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Proposing a Framework to Center Justice in Ambitious Science Teaching

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ABSTRACT

Though educators and researchers have developed shared theory and language for priorities necessary to disrupt the status quo toward more equitable science education, we lack a tool that organizes sets of teaching practices across an instructional unit to support enactment and rehearsal. Core sets of practices, such as those included in the Ambitious Science Teaching (AST) framework (Windschitl et al. 2018), have been shown to nurture diverse students' access, achievement, and identities in science. Though valuable, they stop short of meeting more critical demands of equity, namely that of challenging and expanding what counts as science and using science to transform social injustice. Toward this end, this paper offers the theoretical warrant for the Justice-centered ambitious Science Teaching (JuST) Framework, empirically developed and conceptually aligned with current priorities related to justice-centered science pedagogy. Building on and extending AST, JuST works toward shaping science education in ways that reflect the diversity of sensemaking repertoires of the students in any given classroom and uses science for purposes that matter to them and work toward more just futures. The JuST-FW offers educators and scholars a common organizational tool, language,Davis and core practices as scaffolds for centering justice in planning for and teaching ambitious science units as well as collaboratively reflecting on practice with a common tool.

The Next Generation Science Standards (NGSS) (National Research Council 2013) ushered in a focus on collaborative sensemaking in science classrooms with visions of supporting students' engagement with science and engineering ideas and practices to explain phenomena and solve problems. While this focus addresses important equity aims of more rigorous understanding, boosted achievement, increased interest, and identity development, it falls short in more expansive equity aims (National Academies of Science, Engineering and Medicine (NASEM) 2022, 2025). Philip and Azevedo (2017) describe achievement and identity goals as inclusive, designed to support individual students within a flawed system. Though inclusion is necessary, they suggest that more critical equity aims require the disruption of the status quo in science education as well as in science and society. As cultural practices, both science education and science as a professional discipline have been limited by white supremacy culture to the detriment to both places of learning (e.g., Bang et al. 2013; Harding 1992) as well as accepted methods, foci, and implications of science (e.g. Blackstock 2002; Thomas et al. 2023).

Philip and Azevedo (2017) identify two equity discourses that are needed to disrupt the status quo in science learning, science, and society, namely, to expand what counts as science and to recognize the roles science can play in social transformation. These transformative aims move beyond the focus of NGSS as they have the potential for troubling white hegemonic versions of Western/Eurocentric science. These two equity goals have largely gone unmet (Tzou et al. 2021). Forty-nine United States and the District of Columbia have adopted the NGSS or similar standards based on the Framework for K-12 Science Education (National Research Council 2012) and are, in some capacity, making progress in increasing opportunity and access to high-quality instruction. That said, only a limited amount of attention and resources are available for addressing more pressing societal challenges attributable to a systemically racist system (notable exceptions exist, including Learning in Places 2021; Morales-Doyle 2017 2024; and Patterson and Gray 2019). More specifically, the learning needs of youth and minoritized communities continue to go unmet (Howard 2019; Verstegen 2015). As one example, in Connecticut there exists a $639 million funding gap between schools with at least 25% BIPOC student populations when compared to schools with white student populations greater than 75% (School and State Finance Project 2020). In addition, communities of Color are significantly more exposed to pollution from every type of source (e.g., industry, agriculture, vehicle, construction) (Tessum et al. 2021), lack access to fresh food (George and Tomer 2021), and lack equitable access to health care (Nordyke et al. 2024). If science education is to prepare students to use science to meet the more pressing needs and challenges of today in ways that are just, science educators need concrete practices, common language, and an organizing framework to guide their individual and collective design, implementation and reflective work.

We seek to engage educators and designers of learning environments with asset-based framings of youth and communities which center joy and justice in order to create the kinds of thriving within worlds that reframe science learning as a site of transformative possibilities and future dreaming (Adams 2022; Benjamin 2024; Chavous et al. 2023; Muhammad 2022). Like Kang and Nation (2023), we believe that science and science education can and need to matter to students and can be used for positive change.

In this paper, we begin by clarifying the need for a Justice-centered ambitious Science Teaching Framework (JuST-FW). We build on the Ambitious Science Teaching (AST) Framework as the foundation of our proposed JuST-FW. Importantly, the AST community is an epistemic community that shares theory, codes (language), and tools, important for transforming the learning culture in science classrooms to align with current learning theory (Glazer and Peurach 2015). We identify ways AST can and does support justice-centering and argue that centering social justice would benefit the original AST framework structure. By bringing the four quadrants of AST together with the two transformational aims outlined above, we present four corresponding JuST Goals: one for planning and three for implementing a unit. In addition, essential to all aspects of this justice-centering work but missing from AST is the goal of nurturing a classroom community ready for the work. We therefore add a fifth JuST goal and corresponding set of practice, the JuST Core.

We organize this manuscript by incrementally building the JuST-FW, providing the theoretical warrant and lived examples for each of the five practice sets that address five JuST goals beginning with the JuST Core (See Figure 1). We anchor the JuST-FW in the two overarching transformational aims represented as the top and bottom hemispheres of the figure. We spotlight sets of core practices that address each of the goals, arguing for their transformational importance and potential. We close by amplifying the need for teachers' critical consciousness and providing guidance on how to use this framework.

1 | The Justice-Centered Ambitious Science Teaching Framework (JuST-FW)

Decades of researchers have theorized what it means to teach in ways that promote equity and justice (e.g., Atwater et al. 1995; Rodriguez 1998), yet there is a lack of organized sets of core practices for science teachers to try out, practice, and adapt within the particular contexts of the design, implementation, and reflection of instructional units. In fact, there is argument in the field as to whether such core practices could ever support

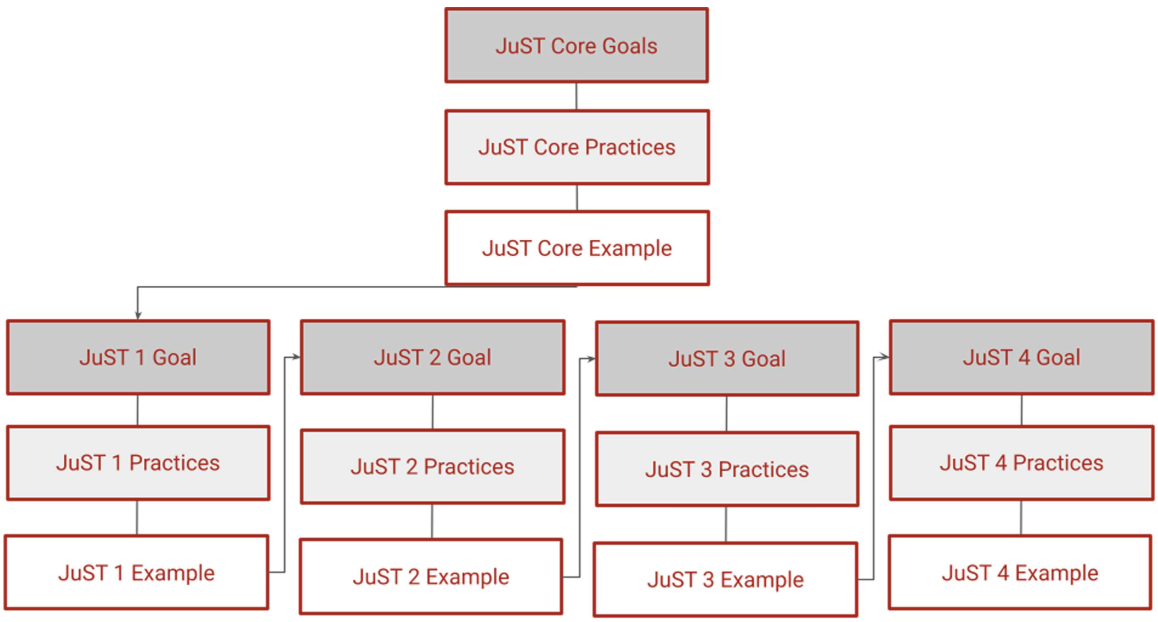

FIGURE 1 | Advanced organizer for the manuscript.

justice-centered teaching (e.g., Philip et al. 2019). Justice-oriented frameworks exist, and each of these offers a valuable tool for reasoning about and informing justice-centered pedagogy in science education. Table 1 provides an overview of justice-centering educational frameworks published across the past three decades, specifically 1993–2025. Not surprisingly, common priorities cut across them and these priorities are also central to our JuST-FW. Like the JuST-FW, most of these frameworks focus on achievement and science identity development in ways that expand what counts as science and use science for transformational aims. Thus, the field of scholars in justice-centering science education share a common theory and language (Table 1, column 3); what we lack is a common tool, or shared map, to support rehearsal, problem-solving, and revision. "Education, as a field, has developed few shared maps that are subject to ongoing, collective debate and that embed the collective experience of practice" (Glazer and Peurach 2015, 189). We offer the JuST-FW as organized sets of core practices, a tool for enactment, that science teachers new to justice-centering can try out and practice during various states of an instructional unit. Following the format of and including the practices of AST, this JuST-FW maps core practice sets to the work of teaching: designing, implementing, and reflecting on instructional units for the specific youth and community a teacher serves.

Ambitious Science Teaching (AST) serves as an important foundation for the JuST-FW. The AST framework identifies a small number of types of key interactions that have the greatest promise for students' academic success (Windschitl at al. 2018). Specifically, the AST goals include *planning for engagement with big science ideas*, *eliciting students' ideas*, *supporting ongoing changes in thinking*, and *pressing for evidence-based explanations* (see Figure 2, Table 2). Its practices engage students with the aim of using core disciplinary ideas to explain a complex scientific phenomenon. AST is responsive to students' ideas, experiences, and questions, while engaging in science and engineering practices like modeling, argumentation, and constructing explanations (Windschitl et al. 2018). Among other research-based benefits, AST has been shown to offer valuable support for centering students' collaborative sensemaking around anchoring phenomena in rigorous and student-centered ways (Thompson et al. 2021).

1.1 | Ambitious Science Teaching and Corresponding Justice-Centering Practices

We deeply value and build on the work of the AST framework, which aims to make science teaching and learning inclusive for all students. The JuST-FW moves beyond a focus on inclusion to a focus on transformative equity work, as it aims to challenge and expand the discipline of science, the norms of science classrooms, and relevant injustices in society. Though AST can be taken up in justice-centering ways as noted in the more recent work of the AST framework authors (e.g., Thompson et al. 2020, 2021), we argue that the field would benefit from justice-centering sets of practices that, like AST, align with stages of unit planning and enactment.

Including and extending AST, we offer a Justice-centered ambitious Science Teaching (JuST) goal for each of the four AST goals as well as one additional goal we argue to be fundamental to all classroom-based justice work:

1. Extending AST's Q1 goal, planning for engagement with big science ideas, the JuST 1 goal focuses on planning toward a meaningful purpose that centers justice.
2. Extending AST's Q2 goal, eliciting students' ideas, the JuST 2 goal focuses on eliciting students' ideas about science, culture, and justice.
3. Extending AST's Q3 goal supporting ongoing changes in thinking, the JuST 3 goal focuses on nurturing revisions of scientific thinking and feeling with nontraditional expertise.
4. Extending AST's Q4 goal, pressing for evidence-based explanations, the JuST 4 goal focuses on using science to make a difference and advocate for justice.
5. Missing from AST, the JuST Core goal focuses on cultivating a justice-centering community.

Five sets of core practices align with each of the JuST Goals to guide teachers in developing both justice-centered and ambitious repertoire of science teaching. The JuST-FW aims to mirror the organization and therefore utility of the AST framework, to provide teachers with explicit and concrete transformational practices for the various stages of unit design and implementation. The intention is to offer teachers justice-centering goals and core practices as possible starting practices for their own transformative pedagogy. The JuST-FW proposed in this paper thus addresses the need for guiding sets of practices, while maintaining space for and expectations of teachers' flexibility, improvisation, and continued development toward critical consciousness.

The JuST-FW aligns with Lampert (2010)'s description of teaching as relational work with students and with disciplinary content (i.e., science in the case of our research and proposed framework). Further, we define core practices in alignment with others engaged in similar work (Ball et al. 2009; Hammerness et al. 2005; Kloser 2014; Stroupe and Gotwals 2018; Thompson et al. 2013; Windschitl et al. 2018) as approaches or strategies that teachers use to guide the navigation and preservation of classroom complexities and accomplish their aims of supporting student engagement and learning. We include practices that teachers can observe and rehearse (e.g., McDonald et al. 2013).

As an example, one of the core practices identified in JuST 1 is *interrogating the role of power and justice* in order to support students in understanding injustices and work toward more just futures. This practice is visible in planning in many ways. First, it is visible as a teacher researches the ways a scientific phenomenon is realized in the world: who benefits and who is harmed, and whose voices have been heard and whose have been silenced. The teacher integrates this social justice-related context in the gapless explanation of the scientific phenomenon and consider the role race and racism might be playing (Shah and Coles 2020). In addition, the activity summary table that lays out an order of the unit's various activities will include an inquiry about the social justice aspects related to the situated nature of the anchoring phenomenon. The activity summary table will also include a description of the final assessment

TABLE 1 | Historical arc of justice centering frameworks,[a] principles, and practices for situating our work.

