority of respondents (54%) did not notice either social identities or SEPs. These respondents noted a lack of scaffolding prior to and during the activity and that the girls feared disciplinary action for being loud due to prior experiences and classroom norms. The second largest group (25%) contained respondents who noticed SEPs but not social identities. This group primarily discussed how the classroom culture might have hindered the girls from engaging fully in the engineering design process. Respondents who noticed social identities but not SEPs made up the next largest group (15%). Respondents who noticed both SEPs and social identities accounted for the smallest group (5%). Importantly, this group discussed the ways that racial bias in and outside of classroom settings contributes to the silencing of Black girls and, therefore, disengagement from science and engineering practices.

Ultimately, we need to increase the number and percentage of leaders who are able to see how engagement in science practice intersects with race and racism in real classrooms. That is, we need leaders who do not draw artificial boundaries between the broader institutions of schooling and society, and what goes on when we seek to engage students in meaningful science learning. We need a boundary spanning consciousness, informed by a vision and theory that can see how both can operate simultaneously to limit opportunity in science education.

A Systemic Approach is Needed to Achieve Three-Dimensional Learning

A systemic approach to achieving equitable three-dimensional instruction will require understanding the central actors within a science network and the resources within a highly under-resourced discipline that can be leveraged (Spillane et al., 2001). In the leadership panel, Jim Spillane described principals as potential gatekeepers, and his research has offered insights into limiting factors in science education. It is not sufficient in itself to have resources, but resources must also be activated. Activation is defined as "how school leaders bring resources together to enhance science instruction" (Spillane et al., 2001, p. 919). Teachers are often offered professional development. However, principals and administrators are often not included in science professional development. As discussant Michael Lach (Assistant Superintendent of

Curriculum, Instruction, and Assessment at Township High School District 113) reminded us, principals and administrators can limit the potential for equitable implementation of standards. Principals and other administrators also need professional development in science so that they know the potential of what science can be and what they should be advocating for (McNeill et al., 2021).

Among the notable recommendations of the recent *Call to Action for Science Education* (National Academies of Sciences, Engineering, and Medicine, 2021a) in this respect is the call for "STEM Opportunity Maps" that would "document and track where opportunities are available, where there are disparities in opportunity, and how much progress is being made toward eliminating disparities and achieving the goals of the state STEM education plan" (p. 10). The idea behind these maps is that it would allow policy makers to direct resources to where they are

But monitoring opportunities is not likely to be sufficient to address systemic racism in the distribution of resources. *Changing* the distribution of resources, or even *augmenting* resources, requires political organizing that is likely to face opposition to equity-minded reforms (Oakes & Rogers, 2006). Without considering explicitly the role of white dominance and countering deficit frames of racially minoritized students' capabilities, pursuing goals of access and inclusion is unlikely to succeed (Zion & Blanchett, 2011). We need to promote an ideal of science and science education as it could be in a just society, rather than seeking to induct students into STEM fields as they find them today (Penuel, 2020).

As recent consensus reports have emphasized (e.g., National Academies of Sciences, Engineering, and Medicine, 2021b), such changes require transformations of educational infrastructures. Educational infrastructures include not only standards, curriculum, and assessments, but also policies and processes related to the preparation and hiring of educators, allocation of resources to schools, and school leadership practice (Hopkins et al., 2013). The work of *infrastructuring* focuses attention on creating, redesigning, and eliminating infrastructures in the service of equity and justice goals (Bell, 2019; Penuel, 2019; Penuel & Roberts, in press). Such work can and does take place within long-term partnerships between researchers and systems-level actors, both at the district and state level.