References	Framework elements (transformational aspects are bolded)	Mapping to the two transformational aims argued by Philip and Azevedo (2017) to be required for transformational equity work
Banks (1993)	Four levels of integration of multicultural content include: Level 1—The Contributions Approach (focus on discrete cultural aspects e.g., famous individuals), Level 2—The Additive Approach (diverse perspectives are added, but curriculum remains the same), **Level 3—The Transformation Approach (curriculum is changed to include diverse perspectives), Level 4—The Social Action Approach (students take action to solve social problems)**	**Expanding what counts as science:** Level 3—The Transformation Approach; **Using science for social transformation:** Level 4—The Social Action Approach
Ladson-Billings (1995)	Culturally relevant pedagogy includes three criteria which teachers demand and facilitate: Academic success, **cultural competence, and critical consciousness**	**Expanding what counts as science:** Cultural competence**; Using science for social transformation:** raise students' critical consciousness
Gutiérrez (2012)	Equity framework in mathematics spatializing equity according to four dimensions along two axes. The framework's dominant axis consists of access to and achievement in mathematics; dominant in its reflection of society's status quo. Along the second, critical axis, are identity and power in mathematics; critical in **addressing students' cultural identities and sociopolitical issues, from the perspective of marginalized groups** (Gutiérrez 2007). Consideration of the role of identity in learning is a precursor to addressing issues of power as they relate to identity.	**Expanding what counts as science:** Addressing students' cultural identities from the perspective of marginalized groups; **Using science for social transformation:** Addressing sociopolitical issues from the perspective of marginalized groups
Dimick (2012)	A framework consisting of **social, political, and academic empowerment for students to use science to address injustices**	**Expanding what counts as science:** Students' engagement in curriculum-making; **Using science for social transformation:** Focus on nurturing students' political empowerment to address injustices
Morales-Doyle (2017)	Theoretical framework merging critical pedagogy and culturally relevant pedagogy to include **social justice science issues (SJSI)**, equitable academic expectations, **students as producers of culture and knowledge**	**Expanding what counts as science:** Students as producers of culture and knowledge; **Using science for social transformation**: Social justice science issues (SJSI)
Philip and Azevedo (2017)	Four equity discourses: Those that (1) emphasize increased student achievement and (2) nurture identification with science; **(3) problematize privileged forms of science; and (4) identify science in justice movements**	**Expanding what counts as science:** Problematize privilege forms of science **Using science for social transformation:** Identify science in justice movements
Finkel (2018)	Organized by three categories, **content** that is connected to broader social justice issues, **processes** that are culturally relevant and provide all students access and **products** as demonstrations of learning that are authentically connected to students' questions and concerns, the framework includes "entry points" for units and assignments	**Expanding what counts as science:** Science content helps students answer issues of concern to themselves, their families, and their communities: **Using science for social transformation:** Students demonstrate their understanding taking action to apply what they learned
Wong (2019)	Six principles of **culturally sustaining pedagogy** (Paris and Alim 2017): With arrows pointing	**Expanding what counts as science:** Recognize that culture is complex, constantly shifting,

(Continues)

References	Framework elements (transformational aspects are bolded)	Mapping to the two transformational aims argued by Philip and Azevedo (2017) to be required for transformational equity work
	outward from the first principle, **(a) "Decenter the white gaze"** to five other principles: **(b) Culture is complex; (c) sustaining, revitalizing and imaging toward socially just, pluralistic societies; (d) desire-based approach to teaching and learning; (e) sustaining lives and reviving souls, and (f) loving critique and critical reflexivity**	intergenerational and locally situated; practice a desire-based approach to teaching and learning that takes up joy alongside pain, offering deeper love; and sustain and "revive" the souls of young people; **Using science for social transformation:** Decenter the white gaze, engage in loving critique and critical reflexivity, and foster, revitalize and teach toward socially just, pluralistic societies
Calabrese Barton et al. (2020)	**Recognition** (creating spaces for noticing, soliciting, legitimizing, and learning from students' experiences), **refraction** (re-orienting classroom discourses and interactions in ways that centered youth resources as integral to disciplinary learning and to reveal unjust teaching practices previously concealed), and **social transformation** (leading to new forms of discourses, participation, and engagement)	**Expanding what counts as science:** Recognition and refraction **Using science for social transformation:** Social transformation that leads to new forms of discourses, participation and engagement
Thompson et al. (2020)	Four-part framework of critical and cultural approaches to Ambitious Science Teaching: **Principle 1: Recognizing our own and other's worlds and developing critical consciousness; Principle 2: Learning about and prioritizing students' communities and cultures; Principle 3: Designing for each student's full participation in the culture of science; Principle 4: Challenging the culture of science through social and restorative justice**	**Expanding what counts as science:** Principle 2: Learning about and prioritizing students' communities and cultures; Principle 3: Designing for each student's full participation in the culture of science; Principle 4: Challenging the culture of science through social and restorative justice; **Using science for social transformation**: Principle 1: Recognizing our own and other's worlds and developing critical consciousness
Kang and Nation (2023)	Five goals to support teachers making principled pedagogical decisions: **(a) make it matter, (b) support sensemaking, (c) attend to race, language, and identities, (d) build a welcoming community, and (e) disrupt power hierarchies**	**Expanding what counts as science:** Attend to race, language, and identities, build a welcoming community; **Using science for social transformation**: Make it matter, disrupt power hierarchies
Davis and Bautista (2025)	Framework of four approaches for including justice moves in elementary science lessons, (1) increasing opportunity and access in science, (2) increasing identity and representation in science, (3) **expanding what counts as science,** (4) **seeing science as a part of justice movements**	**Expanding what counts as science:** Approach 3; and; **Using science for social transformation:** Approach 4: Seeing science as a part of justice movements.
This article	Framework that organizes five sets of core science teaching practices around each goals for planning and implementing a science unit: **Cultivating a justice-centering community, planning toward a meaningful purpose that centers justice, eliciting student ideas about science, culture and justice, nurturing revisions of thinking and feeling with diverse expertise, and using science to make a difference and advocate for justice**	**Expanding what counts as science:** Bottom foundational hemisphere **Using science for social transformation:** Top foundational hemisphere

[a]In this paper, we're using the word "framework" to describe a conceptual and pedagogical tool to guide the teachers' design of learning environments and scaffold teacher practices.

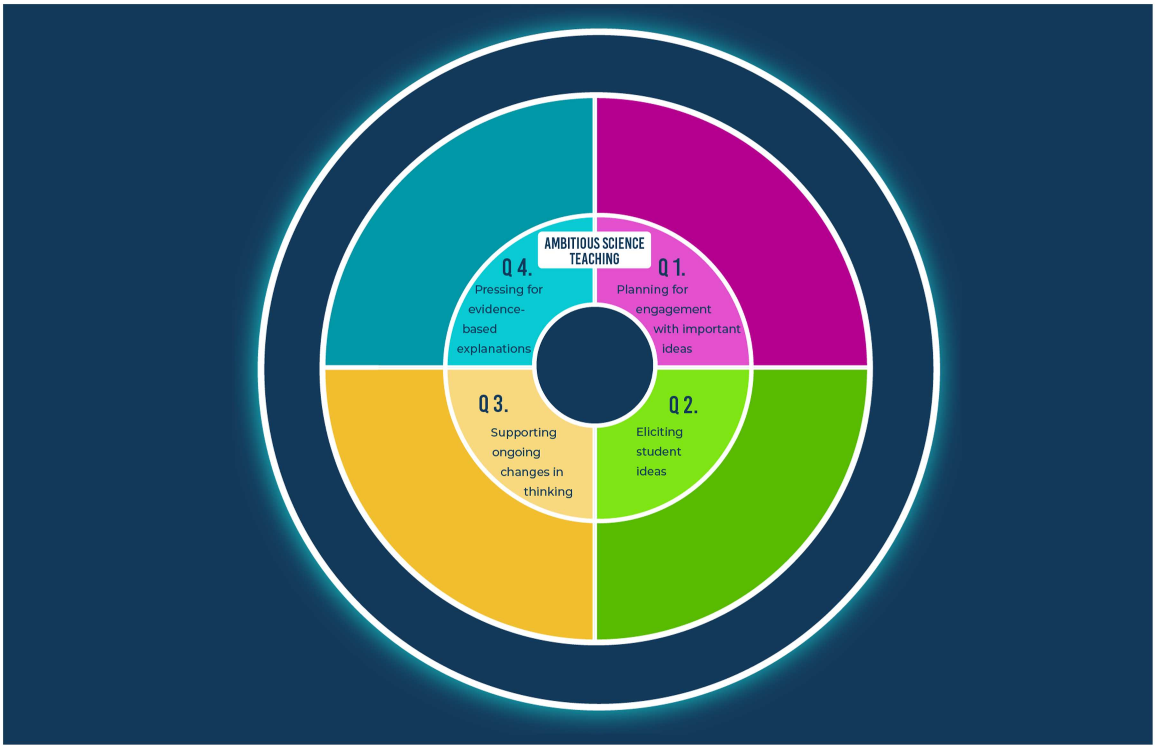

FIGURE 2 | The four core practices of Ambitious Science Teaching (Windschitl at al. 2018).

which could be designed to use the science learned to address the injustice. Finally, the template and teacher sample created to scaffold students' scientific modeling may also include a space for making visible students' thinking about injustices in the social context within which the phenomenon occurs. These varied planning efforts require teachers to critically investigate the role of power as it relates to the science in a given unit.

We now introduce each of the five sets of JuST Practices to demonstrate how they add to and build on the AST framework. The JuST-FW consists of four quadrants that align with the four quadrants of AST centered around a fifth set of practices that we refer to as the JuST Core. In addition, the organization of the JuST five practice sets is motivated by the two transformational goals outlined by Philip and Azevedo (2017), namely (a) using science for social transformation; and (b) shaping science with diverse sensemaking repertoires.

2 | Top Hemisphere: Using Science for Social Transformation

The top hemisphere of the framework, "using science for social transformation" aims to position science learning in service of social transformation as teachers plan for and implement science units that result in students using science to make a positive difference (see Figure 3, Table 2). The JuST-FW aspires to reorient the ultimate aim and purpose of science teaching and learning beyond mere school-based accountability measures, thus eliminating the need for students to ask, "Why do we have to learn this?" AST's first and last quadrants aim to support teachers in "planning for students' engagement with important science ideas" (Q1) and conclude with holding students accountable for this engagement by "pressing for evidence-based explanations" (Q4). The JuST-FW goals include and expand on these important AST goals by "planning for a meaningful purpose that centers justice" (JuST 1) and concluding with "using science to make a difference and advocate for justice" (JuST 4). Each of the JuST Goals will be further explained below with their corresponding sets of practices.

3 | Bottom Hemisphere: Expanding What Counts as Science

The lower hemisphere of the JuST FW, "expanding what counts as science," aims to broaden what science knowledge and practices are legitimized and used as "science." In these quadrants, teachers invite students to use their experiences and sensemaking repertoires, while explicitly highlighting the value of diversity in science and science classrooms (see Figure 4, Table 2). AST's second and third quadrants focus on the pedagogical goals of "eliciting students' ideas" (Q2) and "supporting ongoing changes in thinking." Again, the JuST-FW goals include and expand on these important AST goals by "eliciting students' ideas about science, culture, and justice" (JuST 2) and "nurturing revisions of scientific thinking and feeling with diverse expertise" (JuST 3). As students engage in collaborative inquiry to construct an explanation about a scientific phenomenon, they are simultaneously supported in questioning, critiquing, and revising the black box of where "scientific expertise" lives and how it is done, who and what has been left out, and at what cost. Shedding a light inside the black box of science can reveal how similar and important students' sensemaking practices can be to those of professional scientists, thus offering marginalized students increased potential for seeing themselves and their work as scientific (Warren et al. 2001). They are also supported in investigating the ways that scientific phenomena intersect with powered social contexts and cultures.

TABLE 2 | Ambitious Science Teaching (AST) practices and corresponding justice-centering practices for each section of the JuST Framework.

Framework section	Framework location	JuST Goals include and adds to these AST goals	JuST includes and adds to these AST practices	Justice-centering goal	Justice-centering practices
JuST Core	Center	N/A	N/A	**Cultivating a justice-centered community**	• Practicing criticality (including science) • Challenging classroom cultural assumptions • Functioning as a scientific community
JuST 1	Top Hemisphere: **Using science for social transformation**	Planning for engagement with important science ideas	• Identifying big ideas • Selecting an anchoring event and essential question • Sequencing learning activities	**Planning toward a meaningful purpose that centers justice**	• Collaborating with community • Interrogating the role of power and justice • Planning for students to take action with science
JuST 2	Bottom Hemisphere: **Expanding what counts as science**	Eliciting students' ideas	• Eliciting ideas and activating prior knowledge • Helping student represent their thinking publicly • Adapting further instruction	**Eliciting student ideas about science, culture, and justice**	• Inviting nontraditional ways of engaging with science • Ensuring the presence of diverse perspectives • Drawing out students' thinking about justice
JuST 3	Bottom Hemisphere: **Expanding what counts as science**	Supporting ongoing changes in thinking	• Introducing students to new ideas, • Engaging students in activity and sensemaking, • Collective thinking	**Nurturing revisions of scientific thinking and feeling with diverse expertise**	• Integrating nontraditional forms of scientific expertise • Recognizing and encouraging students' full range of sensemaking tools • Engaging in place-based science investigations
JuST 4	Top Hemisphere: **Using science for social transformation**	Pressing for evidence-based explanations	• Co-constructing gotta-have checklist • Pressing for gapless explanations and models • Assessing for understanding	**Using science to make a difference and advocate for justice**	• Including justice elements in the summative assessment • Empowering agents of change • Connecting students with an authentic audience

Note: Justice-centering aims and goals are bolded.

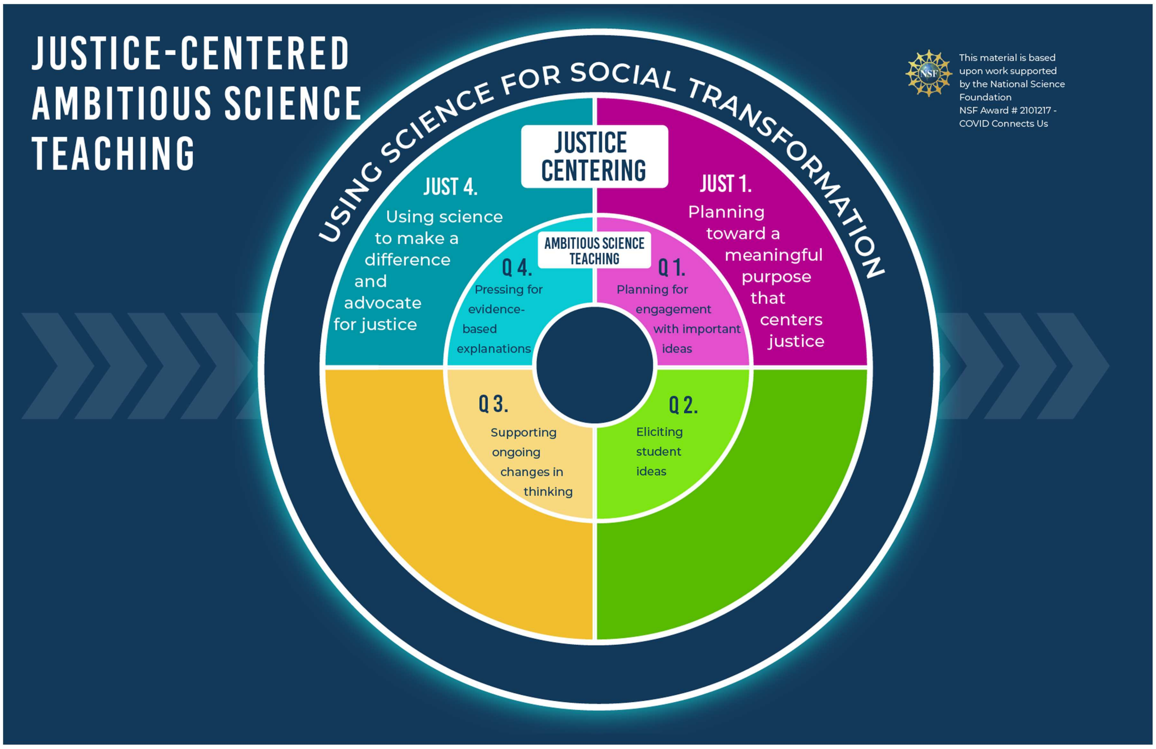

FIGURE 3 | JuST Framework top hemisphere with corresponding JuST 1 and 4 goals named.

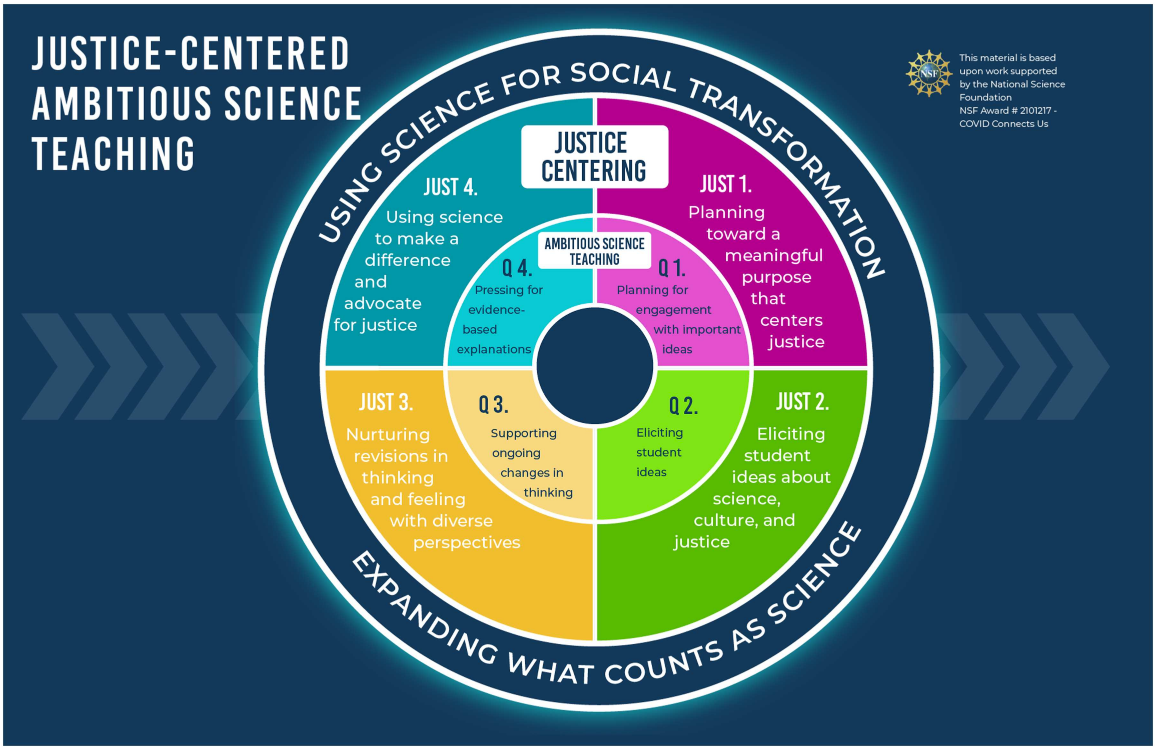

FIGURE 4 | JuST Framework top and bottom hemisphere transformational aims with corresponding four quadrant goals named.

Next, we will fill in the full framework, beginning by adding the JuST Core goal in the center. For each of the five JuST goals, we offer a warrant of the JuST goal before introducing the three JuST practices that address each goal. We follow the description of practices with examples from a 4-year, federally funded grant project on which the authors and many teachers collaborated (Award 2101217). This project involved the engagement of 10 science teacher professional learning communities from three states in 2 year-long design-based research projects to identify, implement, and refine instructional practices that center justice in ambitious classrooms. Over the 4 years of the project, scholars and teachers worked together to develop the theoretical foundations that grounds the JuST Framework, informed by a synthesis of peer reviewed research and theoretical arguments as well as wisdom gained through the sustained and thoughtful efforts of justice-centered classroom teachers (see Cooke et al. 2025; Luehmann et al. 2024).

A shared experience for project teachers was the design (or refinement) and implementation of a curricular unit called Covid Connects Us (Get Real! Science 2021). This unit was intentionally designed to nurture a justice-centered classroom culture at the beginning of a school year (Table 3). Originally created by a number of early career teachers in collaboration with the first author in the summer of 2020 during COVID, this unit was further refined through its implementation by the more than 55 project teachers of the JuST Lab. We offer activities from this unit as an extended example of how the JuST-FW can be used to design and enact curricula. In addition to this unit, project teachers used the framework within their PLCs to direct three cycles of action research across each of 2 years of their participation in the project.

3.1 | Covid Connects Us Curricular Overview

It is important to note that the JuST-FW is a tool for planning, implementation, *and* reflection. Though it can guide teachers, it also serves as a valuable lens to see what was not done that could be. Not surprisingly, we learned that the justice-centering of the Covid Connects Us unit could be improved, and we will offer insights of this as examples of using the JuST-FW for reflection are shared.

4 | JuST Core: Cultivating a Justice-Centering Community

The JuST Core, *cultivating a justice-centering community*, anchors the JuST-FW. The JuST Core goal focuses on teachers' work to plan for and nurture a very different kind of classroom community. Essential for the science teaching and learning detailed above but missing from AST, the JuST Core focuses on necessary shifts in the culture of the classroom community that allow for all voices to be heard, respected, and used to shape scientific sensemaking (Kay 2023; McKenna and Michaels 2024) (Figure 5). Seeing and addressing injustices in science classrooms, in the discipline of science, and in society require the practicing of criticality. Looking for and at ways that power shapes science, science education, and society require new questions to be asked, new methods to be used, and new priorities to be established.

For all students, and especially those from traditionally minoritized groups, to trust that their full selves are seen as welcome in schooling requires radical unlearning of traditional ways of being in classrooms (e.g., Klein 2008). This work begins with teachers' vigilance toward their own awareness of injustices and commitment to take action, so that they establish that foundation for their classroom community (Ladson-Billings 1995). The work of JuST Core is to nurture students' confidence that their diverse identities are truly valued, and their investments will not be used to harm them. Students and teachers need to negotiate and co-construct new ways of being and learning together in the classroom where all students want to be and feel that their classroom pursuits are meaningful and important. JuST Core is rooted in Ladson-Billings (1995) critical consciousness. In science education more specifically, a study by Greenberg et al. (2025) identified many such practices that can support a new way of learning together including collaboratively creating learning experiences, fluidly sharing authority, and embracing humanity. These transformational shifts then inform and shape the ways the classroom can work together as a scientific community. We highlight three JuST Core practices that can be used to nurture a justice-centered classroom community of practice.

4.1 | JuST Core Practices

4.1.1 | Practicing Criticality

Justice-centered classrooms intentionally practice criticality with persistence and vigilance. They search for and expose the role of power as it relates to science and science education, within and outside of the classroom (Morales-Doyle 2017). When a teacher positions science, science education, and society as acceptable sites of critique, the classroom community can challenge injustices that, left unchallenged, perpetuate white supremacy, the erasure of non-dominant cultures, and problematic relationships with nature. Teachers and students need time and space to consider the power imbalances inherent in "normal" science, school science, and society. Justice-centering in and through science classrooms involves nurturing students''critical consciousness (Riley 2026) such that they can read the world for injustices, imagine new possibilities for understanding (Torres-Olave et al. 2025), and engaging with their world, and write (right) the world through action (Freire 1970).

As one important site of critique, Bang et al. (2013) powerfully argue the need to critically challenge the nature-culture divide of science, a false assumption that the natural world can be understood as separate from humans' involvement with it. This separation is artificial and has led to troublesome mindsets including the assumption that nature exists to be extracted from for human needs and wants. One especially painful result of this mindset is climate change and the lack of understanding of the damaging human impacts on the earth.

The discipline of science is another important site of critique. Science happens in social, cultural, historical, and political contexts that shape the science that gets done; and the science that is done, in turn, impacts the social, cultural, historical, and political spaces we inhabit. In addition, humans are a part of every system we study. Lemke (2004) highlights the ways science can be blind to the impact of humans as scientists: "Science also sometimes excessively idealizes the systems it studies, nowhere more so than when it forgets to take account that scientists as human beings are necessarily a part of every system of which we can have human knowledge" (p. 34). When science willfully ignores the role of culture, it perpetuates the damaging falsehood that science is "objective," removing opportunities to explore powerful ways science has been and can be influenced by diverse cultures (Thomas et al. 2023).

Thus, nurturing students' critical consciousness, "with critical vigilance and dialogues" (Lemke 2004, 46) can empower them to engage with science and the world with agency. Student

TABLE 3 | An extended example of a unit designed to support teachers in enacting the JuST Framework. To view an earlier version of the detailed lessons in more detail, see Teacher's Corner (https://getrealscience.wixsite.com/covidxus/lesson-plans).

JuST framework	Lesson details: Includes essential questions, justice-centering is bolded
Lesson 1 Who am I? How has who I am impacted my experience with COVID? What can we, as a community, do about its impact?	
JuST Core: Cultivating a justice-centering community JuST 2: Eliciting student ideas about science, culture, and justice	The purpose of this first lesson is to cultivate a justice-centering community (JuST Core) and begin to elicit students' scientific, cultural and justice-oriented ideas about the spread of the COVID-19 pandemic (JuST 2). Community-building through the creation and sharing of identity maps that highlight a range of identities important to each student that, in turn, support discussions of the **value of diversity in shaping scientific wor**k. **The sharing of identity maps can help to create trust needed for students to share more difficult things later on, such as how life has changed for them since the beginning of the COVID or their related perspectives of fairness** (JuST Core). Students are **encouraged to use different/multiple modalities and language**s to construct their maps. During the discussion about their experiences with COVID, teachers attend to and draw out considerations of **science, culture, and/or justice** (JuST 2).
Lesson 2 What do I need in order to protect myself and my communities?	
JuST 1: Planning toward a meaningful purpose that centers justice JuST 2: Eliciting student ideas about science, culture, and justice	The design team collaborated with the county commissioner of Public Health and the city's mayor to create a video to amplify the importance of and power of youth voices and actions (JuST 1). After watching these videos, **students conduct data analysis of COVID cases by zip code in order to create their initial models of how COVID-19 spreads and why there are differential impact on groups of our communities (JuST 2)**. **Students interview their community members on what they think matters in local communities (JuST 2) which will be revisited in Lesson 8.**
Lesson 3 Do masks and social distancing really reduce the spread of COVID-19? Are these protections equally available to our community members? How do different physical distances and mask types compare?	
JuST 2: Eliciting student ideas about science, culture, and justice JuST 3: Nurturing revisions of scientific thinking and feeling with diverse expertise	Students consider whether or not the current "Six-foot distance" public health guideline related to mask-wearing is enough to ensure people's safety, **and whether or not and to what degree, this distance is feasible for all.** Through this discussion, students share their experience with and perspectives on the guideline. Teachers listen to and respond to ideas (JuST 2). **By designing and conducting experiments** on how far respiratory droplets would travel with or without a mask, they see how wearing masks can change the behavior of respiratory droplets. In addition to pressing for an explanation based on the data generated from the investigation, **students discuss why all people were not able to take appropriate measures to protect themselves by factoring in which type of jobs made it hard to take protective measures. (Both social and technical factors connected to lived experiences of community members inform ongoing refinement of explanations and proposed solutions).**
Lesson 4 How can we argue from evidence about the optimal social distancing and mask-wearing guidelines?	
JuST 2: Eliciting student ideas about science, culture, and justice	Students prepare for a debate by gathering evidence for their position related to "A six feet or greater distance is sufficient to not wear a mask in an indoor space" from the Lesson 3 experiments to construct arguments

(Continues)

TABLE 3 | (Continued)