Zoe Evans, principal of Bowden High school in Georgia, expanded our understandings of the role of a principal, as they also serve as the "filter," as well as sometimes the "motivator." As a filter, Evans shared that it is her responsibility to "filter out the noise" given the conflicting initiatives teachers are inundated with (Coburn, 2005). This description speaks to the multi-faceted role of administrators that must be navigated—specifically for science. Mike Heinz (Science Coordinator, New Jersey Department of Education) shared the importance of cross-border partnerships, where educators from multiple districts work collaboratively on a specific project. According to Heinz, **"**[W]e need to learn how to write assessment items, so let's meet and use the resources to learn how to do that, but in the process of doing that, they're getting evidence-based, great, rich, professional learning. It makes them happy because they get a tool that they leave with. I'm happy because they've had some professional growth." Heinz encouraged us to consider what crossing boundaries offers educators. Creating professional learning opportunities that encourage boundary-spanning has the potential of expanding our knowledge base on resources, tools, engaging the community, and offers collective sensemaking of the potential of science education (Coburn, 2001; Marshall et al., 2021b). A systemic, boundary-crossing approach to science education is necessary to realize the vision the *Framework* offers us.

Community Partnerships and Educational Vision of Science

Multiple participants in the leadership and implementation panels spoke of the power of partnerships, including partnerships between researchers and educators. Research practice partnerships are long-term collaborations that are aimed at equitable transformation and educational improvement, through engagement with research (Farrell et al., 2021). These partnerships are intentionally organized to connect diverse forms of expertise and shift power relations in the research endeavor to ensure that all partners have a say in the joint work. Partnerships are also settings where people conduct their joint work at and across boundaries—boundaries that can span research, practice, and policy (Penuel et al., 2015). Changing systems is likely to require such long-term partnerships among educators, community members, and researchers working toward goals for racial equity and justice in science education. Equity-focused research-practice partnerships are long-term collaborations between research and practice that are specifically organized to address different aspects of equity and justice in education, which share a commitment to addressing power imbalances between research and practice, through giving a say to all partners in the purposes and strategies of joint work in partnership and amplifying the voices and knowledge of those most directly impacted by different forms of oppression (Penuel et al., in preparation).

An example of such a partnership among state leaders in science and researchers is the Advancing Coherent and Equitable Systems of Science Education (ACESSE) project, of which the second author (Penuel) is a leader. The partnership is a collaboration between science education leaders in the Council of State Science Supervisors (CSSS) and researchers at the University of Washington and the University of Colorado. As part of our efforts to help local leaders re-imagine their systems, we have developed tools to help them first visualize their existing systems. Changing any system requires that we *see* the system that reproduces inequities over time (Bryk et al., 2015). The tools we have developed to support state leaders in seeing their systems draws on Actor-Network Theory (Callon & Law, 1989; Latour, 2005), which emphasizes emphasize the role of surfacing knowledge and power in networks and the need to strengthen access to relevant expertise and resources as a means to change. In Actor-Network Diagramming, leaders identify people, groups, policies, and processes that make up an actor-network that accounts for existing inequities in their state science systems. In the current project, we plan to co-design supports with key brokers in CSSS to help new members identify and leverage networks in their state to promote equity goals. State leaders say these kinds of tools help them visualize their systems better, and also help them pinpoint possible places to focus their states' efforts (Riedy et al., 2018).

We have also developed resources that leaders can use and have widely adapted to support professional learning of both educators and leaders in their states, resources intended to be integrated into existing professional learning infrastructures. Leaders have used these with thousands of educators in their states, where a central focus of activities has been on engaging with research on the importance of connecting science instruction to students' interests and identity. State leaders say that the resources related specifically to sensemaking, cultural formative assessment, and facets of student thinking (Minstrell, 1992) have helped educators participating in this PD where they are used to get beyond "right-wrong" thinking in assessment and see beyond past deficit views of students.