JuST framework	Lesson details: Includes essential questions, justice-centering is bolded
JuST 3: Nurturing revisions of scientific thinking and feeling with diverse expertise	for both sides. **Students also use their lived experience related to how COVID infections were spreading within their communities from what they observed and what other community members shared to support their arguments**. Then we construct an individual argument and communicate it on social media platforms (JuST 3).
Lesson 5 How much influence do I have on my community? How big is my circle really?	
JuST 2: Eliciting student ideas about science, culture, and justice JuST 3: Nurturing revisions of scientific thinking and feeling with diverse expertise	**Students collect and analyze data about how much risk might be associated with their social circles during a pandemic by (1) recording the people they contacted in the past 24 h, and (2) asking those people how many people they've come in contact with in the past 24 h, and (3) documenting the employment of those who they've been in contact with (JuST 3)**. Using this set of data, students individually create a contact tree and have a discussion on how contact tracers can be used to inform policy making. They also **use the data set to understand how it looks differently for different communities. Students learn that sometimes people's professions make them riskier than others (JuST 3)**.
Lesson 6 How can we inform our communities of the accurate information about this pandemic?	
JuST 3: Nurturing revisions of scientific thinking and feeling with diverse expertise JuST 4: Using science to make a difference and advocate for justice	Students work alongside local physicians who serve as mentors in this unit. **Students integrate what they learned from their science class in partnership with local physician mentors (JuST 3) to address their communities' needs by creating 'breaking news videos' (JuST 4)**. They realize how **messages about COVID have changed since the pandemic started and understand that science can and will change** (JuST 3). The "breaking news" is **shared with families, community members, and a broader audience on social media** (JuST 4).
Lesson 7 How can we show what we have learned about how COVID affects our community?	
JuST 3: Nurturing revisions of scientific thinking and feeling with diverse expertise JuST 4: Using science to make a difference and advocate for justice	Students refine their initial models of COVID-19 (from Lesson 2) to include **explanations of how these ideas live within and impact their unique communities** (JuST 3). They **detail actions they can take to protect themselves and their communities** (JuST 4).
Lesson 8 How can we enact positive change in our community?	
JuST 4: Using science to make a difference and advocate for justice	Employing our knowledge of our communities, local culture and COVID-19, students **create a proposal for reopening a place or "regathering" of a particular kind in that place** (JuST 4).

agency can support the building of a community of learners like those Freire (1970) challenges us to realize, one in which teachers take on the role of learners of their students, and students take up the role of teachers. Ultimately, JuST practice grounded in JuST Core can help develop youth as "transformative intellectuals" (Morales-Doyle 2017, 1034), those who are recognized as competent in science and use that science to make a difference. This justice-centering teaching involves practicing vulnerability that can grow from the nurturing and maintenance of a welcoming community in which all are seen and valued.

4.1.2 | Challenging Classroom Cultural Assumptions

A second JuST Core practice involves *challenging classroom cultural assumptions* in order to nurture a sense of belonging that eludes many students, especially those from marginalized communities (Warren et al. 2001). Justice-centered classroom community-building involves seeing and calling out these taken-for-granted ways of being in classrooms as limited and problematic. This realization is the precursor to the imagination and adoption of new priorities and ways of being together that are more humanizing and culturally pluralistic. Challenging perceptions of the teacher as the sole expert can disrupt power

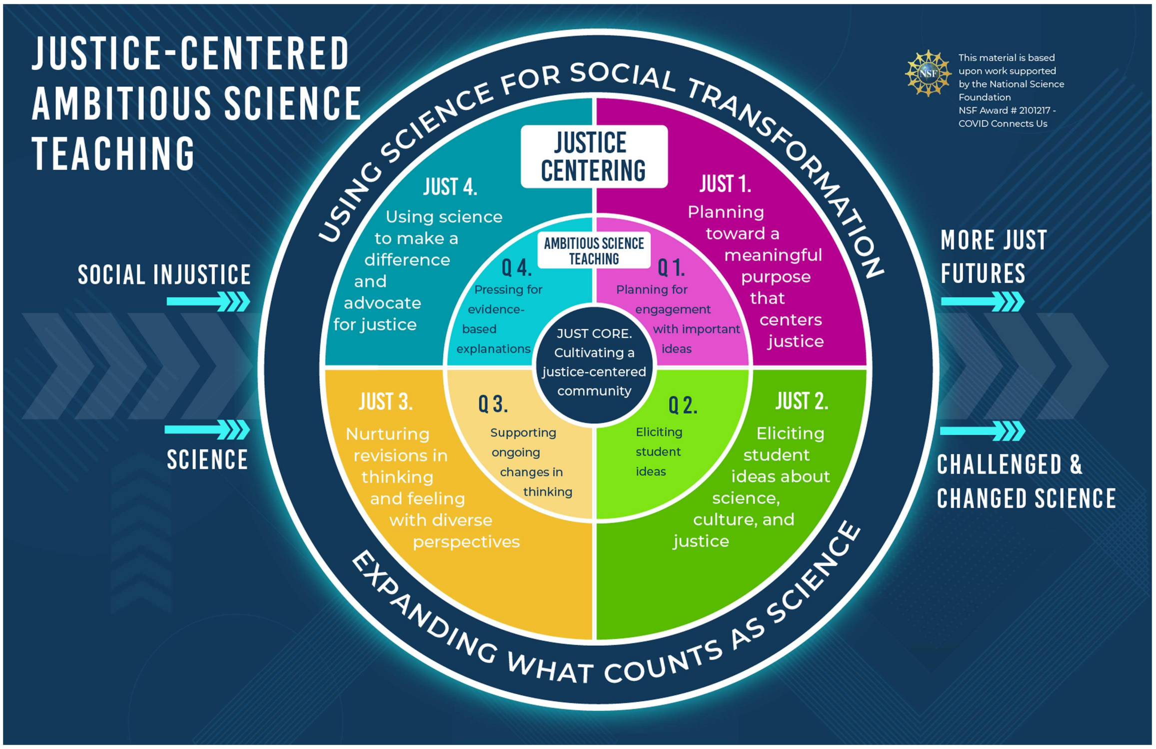

FIGURE 5 | Full Justice-centered ambitious Science Teaching Framework.

hierarchies (Greenberg et al. 2025; Kang and Nation 2023), opening possibilities for multiplicity (Warren et al. 2020), expanding what it means to be "good at science." A sense of belonging is something lived in relationships each day and overtime (El Halwany and Adams 2026), and thus something that requires nurturing, attention, and prioritization (Kay 2023). Investing time in building relationships within the class community leads to not only more productive learning (Kang 2022) but is a necessary prerequisite to engaging in explicitly anti-oppressive work within the classroom setting (Darling-Hammond 2017; Kang and Nation 2023; Suárez and Krist 2023).

As justice-centered science learning can elicit its own range of emotions, centering relationships to build a welcoming community calls out a particularly essential emotion, joy. Youth and teachers need opportunities to laugh and enjoy their time together. This is especially true when learning about injustice and power, as this work can raise feelings of grief, anger, and hopelessness. Experiencing joy in the classroom can be a social justice measure in itself (Jaber and Hammer 2016; Scipio et al. 2026; Soutter 2020). For authors like Gay (2023) and Lorde (2004), joy builds bridges across difference and remains an essential element of building solidarity. When educators prioritize joy in their classrooms, they deepen commitments to building the types of communities where learning and learners can thrive (Ryoo 2019). Muhammad (2023) stance is that "joy is the ultimate goal of teaching and learning, not test prep or graduation," defining joy as "helping students to uplift beauty, aesthetics, truth, ease, wonder, wellness, solutions to the problems of the world, and personal fulfillment" (p. 17). While Muhammad's context is the humanities, this vision shapes a cross-disciplinary set of goals that must also be present within a science classroom to enable the kinds of consequential learning we care about (Adams 2022; Riley and Mensah 2023). Preparing educators to create teaching and learning environments that prioritize joy is an essential part of the ongoing work of nurturing anticipation in science education as a core focus of our work. Specifically, pedagogies of joy demonstrate ways to lean into moments of joy within curricular design, assignments, and ongoing classroom engagements with youth (Luehmann and Wilson 2025). Ultimately, joy-filled classroom spaces prioritize meaningful engagement and well-being for educators and youth.

4.1.3 | *Functioning as a Scientific Community*

Science classrooms have been and continue to be shaped by white supremacy norms (Medin and Bang 2014; Le and Matias 2019; Mensah and Jackson 2018; Okun 2025) such as prioritizing the written word overall forms of communication, individualism over collaboration, or being driven by a sense of urgency or perfectionism (Okun 2025). These attributes conflict with scientific ways of being. Bob Tinker (1997) wrote about the science that students see in typical classroom labs this way:

> *The careful procedures, the concern for safety, and the general atmosphere that penalizes mistakes all mitigate against questioning, risk-taking, thinking, and learning. It is as though both teachers and students subscribe to a mechanistic model of learning which posits that going through certain steps without thinking will somehow magically result in learning. This is antithetical to all science is about.*
>
> (p. 3)

Scientific communities work collaboratively and creatively, engage with everyday language and a range of semiotic resources for sensemaking toward a particular purpose of importance, and as noted in the prior section, share a full range of emotions as they engage in different aspects of coming to understand together (Heath 2001; Lemke 2004; Warren et al. 2001). Functioning as a scientific community includes informal practices such as using everyday language, gestures, and onomatopoeia in sensemaking, and engaging in active listening and organic conversation in order to co-construct explanations as a class (vs. only as individuals), as well as more formal practices such as those defined by NGSS as practices (e.g., modeling, argumentation, and constructing explanations).

One aim of science education is for students to better understand how scientific knowledge is generated and how it can be both trustworthy and tentative (National Science Teaching Association 2020). Sandoval (2005) outlined four core understandings about science and why they are important to understand:

1. Science is constructed by people, not simply discovered somewhere out in the world.
2. Scientific methods are diverse, for example, experiments are conducted in some fields and not in others. No one method can be considered "scientific." Rather than relying on method(s), students need to understand the fit between observations, methods for obtaining them, and the corresponding knowledge claims.
3. Scientific knowledge comes in different forms that vary in explanatory and predictive power, varying in their explanatory or predictive power and in their relation to the observable world.
4. Scientific knowledge varies in certainty. Based on the recognition that current scientific ideas may change as new observations or new, competing ideas come to light. Scientific knowledge needs to be evaluated based on epistemological criteria (pp. 639–641).

Engaging students as a scientific community pursuing authentic problems offers students opportunities to experience and reflect on these elements.

More specifically, to experience and better understand these aspects of science, Duschl and Grandy (2013) argue for the importance of students "being immersed in the cognitive, epistemic and social enactments and practices of science that involve building and refining questions, measurements, representations, models and explanations" (p. 2126) in order for students to better how science is done. Nurturing more nuanced understandings of science through these experiences as a sensemaking community naturally invites students to challenge stereotypes about science that are inaccurate, unappealing and exclusionary.

4.2 | JuST Core Example

The first lesson of the Covid Connects Us unit (Table 3) is designed to begin the work of the JuST Core. Beginning with the scientists in the classroom, the aim of this lesson is to honor students as fully human with diverse interests, experiences, and skills. Students are introduced to "identity mapping" by creating one for Mae Jemison, an American engineer, physician, and former NASA astronaut, the first African American woman to travel into space in 1992 (Creasman 1997). Demonstrating her many and diverse identities, Dr. Jemison described the items she carried with her on her mission to space:

> *An Alvin Ailey American Dance Theater poster, an Alpha Kappa banner, a flag that had flown over the Organization of African Unity, and proclamation from Chicago's DuSable Museum of African American History and the Chicago public school system. I wanted everyone to know that space belongs to all of us. There is science in dance and art in science. It belongs to everyone.*
>
> (Giovanni 1993)

After viewing a short video about the life of Mae Jemison (not just her scientific accomplishments), students create a visual representation of her many identities, including dancer, African American, Chicago public school student, and daughter of a contractor and schoolteacher. This expansive consideration of a well-known scientist explicitly honors her full humanity.

After exploring the ways Dr. Jemison's various identities may have shaped the science she did, students then turn the lens inward and create their own identity map. Teachers provide students with exemplars and scaffolds to help them expand their thinking about what types of identities are welcome in the science classroom (see Figure 6). After individually considering how their varied identities could be assets in a science classroom, students co-construct a class identity map, highlighting the diverse strengths that make up this particular scientific community. Artistic and creative in nature, student-driven by design, identity mapping represents a dramatic shift from the "go over the syllabus" typical first day of class. Students begin to realize that the uniqueness of each student is valued in the community and as important to the scientific thinking that can be done. In addition, teachers have a lens into the identities that matter most to individual students they can use in future unit planning in order to create experiences and foci that are meaningful to youth. Even when project teachers decided to stop using Covid Connects Us as their introductory unit, they continued to engage their students in identity mapping on the first days of school because of its usefulness and impact for culture setting.

The set of JuST Core practices lay the foundation for and intersect with all other science teaching practices (including planning and implementation), within a unit, across the entire school year, and perhaps beyond. A justice-centered classroom community is further developed and reinforced through both routine and criticality focused norms, activities, and lessons.

5 | JuST 1: Planning Toward a Meaningful Purpose That Centers Justice

The goal of JuST 1 is to intentionally plan a unit with the uniqueness of one's students and a commitment to justice in mind, integrated with science ideas and practices (JuST 1, Figure 5). NGSS (2013) calls for science teachers to braid three dimensions of science: disciplinary core ideas, science and engineering practices, and cross-cutting concepts. AST takes up that charge in its first set of core practices focused on the goal of planning for students' engagement with important science ideas, supporting teachers in identifying and prioritizing the science

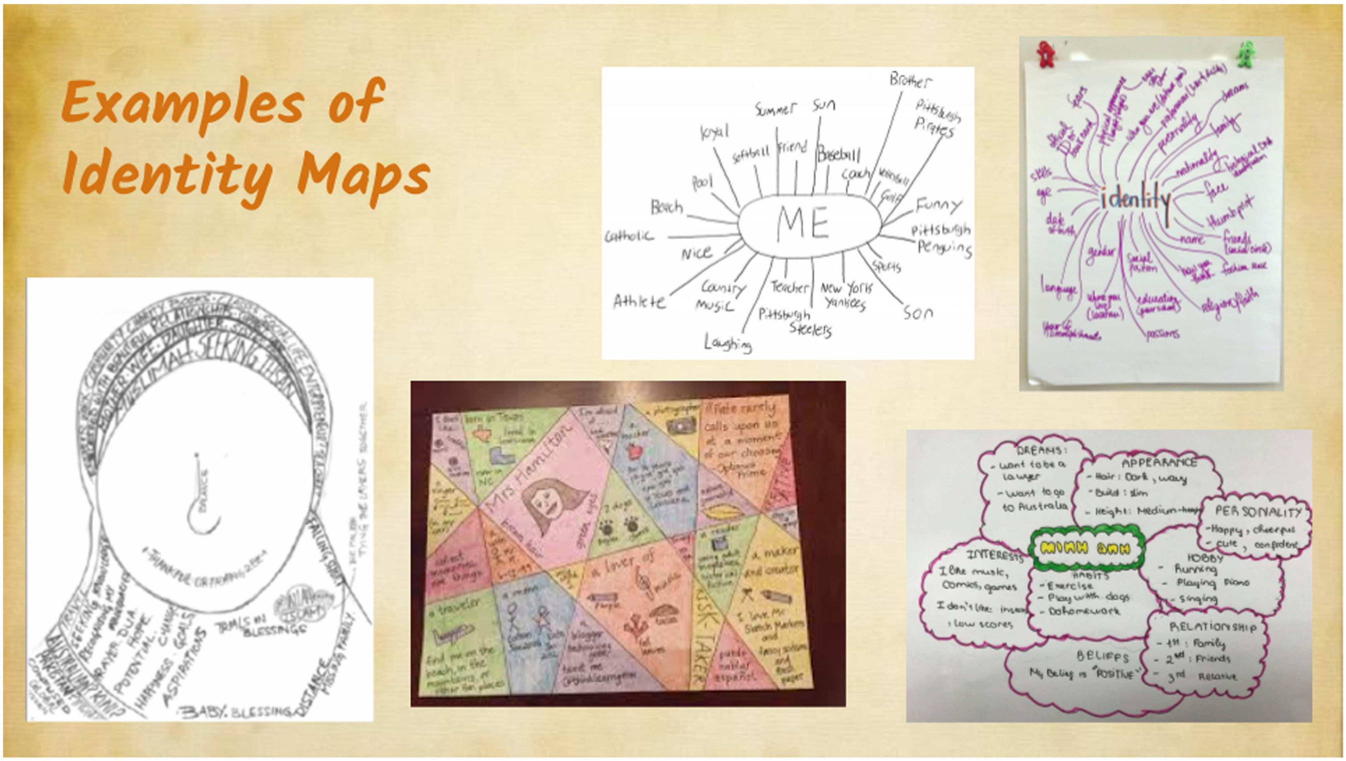

FIGURE 6 | Sample identity maps teachers share with their students.

concepts that have the most explanatory power. Building onto that work, the JuST-FW also reminds us that the three dimensions of science identified in the NGSS occur within cultural contexts that shape them, and these contexts are imbued with and shaped by power in inequitable ways that must be confronted (National Research Council 2012; Nasir et al. 2021).

Choosing a purpose for students' engagement with scientific phenomena that is meaningful to the particular students in the room offers important motivation and connection points for their individual and collective sensemaking (Kang and Nation 2023; Ladson-Billings 2017). Note that being relevant to youth is not the same as being meaningful to youth. Meaningful learning goes beyond connecting to youth interests broadly; meaningful learning implies a sense of importance for the work, a reason that the science (and other ideas) needs to be learned and used. To nurture a sense of purpose, these planning practices require cultural competence (Ladson-Billings 1995) and humility. Planning for students' use of science for transformative purposes can provide them with opportunities to address oppression (Santos 2009; Gutiérrez 2007; Morales-Doyle 2017). Thus, justice-centered planning requires teachers to engage in practices beyond constructing or revising a traditional curriculum; justice-centered ambitious science planning requires integrating science education and social justice aims through planning efforts. In the next section, we describe three core practices for JuST 1.

5.1 | JuST 1 Planning Practices

5.1.1 | *Collaborating With Community*

One JuST Planning practice includes and adds to the foundational AST 1 practices of identifying core science ideas, selecting an anchoring event and driving question for the unit, and sequencing learning activities to construct a scientific storyline (Windschitl et al. 2018). JuST 1, *collaborating with community* to center one's students extends AST 1 practices by more closely attending to, learning about, and integrating students' cultural learning resources including people, places, and priorities (Table 2). Learning from and with community, in turn, allows teachers to develop more nuanced and situated understandings of their students (Cooper 2007). This collaboration in service of justice requires care, humility, intentionality, and time:

> *Partnering for justice in and through science education must be a conversation, a work in progress, and a critical examination that leads to intentional and careful forward movement. It must involve a willingness to make mistakes with an acute awareness of potential harm we could cause along with a commitment to correct mistakes with authentic care for those who have been harmed in the past. It must involve a love for science partnered with an anger for the damage done to human and more-than-human others we care about. Partnering for justice in and through science education is a commitment to something that is evolving as we seek to understand epistemic plurality in local places and cultures.*
>
> (Luehmann 2022, 1347)

Pitching possible anchoring phenomena and lesson ideas to a small group of parents, teachers, businesspeople, school board members and youth can reveal many potential connection points that could matter to youth (Luehmann et al. 2024). Community-led asset-based neighborhood walks could reveal other connection points (Thompson et al. 2020). Some of the objectives for these teacher-community member relationships are to (a) identify sources of nontraditional expertise that could elevate and sustain local culture, support student engagement and learning, and serve as cultural translators for teachers (Bouillion and Gomez 2001); (b) understand ways local places link science objectives with community histories, cultures, and priorities (Morales-Doyle 2017; Semken and Freeman 2008); (c) learn about the unique composition of the students who will be in the room, attending intentional attention to race, language, and identities (Kang et al. 2023); and (d) nurture ongoing relationships with these community members to be mutual support for one another over time (Cuban 1969; Zeichner et al. 2016). Note that when we use the term, "nontraditional" in this manuscript, we are referring to insights, sensemaking practices, and scientific understandings that, though rich in instructional potential, are rarely elevated as "scientific" in classrooms. With this definition, "nontraditional" includes, among other sources and forms of expertise, the use of gestures, onomatopoeias, emotions, and language other than English as useful communication and sensemaking resources (e.g., Suárez and Otero 2024), local community members' including family expertise (e.g., Luehmann et al. 2024), and Indigenous ways of understanding our world that teach us to center ecological ways of knowing over a focus on an individual organism (e.g., Bang et al. 2013). In our work, meetings and relationships with community members have resulted in all of the aforementioned outcomes (Luehmann et al. 2024). They have helped us learn about beekeeper suits that youth can try on when studying pollinators, local debates regarding ways to address recent flooding, ways a school board member-farmer uses genetic engineering on his apple tree farm, and the community's struggle to understand how electric chargers benefit those beyond electric car owners.

5.1.2 | *Interrogating the Role of Power and Justice*

According to Ladson-Billings (1995), teachers "must help students to recognize, understand, and critique current social inequities" (p. 476), which means that JuST teachers must do the same. Thus, this second JuST Planning practice challenges teachers to interrogate their emergent thinking and curricular ideas for equity and justice, specifically identifying ways power has or continues to benefit some at the detriment of others. Relevant injustices exist in how particular scientific understandings have come to be accepted, as well as ways science can understand and redress injustices such as environmental racism of the Flint water crisis (Hansson and Yacoubian 2020). JuST planning requires the ongoing development of teachers' critical consciousness in order to identify intersections of science and power imbalances. This planning work may include considering current events with an investigative and critical lens for considering the ways power is at play. Mainstream media does not typically report on the root cause of injustices (Atton 2002). JuST planning requires teachers to attend to larger systems and the way injustice shows up. Connecting science to a real-world injustice can offer purpose to students' learning (Santos 2009; Morales-Doyle 2017). We include the core practices of AST into the JuST-FW but warn readers of potential conflicts between the two frameworks. For example, when planning for a unit, the teacher authors a "gapless explanation" that synthesizes core science concepts to explain the scientific phenomenon. Though valuable in supporting teachers' development of relevant background knowledge and identifying possible pathways students might follow, without teachers' critical attention, a gapless explanation can serve to privilege Western, canonical knowledge. It is important that all practices align with the two transformational aims of expanding what counts as science and using science for social transformation. In order to create a causal explanation of a scientific phenomenon that includes potential injustices, JuST teachers may need additional content knowledge or historical understanding to connect NGSS with systems of power (Crabtree and Stephan 2023). Such interrogation also includes learning about the ways that the community is thriving and resilient despite historic and modern oppression (Luehmann et al. 2024).

5.1.3 | *Planning for Students to Take Action With Science*

A third JuST Planning practice involves *planning for students to take action with science* in ways that matters to them. Here, again, we take up mattering (Kang and Nation 2023) and relevance (Ladson-Billings 1995) to mean more than just connecting to youth's general interests or hobbies. Rather, mattering means learning experiences that are personal to the specific students in the room and the people they care about. Planning for students to use science for a purpose outside of the classroom involves designing performance-based assessments for an authentic audience, creating artifacts to demonstrate one's three-dimensional science learning to address a need or problem.

This type of assessment can nurture student motivation far beyond learning for the sake of a grade in a class. Establishing a purpose that uses science to address injustice in the world can support students in nurturing identities as change makers that simultaneously nurtures a sense of pride and care for their communities (local or global). They can also develop a more nuanced understanding of the important but limited role science can play in righting wrongs. Morales-Doyle (2017) highlights the powerful impacts of engaging his advanced chemistry students in using their science in service of community-identified social and environmental justice issues:

> *The findings include evidence that curriculum organized around an issue of environmental racism supported academic achievement that exceeded the expectations of a typical high school chemistry course... As transformative intellectuals, students demonstrated complex thinking about science and social justice issues, cultivated their commitment to their communities and cultures of origin, and developed credibility as local youth knowledgeable in science.*
>
> (p. 1034)

In another context studied by Luehmann and Wilson 2025; under review), girls from minoritized groups engaged in afterschool film making projects took up central roles in STEM to make a positive difference in their lives and communities. One team's documentary film investigated the abnormal intensity of teen depression that they and their peers experience at their underserved high school, ultimately providing viewers with science-based, positive coping strategies and a clear message that "you are not alone." The project afforded youth the opportunity to integrate scientific knowledge with their own cultural repertoires which resulted in both the creation of trustworthy science and the affirmation of their own rightful place in science.

When students use science to take action on identified injustices such as exposing environmental racism or tackling teen depression, they develop critical science agency that has been shown to be especially important to marginalized youth (Clark 2024; Diemer et al. 2021; El-Amin et al. 2017; Morales-Doyle 2017; Tan and Barton 2023). Students feel empowered when they can take action that matters to them and their communities (Dimick 2012) and this empowerment can, in turn, nurture academic achievement (e.g., El-Amin et al. 2017; Morales-Doyle 2017). Being aware of injustice and identifying potential ways for students to take action are part of a teacher's ongoing development of critical and sociopolitical consciousness.

In summary, the first quadrant of the JuST-FW offers teachers practices for planning phenomenon-driven scientific units for a purpose that students could find to be meaningful. Partnering with and learning from local stakeholders can serve as relational bridges between students' home and school cultures. Given that racism and other hegemonic realities are part of our everyday taken-for-granted realities in the United States, using science to identify and address social injustice requires teacher intentionality in planning.

5.2 | JuST 1 Planning Example

Planning for a JuST unit requires more of teachers than a deep understanding of science content and ideas about how concepts might be grouped in service of an explanation of a scientific phenomenon. They also need meaningful understandings of students and their communities and critical understandings of the ways in which power intersects with the scientific phenomenon in just and unjust ways. Planning for the first iteration of the Covid Connects Us centered on using the existing current event of Covid-19 that we were all experiencing as the anchoring phenomenon. Intended to be used as the first unit of the school year, this unit was designed to support the teacher in establishing a justice-centered and ambitious learning culture. The curriculum was "ambitious" as it engaged students in collaborative sensemaking through engagement in all eight NGSS scientific practices to figure out and synthesize concepts such as particle motion and kinetic energy, surface interactions, and systems interactions. To launch the unit, we invited the city's mayor and public health commissioner to create videos highlighting the unique and important role youth play in linking science classrooms with their communities, especially at such an important time (Get Real! Science 2021). We also partnered classrooms with local "medical mentors," physicians who students interviewed about the changing understandings of Covid and their implications for public safety. To better understand how varied students' communities were experiencing the pandemic, we sought out data repositories for Covid case data including corresponding demographics. These data revealed important injustices about the experiences of frontline workers, those living in close quarters with others such as multigeneration homes, and people of Color living in historically redlined areas. Wanting to create a place where students could discuss inequities including those stemming from racism, we chose the unit's driving question, "Why are people of Color disproportionately impacted by Covid, and what can we as a community do about it?" This question implied from the beginning that the science we learned during this unit would be used for more than a grade in science class; it would be used to advocate for more just futures. With these foundational decisions in place, we used the following AST practices, but in explicitly justice-centering ways:

- We authored a gapless explanation of the scientific phenomenon that included relevant injustices of how and why this phenomenon was being experienced. This gapless explanation required a shift from AST to include both science and relevant social justice considerations.
- We created a model scaffold for students and a final example model with space for representing and connecting the unobservable processes of the spread and impact of Covid-19 as well as space to represent, connect, and explain the justice aspects of the phenomenon.
- We created an activity summary table of diverse student investigations, the sum total of which are designed to create a storyline (Reiser et al. 2021) that explained the phenomenon and answered the driving question. Included in this storyline were activities that would engage students in figuring out both science and related social justice issues. The final column of this table served as the checklist of elements that would be co-constructed with students across the unit that they would be expected to include in their final models.