A third line of joint work within ACESSE has been work to support leaders in strategically making use of opportunities to promote equity within their state agencies by paying

close attention to what has been called "the zone of mediation" (Oakes et al., 1998). The zone of mediation refers to "what is possible" to propose as a policy solution, and it is a constantly shifting zone, given both internal priorities of state agencies and external circumstances. A challenge for many leaders in state agencies is to locate that zone and find ways to advocate productively within it. Occasionally, some leaders are in a position to help shift what is considered possible, when they are supported by teams. Through rehearsing challenging conversations in a safe environment, we aim to help leaders find their own voice as advocates for equity in science education.

What can we do?

One of the most valuable things we can do as education leaders and researchers to support equitable implementation of standards is to maintain a focus on the purpose of science education in ways that reflect the vision of the *Framework.* As James Blake (Director of Strategic Initiatives and Focus Programs, Lincoln Public Schools) asked provocatively during the session, "What if we could teach for joy and fun, without standards and tests?" And Takako Olson (Director of Curriculum, Lincoln Public Schools) reminded us that investigations should not just "confirm concepts" but allow students to uncover those ideas. Echoing the ideas of Schwarz and colleagues (Schwarz et al., 2017), she underscored the need to keep the focus on shifting science learning from "learning about to figuring out." Further, as Ravit Duncan (professor of learning science and science education, Rutgers University) shared in her closing remarks, our charge "is to make sure that what happens in classrooms really allows students, especially minoritized and marginalized students, to see themselves as doers and knowers of science. How necessary it is to expand what counts as science in the classroom…[that is] whose knowledge and whose ideas we value and celebrate in science."

To promote equity, we need to devote our energy to changing systems so that this vision can become a reality. Additional resources like time are needed, but as Takako Olson advised, "We talk about time a lot, but the system has to change to get the time." To secure high quality curriculum resources requires considerable funding to develop, study, and supply them in a wide range of schools and districts. Supplying those resources, moreover, will be insufficient, as curriculum materials do not implement themselves. Sustained professional learning linked to those materials will be necessary (Short & Hirsh, 2020), as will support for customization of professional learning for teachers with varying levels of knowledge and skill (Frank et al., 2011) based on their own goals for professional growth (Penuel et al., 2020). And, it will require implementation monitoring over the long haul. That monitoring will need to include measures of educational equity (National Academies of Sciences, Engineering, and Medicine, 2019c), to maintain shared accountability to the broader goal of addressing the education debt owed to students from racially minoritized communities (Ladson-Billings, 2006).

There is, moreover, no escaping the political nature of the work of promoting equity. As James Blake reminded us, it is critical to understand "the players and the micro politics in your area, even if it's the right thing to do, if you don't do it at the right pace, we've kind of heard that theme today, it may fail." In a context where it is not always possible to foreground racial equity—or even equity—attention to the "zone of mediation" (Oakes et al., 1998) is key. We would be remiss if we did not emphasize the necessity of being both prepared and willing to engage in the work of creating equity (Burgess & Patterson Williams, forthcoming). Without understanding one's own positionality and moral compass, one's efforts towards engaging with those who embody this mission will fall flat. It is one's day-to-day interactions in the world with

minoritized persons demonstrate their commitment to a more just world. Recognize that one may not be accepted to work in communities that they are not a part of immediately, as they must demonstrate that they will not harm our communities. If one is unwilling to prove their trustworthiness, it may be best to reconsider ones' capacity to work *with communities* rather than *on communiti*es.

No single leader, school, district, or state agency can accomplish these aims on their own. There will need to be robust partnerships among educators, leaders, community-based organizations, cultural institutions like museums, and researchers, to achieve equity. As panelist Gudiel Crosthwaite argued, those partners need to provide not only support, but also "to give us help with holding us to account for and supporting priorities." Those partners, Crosthwaite argued, need to share the vision, and we would add, need to share in the risk by engaging in collaborative design and testing of solutions to the challenges raised for equitable implementation of standards. Further, as Trish Shelton (Chief Learning Officer, National Science Teachers Association) argued in her closing remarks, she articulated a "large responsibility that we have to stay connected together in working together," to achieve the ambitious vision of the *Framework*.

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of educational research*, *81*(2), 132-169.

Bang, M., Curley, L., Kessel, A., Marin, A., Suzukovich III, E. S., & Strack, G. (2014). Muskrat theories, tobacco in the streets, and living Chicago as Indigenous land. *Environmental Education Research*, *20*(1), 37-55.

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M., L. (2018). *Report of the National Survey of Science and Mathematics Education*. Horizon Research, Inc.

Basile, V., & Lopez, E. (2015). And still I see no changes: Enduring views of students of color in science and mathematics education policy reports. *Science Education, 99*(3), 519-548. https://doi.org/10.1002/sce.21156

Bell, P. (2019). Infrastructuring teacher learning about equitable science instruction. *Journal of Science Teacher Education, 30*(7), 681-690.

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). *Learning to improve: How America's schools can get better at getting better*. Harvard University Press.

Burgess, T. & Patterson Williams, A. D. (2022). The Work of Creating Equity for Transformation within the Science Classroom. *Science Education, 106* (4), xx – xy.

Callon, M., & Law, J. (1989). On the construction of sociotechnical networks: Content and context revisited. *Knowledge and Society, 8*(1), 57-83.

Ceperich, R., Tran, T., Salinas del Val, Y., & Davidson, K. L. (2022, March). Science education leaders' sense-making and noticing for equity subject/problem. Paper to be presented at the NARST 95th Annual International Conference, Vancouver, BC.

Chambers, T. V. (2009). The" Receivement Gap": School Tracking Policies and the Fallacy of the" Achievement Gap". *The Journal of Negro Education*, 417-431.

Coburn, C. E. (2001). Collective sensemaking about reading: How teachers mediate reading policy in their professional communities. *Educational Evaluation and Policy Analysis*, *23*(2), 145-170.

Coburn, C. E. (2005). Shaping teacher sensemaking: School leaders and the enactment of reading policy. *Educational Policy*, 19(3), 476-509.

Crenshaw, K. W. (2010). Twenty years of critical race theory: Looking back to move forward. *Conn. L. Rev.*, *43*, 1253.

Erickson, F. (2011). On noticing teacher noticing. In M. G. Sherin, R. Phillip, & V. R. Jacobs (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 17-34). Routledge.

Espinoza, M. L., Vossoughi, S., Rose, M., & Poza, L. E. (2020). Matters of participation: Notes on the study of dignity and learning. *Mind, Culture, and Activity, 27*(4), 325-347. https://doi.org/10.1080/10749039.2020.1779304

Evans, A. E. (2007). School leaders and their sensemaking about race and demographic change. *Educational Administration Quarterly*, *43*(2), 159-188.

Frank, K. A., Zhao, Y., Penuel, W. R., Ellefson, N. C., & Porter, S. (2011). Focus, fiddle and friends: A longitudinal study of characteristics of effective technology professional development. *Sociology of Education, 84*(2), 137-156.

Hopkins, M., Spillane, J. P., Jakopovic, P., & Heaton, R. M. (2013). Infrastructure redesign and instructional reform in mathematics. *Elementary School Journal, 114*(2), 200-224. https://doi.org/https://doi.org/10.1086/671935

Krist, C., & Suárez, E. (2018). Doing science with fidelity to persons: Instantiations of caring participation in science practices. In J. Kay & R. Luckin (Eds.), *Proceedings of the 13th International Conference of the Learning Sciences* (Vol. 1, pp. 424-431). International Society of the Learning Sciences.

Krumm, A. E., Penuel, W. R., Pazera, C., & Landel, C. (2020). Measuring equitable science instruction at scale. In M. Gresalfi, I. S. Horn, N. Enyedy, H.-J. So, V. Hand, K. Jackson, S. E. McKenney, A. Leftstein, & T. M. Philip (Eds.), *Proceedings of the International Conference of the Learning Sciences* (Vol. 4, pp. 2461-2468). International Society of the Learning Sciences.