In addition to the unit planning, it was also important to anticipate and plan for conversations about potentially sensitive topics as well as a shift toward working as a community instead of a group of individuals. In planning particular lessons, we integrated opportunities for students to process emotions individually before collectively (always providing the choice to opt out of sharing). Science circles were planned in order to nurture active and empathetic listening and collect class level data for analyses.

Though much of JuST Planning is done in advance of a unit, it continues throughout the lessons as teachers adjust be responsive to student interests and needs as they implement the unit. In addition, the JuST planning practices used to meet the JuST 1 goal of "planning toward a meaningful purpose that centers justice" span units as teachers nurture new and ongoing relationships with community members, deeper understandings of the intersections of science and justice, and concrete, often local, visions of change efforts students could engage with.

6 | JuST 2: Eliciting Student Ideas About Science, Culture, and Justice

The goal of JuST Eliciting is to launch a given unit in intentionally expansive ways that position teachers as learners of their students' experiences, priorities, cultures and sensemaking repertoires along with their current understandings of science and justice (JuST 2 of Figure 5). The lessons teachers learn as students make their thinking visible through the set of JuST 2 practices will be instrumental to their future framing and support of student learning. Including and building on AST's goal of eliciting students' individual and collective thinking about preliminary science ideas (Windschitl et al. 2018), JuST 2 seeks to draw out more than students' science ideas to include the cultural contexts in which they have experienced that science. Students' stories, as insights into their personal and heritage cultures and priorities, serve as a means for teachers to learn from students about how they understand the world as well as for students to identify relevant experiences they can draw from during the unit. The set of JuST Eliciting practices explicitly appreciates and sustains local cultures (Bang et al. 2017; Paris and Alim 2017; Wong 2019) as the classroom community seeks out, benefits from, and explicitly values the diversity of resources in the room. In this way, teachers, especially those not from the community they serve, can develop textured understandings of students' experiences (Swindler Boutte and Hill 2006; Wong 2019). To that end, JuST teachers stay attuned to students' cultural connections and record those alongside initial science ideas related to the phenomenon.

Signaling that addressing injustices is a goal for science learning, JuST 2 also involves beginning to interrogate the anchoring phenomenon for student understandings of the roles power and justice might play. Teachers and students alike, then, can continue to use what students share as steppingstones to shape future interactions and conversations in ways that are locally situated, student-informed, and justice-focused (Paris and Alim 2017).

6.1 | JuST 2 Eliciting Practices

6.1.1 | Eliciting Nontraditional Ways of Thinking and Engaging With Science

JuST Eliciting practices include and build on AST's core practices of eliciting students' knowledge of an anchoring phenomenon, representing beginning science ideas publicly, and crafting initial models. In addition, JuST Eliciting practices involve launching a unit in ways that make space for student stories that often make visible cultural cues, contexts, and priorities. To effectively draw out students' scientific understandings *and* related experiences, JuST 2 involves *eliciting students' nontraditional ways of thinking and engaging with science*, inviting them to be transparent about not only *what* they understand but also *how* they have come to know these things. Students are welcome to share these ideas and experiences in ways that feel most natural and comfortable to them. Students are encouraged to take up the role of teacher to introduce the classroom community to ways they experienced something similar to the anchoring phenomenon in their own lives.

Any activity has the potential to differently open up or close down contributions and conversations (Brown et al. 1989; Nasir and Hand 2008; Warren and Rosebery 2011). This first JuST Eliciting practice involves creating opportunities to draw out diverse students' cultural as well as scientific connections with the phenomenon. This practice legitimizes students' everyday ways of communicating as valid and essential scientific sensemaking tools, offering youth numerous access points to science concepts that will eventually be communicated in more formal scientific registers (Grapin et al. 2023; Suárez and Otero 2024). Some activities that invite students to tap into local knowledge and personal experiences include physically creating and building (e.g., Luehmann et al. 2024; Voussoughi and Bevan 2014), collecting and sharing photographs related to a theme (Cook 2015), or analyzing local data or news articles (e.g., Lisy 2023; Mensah 2011). Capitalizing on what is shared, teachers are given opportunities to foreground the importance of diverse voices in science rather than unconsciously erasing or invisiblizing them. In contrast to the AST 2 tool, the rapid survey of student thinking (RSST), where teachers look for students' initial partial understandings (sometimes named with a deficit framing as misconceptions), this JuST 2 practice calls for teachers to identify students' assets.

As teachers seek to invite student sharing, which is a form of intellectual risk taking, it is important to note the special power teachers hold to honor or dismiss, value or diminish, build on or ignore student contributions. Interpretive power, as defined by Rosebery et al. (2016), is the work to:

> *...cultivate their [teachers'] attention to students' diverse sense-making repertoires as intellectually generative in science learning and teaching (Rosebery and Warren 2008; Warren and Rosebery 2011)....[and involves] two core dimensions, ... namely, teachers' attunement to the forms and functions of (a) students' wide-ranging sense-making repertoires as generative intellectual resources in science learning and teaching, and (b) expansive pedagogical practices that encourage, make visible, and intentionally build on students' ideas, experiences, questions, and perspectives on scientific phenomena.*
>
> (p. 1572)

The dangerous potential of the opposite use of interpretive power is also true: teachers could judge ideas as "off track" or "disruptive" (Bang et al. 2017; Warren and Rosebery 2011). JuST Eliciting explicitly calls for teachers to use their very impactful power to promote equity. It is important to recognize that teachers can foster or limit student contributions through their verbal *and* nonverbal reactions. Using interpretive power for equity, and therefore justice, means deliberately elevating ideas from students who come from marginalized backgrounds. This practice may require spending extra time to understand and validate students' ideas.

6.1.2 | Ensuring the Presence of Diverse Perspectives

Another and related JuST Eliciting practice involves explicitly *ensuring the presence of diverse perspectives* as parts of a rich repository of knowledge and experiences available for the class to learn and think with. More than inviting and validating contributions from students who come from marginalized backgrounds, this practice requires teachers to underscore how diverse sensemaking repertoires are generative for collective student sensemaking and learning (Fehr 2011; Phillips 2014; Rosebery et al. 2016). When classrooms are relatively homogenous and come primarily from culturally privileged backgrounds, teachers may need to introduce diversity in viewpoints, practices, and understandings in ways other than student sharing. These perspectives could be presented through case studies (e.g., Wong et al. 2022), debates (e.g., Soysal 2024), or perspective-taking (e.g., Kahn and Zeidler 2019) activities like the one described next.

An example of introducing science students to new ways of seeing and being is a lesson designed by Déana Scipio and Priya Pugh in their unit learning context of Islandwood environmental center. This lesson called "Perspective Taking" involves a scaffolded approach to take on the perspectives of a more-than-human-other, what many would call something other than human, living or non-living. Examples include a leaf, caterpillar, water, or tree. After considering what lives above, below and beside the more-than-human-other, the student considers relationships with others. Students construct a "Who am I?" poem for their peers to highlight these perspectives. Following this conversation, students consider why Indigenous scholars urged us to stop using the pronoun "it" to refer to these more-than-human-others (i.e., "ditch the it,"); instead use the pronouns they, she or he to honor their importance and relationships to humans as "kin" (e.g., Kimmerer 2013). New to many students, this diverse lens offers transformational potential for studying science concepts in more relational ways.

6.1.3 | *Drawing Out Students' Thinking About Justice*

A third JuST Eliciting practice calls for *drawing out students' thinking about justice*. Scientific phenomena occur within cultural contexts imbued with power imbalances. As JuST Eliciting is focused on opening up important questions to be explored, a JuST anchoring phenomenon routine (see pp. 207–209, Penuel and Watkins 2019) holds the potential to ask direct justice-related questions, such as "Do all benefit equally from this phenomenon?" "Do the people who pay the price for this phenomenon also reap the benefits?" Practicing one's ability to notice and describe the roles power plays in how scientific phenomena are experienced by humans *and* more than human others (Nxumalo and Pacini-Ketchabaw 2017) nurtures critical consciousness and motivation to make the world more just. Students' personal experiences, when shared in a safe environment, can offer a powerful starting point to examine injustice (Griffin and Ouellett 2007; Storms 2012) and a way to connect abstract concepts with one's life (Adams et al. 2007). Students can collectively begin to interrogate components of the social reality in which an anchoring phenomenon exists, signaling to students that science cannot be divorced from the social context in which it happens.

In summary, JuST Eliciting practices extend the work of eliciting students' science ideas to include the cultural contexts in which they have come to develop these ideas. In this way, a teacher can both garner a fuller sense of each student's mental models and draw out more connection points and shared understandings among peers, resulting in a rich collection of ideas as sensemaking resources for the rest of the unit (Gray et al. 2022). Equally important, JuST Eliciting involves drawing out students' initial ideas about related injustices. Similar to and connected to the science ideas, students' prior experiences and understandings of injustices become resources for class-level meaning-making and action as well as resources for connected and responsive further instruction.

6.2 | JuST 2 Eliciting Example

Following the identity mapping lesson described above, the launch to the Covid Connects Us unit's anchoring phenomenon is a zip code data analysis activity. Students are provided with Covid case data along with corresponding race and class for local urban, rural, and suburban communities. Local counties are initially deidentified, and students are encouraged to notice and wonder about patterns they see in the data. As the lesson continues, students guess which county aligns with which set of data, leading to initial explanations for why Covid cases might be higher in some areas than others. This activity provides the first opportunity to support students in considering the roles of systemic injustices while seeking to empathize with lives other than one's own (e.g., cultural practices of multi-generational living, various reasons for working in "first responder" jobs, cultural distrust of medical recommendations). The result of this unit launch is the development of a list of student questions that will be used to drive the unit as well as an agreed upon unit driving question, "Why are people of Color disproportionately impacted by Covid, and what can we as a community do about it?"

Note that learning about students' ideas, experiences and wonderings about the science and justice of Covid continues throughout the unit. It is not complete after the unit's launch lesson. More questions will be revealed through a student debate regarding the mandate to maintain six-foot distance that happens in Lesson 4, as well as when students conduct and share "contact trees" of their own social circles in Lesson 5. The meaningfulness of this anchoring phenomenon nurtures personal connections throughout the lessons of the unit.

7 | JuST 3: Nurturing Revisions in Thinking and Feeling With Diverse Perspectives

Also located in the bottom hemisphere of the JuST-FW, the goal of JuST 3 is to *nurture revisions of scientific thinking and feeling with diverse expertise* with attention and appreciation for diversity similar to JuST 2 (Quadrant 3, Figure 5). This quadrant focuses on the bulk of the work students and teachers do together during science class, including providing students new experiences that prompt their revisions of thinking over time. Students engage in science and engineering practices to explore core science concepts that contribute to an explanation of the anchoring phenomenon (e.g., Penuel et al. 2022). Supporting on-going changes in student thinking, AST 3 aims to replace disconnected, topic-based study typical in many science classrooms (Windschitl et al. 2018).

JuST Revising practices support students in desettling problematic assumptions about what science is, how it is done, and by whom in order to expand what scientific sensemaking can entail (Bang et al. 2013). As one example, what role do emotions play in the doing of science? Jaber and Hammer (2016) offer compelling arguments that feeling a wide range of emotions is integral to the doing of science, and therefore students need to experience the affective work of doing science and value these feelings as scientific. In addition, what questions are considered "scientific" and how do/should they link to broader questions of fairness? For example, who pays the greatest price for the raw materials used for fireworks? Tolbert and Azarmandi (2025) highlight the empowering perspectives and agency afforded learners when they are invited to take up a critical lens of responsibly engaging with science:

> *When students are critical interlocutors of science, they learn not only about scientific facts and theories, but they also learn about affordances and limitations of science, the intersections with heteropatriarchy, colonialism, and racism, and the inevitable muckiness of doing science (Krishnamoorthy and Tolbert 2022; Liboiron 2021). As critical interlocutors, they learn to stay with the trouble of science as part of what it means to do more respons-able science, thereby reshaping what is possible and doable and perceptible in (school) science (Haraway 2016; Tolbert 2019; Tolbert and Bazzul 2020).*
>
> (p. 256)

As teachers expose students to established understandings in science and the methods by which we have come to accept these understandings, a parallel conversation focuses on ways in which the dominant culture has elevated particular methods and understandings at the expense of others.

7.1 | JuST 3 Revising Practices

7.1.1 | Integrating Nontraditional Forms of Scientific Expertise

As students engage in authentic science and engineering practices, the practices in the JuST-FW intentionally ask students to challenge and extend traditional Eurocentric and hegemonic versions of science by exploring and *integrating nontraditional forms of expertise*, thus expanding who counts as having scientific expertise (Bang et al. 2012) (Table 2). Leaning on diverse, previously marginalized forms of expertise and expression challenges stereotypes of where scientific expertise lives and what it looks like. An important example is how Indigenous knowledge is honored and included in science classrooms. Snively and Corsiglia (2001), back in 2001, highlight the importance of including Traditional Ecological Knowledge (TEK) in the science classroom:

> *Especially during the last 25 years, biologists, ecologists, botanists, geologists, climatologists, astronomers, agriculturists, pharmacologists, and related working scientists have labored to develop approaches that are improving our ability to under- stand and mitigate the impact of human activity upon the environment... Because TEK is being used by scientists to solve important biological and ecological problems and because problems of sustainability are pervasive and of very high interest to students and others, it becomes increasingly important for science educators to introduce students to the perspectives of both WMS [western modern science] and TEK.*
>
> (p. 8)

Bang et al. (2017) also highlight the importance of including Indigenous science as a complement to traditional classifications of classroom sciences. Leaning on Indigenous priorities of relationships, responsibilities, and reciprocity are necessary to prepare youth to understand and address challenges related to sustainability and climate change.