Ladson-Billings, G. (1998). Just what is critical race theory and what's it doing in a nice field like education?. *International journal of qualitative studies in education*, *11*(1), 7-24.

Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in US schools. *Educational researcher*, *35*(7), 3-12.

Langer-Osuna, J. M. (2015). From getting "fired" to becoming a collaborator: A case of the coconstruction of identity and engagement in a project-based mathematics classroom. *Journal of the Learning Sciences, 24*(1), 53-92. https://doi.org/10.1080/10508406.2014.944643

Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory*. Oxford University Press.

Louie, N. (2018). Culture and ideology in mathematics teacher noticing. *Educational Studies of Mathematics, 97*, 55-69. https://doi.org/10.1007/s10649-017-9775-2

Marshall S.L., Haverly C., Ibourk A. (2021a) Toward Equitable Science Instruction: The Current State of Elementary Science Education in the United States and Policy Considerations. In: Atwater M.M. (eds) International Handbook of Research on Multicultural Science Education. Springer International Handbooks of Education. Springer, Cham. https://doi.org/10.1007/978-3-030-37743-4_22-1

Marshall, S. L., Nazar, C. R., Ibourk, A., & McElhaney, K. W. (2021b). The role of collective sensemaking and science curriculum development within a research–practice partnership. *Science Education*, *105*(6), 1202-1228.

McNeill, K. L., Lowenhaupt, R., Cherbow, K., & Lowell, B. R. (2021). Professional development to support principals' vision of science instruction: Building from their prior experiences to support the science practices. *Journal of Research in Science Teaching*.

Marx, R. W., & Harris, C. J. (2006). *No Child Left Behind* and science education: Opportunities, challenges, and risks. *Elementary School Journal, 106*(5), 467-477.

Minstrell, J. (1992). Facets of students' knowledge and relevant instruction. In F. Duit, F. Goldberg, & H. Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 110-128). IPN.

Munter, C., & Haines, C. (2019). Mathematics teachers' enactment of cognitively demanding tasks and students' perception of racial differences in opportunity. *Mathematical Thinking and Learning, 21*(3), 155-177. https://doi.org/10986065.2019.1576002

National Academies of Sciences, Engineering, and Medicine. (2019b). *Science and engineering for grades 6-12: Investigation and design at the center*. The National Academies Press. https://doi.org/doi:10.17226/25216

National Academies of Sciences, Engineering, and Medicine. (2021a). *A call to action for science education: Building opportunity for the future*. The National Academies Press. https://doi.org/10.17226/26152

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

National Academies of Sciences, Engineering, and Medicine. (2019c). *Monitoring educational equity. National Academies Press.*

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Research Council. https://doi.org/10.17226/13165

Oakes, J., Welner, K., Yonezawa, S., & Allen, R. L. (1998). Norms and politics of equity-minded change: Researching the "zone of mediation". In A. Hargreaves, A. Lieberman, M. Fullan, & D. Hopkins (Eds.), *International Handbook of Educational Change* (pp. 952-975). Klewer.

Oakes, J., & Rogers, J. (2006). *Learning power: Organizing for education and justice*. Teachers College Press.

Patterson Williams, A., Higgs, J. M., & Athanases, S. Z. (2020). Noticing for equity to sustain multilingual literacies. *Journal of Adolescent and Adult Literacy, 63*(4), 457-461. https://doi.org/10.1002/jaal.1025

Penuel, W. R., Allen, A.-R., Farrell, C., & Coburn, C. E. (2015). Conceptualizing research-practice partnerships as joint work at boundaries. Journal for Education of Students at Risk (JESPAR), 20(1-2), 182-197. https://doi.org/10.1080/10824669.2014.988334

Penuel, W. R. (2019). Infrastructuring as a practice of design-based research for supporting and studying equitable implementation and sustainability of innovations. *Journal of the Learning Sciences, 28*(4-5), 659-677. https://doi.org/10508406.2018.1552151

Penuel, W. R. (2020). Commentary: To promote equity, prepare students for what science could be. *NSTA Reports*. https://doi.org/https://www.nsta.org/promote-equity-prepare-students-what-science-could-be

Penuel, W. R., Bell, P., & Neill, T. (2020). Creating a system of professional learning that meets teachers' needs. *Phi Delta Kappan, 101*(8), 37-41. https://doi.org/10.1177/0031721720923520

Penuel, W. R., Farrell, C. C., & Daniel, J. (in preparation). Research-practice partnerships: Linking policy, practice, and research for equity. In L. Cohen-Vogel, J. Scott, & P. Youngs (Eds.), *Handbook of education policy research*. AERA.

Penuel, W. R., & Roberts, V. (in press). The theory and practice of democracy and community. In D. J. Peurach, J. L. Russell, L. Cohen-Vogel, & W. R. Penuel (Eds.), *Handbook of improvement research in education*. Rowman Littlefield.

Perry, A., Rothwell, J., & Harshbarger, D. (2018). The devaluation of assets in black neighborhoods. *Library Catalog: www. brookings.edu*.

Reardon, S. F., & Owens, A. (2014). 60 years after Brown: Trends and consequences of school segregation. Annual Review of Sociology, 40, 199-218. https://doi.org/10.1146/annurev-soc-071913-043152

Riedy, R., Van Horne, K., Bell, P., Penuel, W. R., Neill, T., & Shaw, S. (2018). Mapping networks to help education leaders gain insights into complex educational systems. In J.

Kay & R. Luckin (Eds.), *13th International Conference of the Learning Sciences* (Vol. 1, pp. 656-662). International Society of the Learning Sciences.

Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). Moving beyond 'knowing about' science to making sense of the world. In C. Schwarz, C. Passmore, & B. J. Reiser (Eds.), *Helping students make sense of the world using next generation science and engineering practices* (pp. 3-21). NSTA.

Short, J., & Hirsh, S. (2020). *The elements: Transforming teaching through curriculum-based professional learning.* Carnegie Corporation of New York.

Spillane, J. P., Diamond, J. B., Walker, L. J., Halverson, R., & Jita, L. (2001). Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *38*(8), 918-940.

Sugrue, T. J. (2018). The Black Freedom Struggle in the Urban North. In *Oxford Research Encyclopedia of American History*.

Tate, W. F. (2001). Science education as a civil right: Urban schools and opportunity-to-learn considerations. *Journal of Research in Science Teaching, 38*(9), 1015-1028. https://doi.org/10.1002/tea.1045

van Es, E., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education, 10*(4), 571-596.

van Es, E. A., Hand, V., & Mercado, J. (2017). Making visible the relationship between teachers' noticing for equity and equitable teaching practice. In E. O. Schack, M. H. Fisher, & J. A. Wilhelm (Eds.), *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 251-270). Springer.

Weick, K. E. (1995). Sensemaking in organizations (p. 3). Sage.

Patterson Williams, A., Athanases, S. Z., Higgs, J., & Martinez, D. C. (2020). Developing an inner witness to notice for equity in the fleeting moments of talk for content learning. *Equity & Excellence in Education, 53*(4), 504-517. https://doi.org/10.1080/10665684.2020.1791282

Wright, C., Wendell, K. B., & Paugh, P. B. (2018). "Just put it together to make no commotion:" Re-imagining urban elementary students' participation in engineering design practices. *International Journal of Education in Mathematics, Science, and Technology, 6*(3), 285-301. https://doi.org/10.18404/ijemst.428192

Zion, S., & Blanchett, W. (2011). [Re]conceptualizing inclusion: Can critical race theory and interest convergence be utilized to achieve inclusion and equity for African American students? *Teachers College Record, 113*(10), 2186-2205.