Scientific expertise that exists in students' close communities often goes unrecognized. When identified and invited into the classroom, community members can legitimize new ways of being scientific, and in so doing, shape the culture of science for that community of young scientists (Luehmann 2007; Carlone and Johnson 2007). For example, in our work, after a local farmer shared her perspectives on the implications of soil composition for growing "good" versus "great" strawberries, a teacher helped students select soil samples to test the chemical soil composition in the classroom (Luehmann et al. 2024). Students and this farmer, herself then saw this familiar community member in a whole new light—as a practicing scientist with significant and relevant expertise. This type of experience can provide an opportunity to contest limited and problematic notions of what counts as science and who counts as scientist thus challenging toxic systems that marginalized scientists are forced to navigate (Carlone 2003).

7.1.2 | Recognizing and Encouraging Students' Full Range of Sensemaking Tools

Another JuST Revising practice is *recognizing and encouraging students' full range of sensemaking tools*. When allowed and encouraged, braiding youth culture with science culture through translanguaging for sensemaking (Suárez and Otero 2024) can result in deeper scientific understandings that are more meaningful and accessible (Luehmann and Wilson 2025). When teachers do not recognize and value the full range of students' sensemaking and communication tools, students from marginalized groups find their epistemologies and cultural practices unwelcome in science class, leaving this group of students invisibilized and underserved by public education (Mensah and Jackson 2018). Again, this practice opens opportunities to demonstrate the rich ways that culture shapes and enhances science, including when youth do science.

Recognizing that doing and learning science importantly involves a range of emotions, from frustration to excitement, confusion to elation, and many others in between, this JuST practice involves prioritizing affect and joy. Epistemic affect has been shown to be core to the instigation and sustainment of scientific engagement (Jaber and Hammer 2016; Pierson et al. 2023).

7.1.3 | Engaging in Place-Based Science Investigations

A third JuST Revising practice is *engaging students in place-based science investigations*. Megan Bang et al. (2013) catalyzed the field's movement to desettle the false belief that nature and culture are or can be kept separate. Engaging in place-based investigations can help bridge this divide by making learning experiences explicitly connected to the physical, social, environmental, and historical environment. Further, conducting science in familiar local lands can connect science to students' understandings of themselves as individuals as well as members of a community (Chinn 2006), leading to a sense of science as useful and real (Barton 2001; Mensah and Jackson 2018). Scientific study of students' community explicitly challenges the taken-for-granted notion of an objective science from "nowhere," which privileges the dominant culture (Aikenhead et al. 2006, 408).

Bringing students out of the classroom to do science with and within their community can both enhance students' sense of purpose and challenge the dominant culture in science (Bouillion and Gomez 2001).

In summary, JuST 3 Revising practices support students in revising their thinking and feeling through their engagement in scientific practices. Specifically, JuST Revising practices involve teachers nurturing student appreciation for diverse ways of participating in science within the classroom as well as more broadly. Students are encouraged to use the varied and rich linguistic resources to communicate and negotiate meaning with one another. Complementary ways of understanding the world are considered and valued into the classroom, including and especially Indigenous ways of knowing. In addition, students are supported in experiencing place as a valuable teacher and a core part of doing and learning science.

7.2 | JuST 3 Revising Example

Covid Connects Us included a range of student-centered experiences to support their revisions of scientific thinking and feeling with nontraditional expertise in their own communities. Students' experiences with Covid were treated as data throughout the unit; cases that needed to be explored and explained. Importantly, many students drew on these experiences as they prepared for and engaged in debates in the fourth lesson focused on "How can we argue from evidence about the optimal social distancing and mask-wearing guidelines?" These experiences coupled with published scientific explanations and evidence were interwoven with emotion as cases were made.

Prioritization of the local was clear from the launch of the unit, zip code data analysis of Covid case data, to the final performance-based assessment, a reopening guide for a particular organization. Lesson 5, "How big is my circle, really" engaged youth in an approximation of contact tracing. One of the learning objectives was stated this way,

> *I can explain why my community is at higher (or lower) risk because we lack (or have) adequate access to proper support and access to resources, live in smaller households with more generations (larger homes with fewer people), my family members are (or are not) essential workers, and there are (or aren't) barriers between our community and healthcare professionals (e.g., cultural competency, language, distrust of health professions).*

The debate about the sufficiency of the six-foot distance mandate in Lesson 4 and the contact tracing data analysis experience of Lesson 5 invite students to naturally integrate scientific explanations with specifics from the social contexts in which the phenomenon was occurring. Students built these explanations and arguments with emotions tied to personal experiences as resources. Beyond exploring patterns of virus transmission, students were supported in seeing their social connections as circles of influence. They could use science to help keep their circles safe, thus connecting the goals and practices of JuST 3 with those of the final quadrant, JuST 4.

8 | JuST 4: Using Science to Make a Difference and Advocate for Justice

The goal of JuST 4 Using Science centers on supporting students in enacting the social change work the teacher imagined in the planning work of JuST 1; science learning has been motivated by a purpose that matters to youth and their communities (See Quadrant 4, Figure 5). Pressing for evidence-based explanations by synthesizing key ideas throughout the unit for sensemaking in justice-centered ways moves past learning science content in order to succeed in science class, though this is an essential aspect (c.f., Banks 1993; Ladson-Billings 1995). Students also need to understand science content to comprehend reality and transform it (c.f., Banks 1993; Ladson-Billings 1995; Tolbert et al. 2016; Rodriguez and Morrison 2019). In this work, teachers support students in seeing the real-world value of science alongside its limitations. Science alone cannot transform the injustices of the world; science must work hand-in-hand with other ways of knowing the world such as politics, sociology, mathematics, economics, and others. Philip and Azevedo (2017) write about a powerful shift in focus where science works alongside other ways of knowing in service of social justice movements:

> *From this perspective, science does not exist in a necessarily privileged position; the epistemological and ontological assumptions in science also make scientific knowledge partial and incomplete (Harding 1992). By studying the authentic struggles of groups, as it exists alongside, overlaps, intersects, and conflicts with other human practices, this discourse can reveal the potential of everyday science learning as a part of social change.*
> (p. 529)

Thus, the aim of JuST Using Science practices is to build on AST 4's work of supporting youth in synthesizing the various elements of their learning (Windschitl et al. 2018) to create a complete causal explanation that is used *to make a difference and advocate for justice*.

8.1 | JuST 4 Using Science Practices

8.1.1 | Including Justice Elements in the Summative Assessment

JuST Using Science practices include the ambitious science teaching practices of co-constructing "gotta-have" checklists of elements for explanations, pressing for gapless explanations and scientific models, and assessing for understanding while also identifying a purpose for these scientific understandings that shift the gaze outside of the classroom. The first Just 4 Using Science practice, *including justice elements in the summative assessment*, ensures that the injustices that were exposed during the unit remain a focus through to the summative assessment. One example in our work is including a protected space in the scientific model scaffolds for students to explain the reasons for the social injustices that relate to the scientific phenomenon. Sheth (2019) reminds us that careful attention to dismantling injustices with and within science requires follow-through. Finkel (2018) framework for integrating social justice into science teaching advocates for content to be "science that is connected to broader social justice issues" and the outcomes to be "demonstrations of learning [that] are authentically connected to students' questions and concerns" (p. 52). The author offers examples of assignments that integrate justice into final assessments, including community-based assets and needs maps, developing an activist campaign, or developing instructional materials to nurture awareness. Though social justice may be implied in these assignments, it would be important to articulate or co-develop relevant assessment criteria to guide students' work.

8.1.2 | *Empowering Agents of Change*

The second JuST Using Science practice, *empowering agents of change* involves positioning students to use the science they in service of more just futures. Building on Freire (1970) problem-posing education, Morales-Doyle (2017, 2024) argues that social justice science issues require students to understand *and address* oppression. These efforts rarely, if ever, are solely science issues; nor are they problems that one organization alone can solve. Empowering agents of change may mean connecting students to existing organizations and projects to situate, motivate, and perhaps amplify the impact of students' science work for change. In the case of Morales-Doyle (2017), students collaborated with a community organization called "Communities Organized Versus Environmental Racism (COVER)" to collect and analyze soil data connected to the previous existence of a coal plant. The project concluded with a Family Night to share the findings organized by students and members of the US Environmental Protection Agency. Such social change projects can benefit from young people's insights, energy, creativity, and social networks. When youth collaborate with stakeholders of a related cause in their own communities, youth can be considered more credible narrators of science than scientists who may be seen as community outsiders (Luehmann et al. 2024; Morales-Doyle 2017). In a study by Bouillion and Gomez (2001), fifth graders collaborated with scientists, environmental conservation organizations, and local artists on a restoration project on the Chicago River. The youth were able to mobilize their largely Mexican immigrant parents and community members for the project. Students' work can be a source of joy when they have opportunities to use science to advocate for wellness, health, personal fulfillment, and solutions to the problems of the world (Muhammad 2022).

Further, engagement in activism projects that challenged oppression during school has led to increased science competence and interest (Bouillion and Gomez 2001; Morales-Doyle 2017), overall academic achievement (El-Amin et al. 2017), and increased enrollment in 4-year colleges and universities (Rogers and Terriquez 2013). These experiences allowed youth to build social capital for future civic action (Rogers and Terriquez 2013). This JuST Using Science practice highlights the importance and value of engaging youth in using science to right wrongs that they have identified and doing this with others currently engaged in change-making projects, including those occurring outside of the school.

8.1.3 | *Connecting Students With an Authentic Audience*

Related to the previous JuST Using Science practice, a third practice highlights the explicit value of *establishing an authentic audience for student work* that expands beyond that of the teacher and classmates as a core aspect of scientific work (e.g., Finkel 2018). Authentic audiences are those who can relate and use the science that students have to share. This practice aligns with the science and engineering practice of the NGSS "obtaining, evaluating and communicating information." Providing opportunities for students to prepare for and share the science they learned with an external audience can motivate their choice and use of technical, graphical, mathematical, oral and written presentation. Heath (2001) describes a "temporal arc" that is characteristic of science laboratories as well as other productive learning environments:

> *Work takes place within a "temporal arc," with phases that move from planning and preparation for the task ahead; to practice and deliberation along with ample trial-and-error learning, to final intensive readiness for production or performance; and, ultimately, to a culminating presentation of the work that has gone before.*
> (p. 12)

Preparing for and enacting a final performance for an authentic audience can provide a classroom community a shared focus throughout the unit and motivation for competent participation and careful communication. Authentic performances can invite youth to also draw upon youth-centered expertise (e.g., film making; social media authoring) and position educators as collaborators who support students sharing their work with a personally consequential and community-connected audience (Emdin 2017; Luehmannand Wilson 2025; Soep and Chavez 2019). Lu and Steele (2019) highlight the power of inviting students of Color to draw upon song, storytelling, and signifying as part of their rich cultural and historical resources for communicating their science advocacy work. Sharing work with people outside of school provides students opportunities for recognition as capable science people, a core aspect of identity development (Gee 2003; Luehmann 2007; Morales-Doyle 2017; Sfard and Prusak 2005).

In summary, JuST 4 Using Science practices focus on supporting students in constructing evidence-based explanations as a synthesis of their varied learning experiences across the arc of a unit and positioning these explanations in service of a purpose beyond school. Positioning students to use their science learning to make a positive difference and advocate for justice can provide many, complementary benefits for students, especially students traditionally underserved by school.

8.2 | JuST 4 Using Science Example

The primary purpose of the Covid Connect Us unit is to provide youth with opportunities to author questions about the virus that they and their families care about most. Especially important during the first 2 years of implementing this unit, many were confused and scared by the changing recommendations that seemed to be based in uncertain science. As injustices were being publicly questioned with respect to Covid cases, Covid deaths, and unsupported rumors of harms stemming from vaccine use, supporting students' critical engagement with this scientific phenomenon was necessary and welcomed by many students. Two of the three JuST 4 Using Science practices focused on the culmination of a unit were present in the curriculum. First students were asked to synthesize the explanations from various investigations to create a final model of the anchoring phenomenon (see teacher example model, Figure 7). In addition, students were asked to use what they learned in the creation of a re-opening guide for an organization they cared about.

As students prepared public-facing artifacts to share their scientific understandings with the communities, science was personalized with particular, local audiences in mind. In one case, a group of learners in an afterschool club hosted a community forum to bring families together with three physician "medical mentors" to discuss vaccine hesitancy. Tears were shed as a scared new mother connected with a physician who shared that she too was a new mother. All present benefited from the humble, compassionate science-related questions and explanations that were interwoven with a desire for connectedness.

In another case, one chemistry teacher in the Bronx invited his students to create frequently asked questions (FAQ) documents addressing myths about Covid that that they had encountered that were then shared with school families. Though this unit did not explicitly partner with a local organization also fighting misinformation, one could have imagined youth creating this FAQ artifact for teens to be shared in the offices of the "medical mentors" who served as their advisors. This partnership could have introduced an authentic review by mentors for the students' claims and evidence.

9 | A Need for Sustained Critical Consciousness Development

To take up JuST practices in ways that are internally consistent and purposeful, teachers need particular orientations that acknowledge, in deep ways, the ways that racism and other forms of oppression have and continue to shape all social interactions in the United States. Science, science education, teachers, and classrooms are not immune (Calabrese Barton 2000; Ladson-Billings 2009; McGee 2021; Mensah 2009; Sheth 2019). Developing critical consciousness requires intentional unlearning of taken-for-granted assumptions (Diemer and Blustein 2006; hooks 1994), such as the belief that science and science education are value- and culture-free (e.g., Aikenhead 1996; Bang et al. 2018). Educators benefit from critical self-reflection (Milner et al. 2018; Philip 2011; Sealey-Ruiz 2021) and sustained learning that includes critiquing science, society, school systems, and themselves (Basile and Azevedo 2022; Crabtree and Stephan 2023). This professional development work helps teachers clarify the why and for whom they are fighting (Madkins and McKinney De Royston 2019),

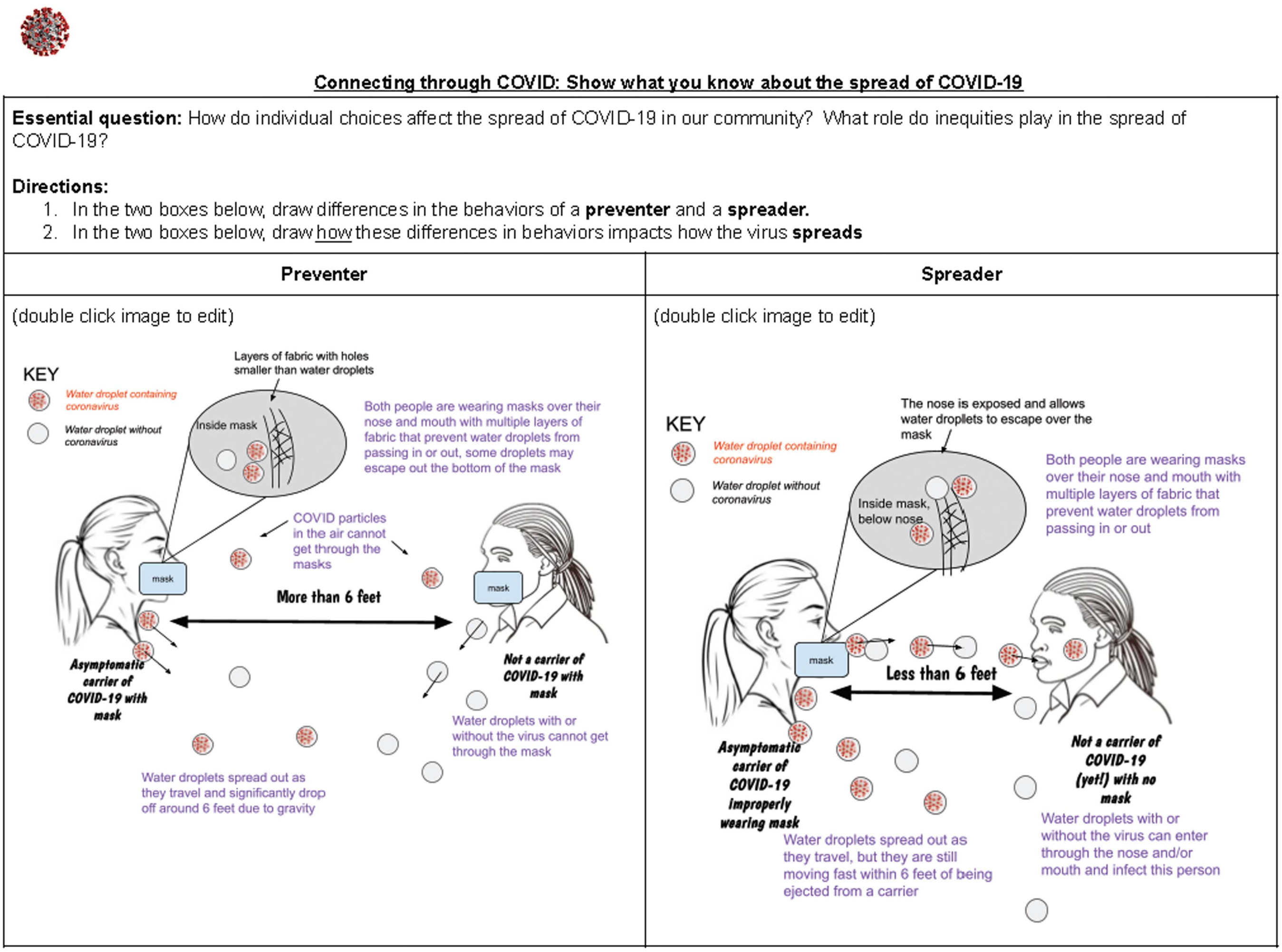

FIGURE 7 | Teacher sample model.

Preventer: 1. Use your drawings to write an explanation about the differences in behaviors & resulting impacts of a preventer on the spread of COVID-19	**Spreader**: 2. Use your drawings to write an explanation about the differences in behaviors & resulting impacts of a spreader on the spread of COVID-19
The asymptomatic carrier does not show symptoms of COVID, but still wears a mask to prevent spreading or catching the water droplets. These people have access to the resources they need to protect themselves and others. They are able to socially distance as well without a problem. They may live in areas with less people around and homes with enough space to stay apart.	The asymptomatic carrier may not realize they have COVID, but either way, the mask under their nose allows the water droplets from their breath to escape and pass along to the other person who is too close. The water particles can travel 6 feet before it starts to drop off and now the person without a mask has exposed himself. These two people may be essential workers who need to interact with people. They may live in crowded homes that make it difficult to socially distance. They may not have money or access to proper masks or enough masks to keep themselves safe. These two people may not have been told about safe practices for preventing the spread of COVID-19.

3. Individuals and communities have been impacted differently by COVID-19. **Equity** is when all people are treated fairly and **inequity** is when there are unfair or unjust conditions that negatively impact individuals or communities.
   a. Explain ways that individuals or communities have experienced **equity** or **inequity** during COVID-19
   b. How might inequity affect the preventer and spreader in your model?

Communities of Color have been disproportionately impacted by COVID-19. These communities that have had significantly higher cases of COVID-19 show lower levels of socioeconomic status, higher numbers of people living in a single home, and higher numbers of people living in more densely populated areas. Many of the people in these communities may be essential workers who cannot stay home to quarantine or may not have enough money to support their families if they are unable to work. The healthcare systems in densely populated communities are overcrowded, so people in these communities may have to wait longer and are exposed to more ill people. People in urban communities may depend on public transportation to travel, which puts them in contact with more people and may make it more difficult to get emergency medical services. The workers in these facilities are also overworked and may live in the same community that they work in. Historically, the healthcare system has discriminated against People of Color, resulting in a lack of trust, so people who need medical attention may not be seeking it out when they need it. These inequities cause People of Color to spread COVID-19 more easily and quickly and to have a lower chance of survival if they do contract the virus.

On the other hand, suburban and rural communities, which are typically dominated by White people are less densely populated and better able to socially distance themselves. They do not rely on public transportation and are able to stay isolated as they commute to different places. People living in the suburbs tend to have more resources to work from home and for students to attend school at home. People in these communities tend to have enough money where they can afford to not work for a period of time. They have significantly less cases of COVID-19 and those that do contract the virus are more likely to get the medical treatment they need without fear of discrimination. People living in rural communities may have to drive further distances to get the medical treatment they need or for medical services to come to them. Their access to masks and cleaning supplies may be limited as there may be less stores available and further distances are required to get there.

FIGURE 7 | (Continued)

which, as Freire (2025) argues, is essential for revolutionary teaching. Developing critical consciousness (Freire 1970), recognizing injustice, and acting to challenge that injustice, is not an outcome or an achievement but rather an ongoing process (Basile and Azevedo 2022; Luehmann et al. 2024; Morales-Doyle et al. 2021). Without consistent engagement in developing one's own critical consciousness, teachers will struggle to support students in similar learning experiences.

There are known barriers to teachers enacting critical consciousness (Jones and Donaldson 2022; Ladson-Billings 2014; Ranschaert 2023; Young 2010). Teaching in ways that might be perceived as revolutionary may involve professional (Windschitl 2002) and emotional risks (Luehmann 2007). Teachers, especially novices, may reject taking action against injustice because of perceived pressure to teach to high-stakes tests, limited bandwidth, and lack of trust in their ability (Cooke et al. 2025). Although we acknowledge the myriad reasons that teachers do not enact curriculum and pedagogy that challenge traditional forms of science education, we argue that a sustained commitment to praxis, iteratively developing and nurturing one's own sociopolitical awareness and action (Freire 1970), is essential to making science teaching, schools, and science itself not only more accessible but better and more just.

10 | How to Use the JuST Framework

We recommend using the JuST-FW as a tool toward the ongoing development of a justice-centered ambitious science teaching epistemic community (Glazer and Peurach 2015). As stated previously, this tool aligns with shared theory and language being put forward by many justice-centering ambitious science education scholars, namely the urgency of disrupting the status quo by expanding what counts as science and using science for social transformation (Table 1). Given this shared theory and language for justice-centering, the JuST-FW provides an important addition for uniting our field's varied justice-centering science teaching efforts, offering a tool for enactment that can be used to (a) inform practice; (b) facilitate local interpretation and problem solving; and (c) support cross-site communication and ongoing refinement of our shared tools and resources (Glazer and Peurach 2015).

We suggest using the JuST-FW in much the same way that Windschitl et al. (2012), articulated the recommended use of AST, "to anchor instruction by both teacher educators and beginning teachers" (p. 2) in order to improve instruction within and across institutions in a coherent and sustaining way. In addition, like the AST practices, we offer the JuST-FW as sets of science-specific, core practices that "the broader teacher education community could collectively refine" (p. 18) as we seek to unite disparate efforts in order to discuss and develop justice-centering tools and other resources in various contexts and communities of practice.

Our use of the JuST-FW has supported our work in a cross-site NSF-funded project (Award 2101217) focused on justice-centered science teaching (Cooke et al. 2025). The language of the JuST-FW became the codified sensemaking tool among teachers and scholars across states, K12 school-based institutions, and universities. As one example, the following excerpts from a focus group conducted with five project teachers working in different schools and districts. First, Cathryn (pseudonym, 2023 focus group) highlights the value of the tool as a potential evaluation tool at the district level:

> *It's interesting, I could use it [the JuST-FW] to evaluate where my own district is in our justice centered teaching approach. I think that my district spends a lot of time in quadrant one just to the right of what we were doing there. And trying to think about ways to incorporate all of the quadrants into instruction is something that I find looking at this model to be useful with. Because once it's all laid out here in front of you like this, you see the need for each of these quadrants and it's easy to assess kind of where you're at in your individual classroom, where your building is at, and where your overall district is at in terms of the curriculum that they have developed for its students.*

Esther follows Cathryn by using the various quadrants to describe the focus of her professional learning community the previous year as well as her professional goals going forward. Note the shorthand that Esther uses to communicate with the project teachers from different schools:

> *I totally agree with [Cathryn] - having students be the voice in Quadrant 4 I think is where we spend a lot of our time. And I learned a lot about that specifically, but even thinking about our discussions as a PLC, we did a lot of, man, of "we need to bring in local experts" and "how can we broaden using community expertise." And there's Quadrant 3. We talked about that a ton, and I think that that's where we need to go forward... So, I think even though I think we did mostly [Quadrants] 4 and 1 in our own practice and in our own projects, I think [Quadrants] 2 and 3 has always been our goal, but again, time is so limited.... we all have curriculum that we have to work within and all of this stuff that I feel like it's challenging, but I definitely have ideas about how to do that better next year and I'm looking forward to that, to [Quadrants] 2 and 3 specifically.*

Though the language and tool supported sensemaking across schools and districts, the ways the sets of core practices are enacted are, and must be, unique. The Framework represents core practices that will necessarily be lived out in different ways in different contexts so as to respond to and sustain the local cultures of particular groups of learners, a core tenant of justice-centering work.

Glazer and Peurach (2015) argue that an epistemic community such as JuST, despite not sharing the same location or institution, can unite forces. They describe the potential power of an epistemic community this way:

> *...geographically dispersed communities of practitioners, operating within a constellation of regulatory and market pressures, can collectively exert control on the core, technical work of teaching via the production and use of practical knowledge. (p. 197)*

In this case, a tool such as the JuST-FW can coalesce various efforts toward realizing more just futures for schools through shared theory, language and practices that would allow collaborative initiatives, sensemaking, and revisions; all while addressing the age-old challenge of developing knowledge about teaching and learning through the use of common theory, codes, and tools aimed at common justice-centered pursuits (Glazer and Peurach 2015).

11 | Conclusion

Centering justice in science classrooms requires a paradigm shift for most teachers in both the core aims of science education as well as the means to realize these aims. Daniel Morales-Doyle (2024) captures this shift well as he points to the need to support students as learners of science with aims of equity, justice, and sustainability. This aim stands in stark contrast to enculturating students into a scientific enterprise that has historically been complicit in oppression, injustice, and planetary destruction. Ensuring that all students, especially our most vulnerable students, are engaged in understanding their world through science as a discipline that is inclusive of all of their cultural identities requires investments by teachers at each stage of pedagogical planning and instructional practice. The JuST-FW offers educators the organizing and communicating value of a coherent model of core practices as footholds to engage in the work. Merging the value and tools of AST with the theoretical clarity and urgency of the literature on justice-centering in science classrooms, the framework provides much-needed scaffolds (shared language, organizing structure, and actionable practices) for educators engaged in this challenging but necessary work.

Though we see the value in frameworks as starting points, conversation mediators, and a lens for organizing and accelerating more rigorous justice-centering in school, we also realize the harm that labels can do to really important efforts. For example, "culturally relevant pedagogy" (CRP) has been reduced to a buzzword in many contexts often lacking what Ladson-Billings (1995) identifies as a core element of CRP, namely that of taking action to address injustices, (e.g., Ladson-Billings and Dixson 2021). Thus, we invite the users of the framework to hold tight to the commitments of rigorous equity work (expanding what counts as science and using science as a tool for social movements) as you explore what is most useful to your students and their community.

Author Contributions

April Luehmann: conceptualization, investigation, funding acquisition, writing – original draft, writing – review and editing, resources, project administration, supervision, visualization. **Déana Scipio:** conceptualization, investigation, writing – review and editing, funding acquisition, resources. **Todd Campbell:** conceptualization, investigation, writing – review and editing, resources, project administration. **Gena Merliss:** conceptualization, investigation, writing – original draft, writing – review and editing, resources, project administration. **Yang Zhang:** conceptualization, investigation, funding acquisition, writing – review and editing, project administration, resources. **Hannah Cooke:** conceptualization, investigation, writing – review and editing. **Elizabeth Wilson:** conceptualization, investigation, writing – review and editing. **Priya Pugh:** conceptualization, investigation, writing – review and editing. **Adma Gama-Krummel:** conceptualization, investigation, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

There are no empirical data to share as this is theoretical paper.

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