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Toward a justice-centered ambitious teaching framework: Shaping ambitious science teaching to be culturally sustaining and productive in a rural context

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Abstract

We find ourselves at a time when the need for transformation in science education is aligning with opportunity. Significant science education resources, namely the Next Generation Science Standards (NGSS) and the Ambitious Science Teaching (AST) framework, need an intentional aim of centering social justice for minoritized communities and youth as well as practices to enact it. While NGSS and AST provide concrete guidelines to support deep learning, revisions are needed to explicitly promote social justice. In this study, we sought to understand how a commitment to social justice, operationalized through culturally sustaining pedagogy (Paris, Culturally sustaining pedagogies and our futures. *The Educational Forum*, 2021; 85, pp. 364–376), might shape the AST framework to promote more critical versions of teaching science for equity. Through a qualitative multi-case study, we observed three preservice teacher teams engaged in planning, teaching, and debriefing a 6-day summer camp in a rural community. Findings showed that teachers shaped the AST sets of practices in ways that sustained local culture and addressed equity aims: anchoring scientific study in phenomena important to community stakeholders; using legitimizing students' stories by both using them to plan the following lessons and as data for scientific argumentation; introducing local community members as scientific experts, ultimately supporting a new sense of pride and advocacy for their community; and supporting students in publicly communicating their developing scientific expertise to community stakeholders. In shaping the AST framework through culturally sustaining pedagogy, teachers made notable investments: developing local networks; learning about local geography, history, and culture; building relationships with students; adapting lessons to incorporate students' ideas; connecting with community stakeholders to build scientific collaborations; and preparing to share their work publicly with the community. Using these findings, we offer a justice-centered ambitious science teaching (JuST) framework that can deliver the benefits of a framework of practices while also engaging in the necessarily more critical elements of equity work.

KEYWORDS

ambitious (AST), community science, culturally sustaining pedagogy, next generation science standards, rural education, science teaching, science teaching, social justice

> What if the goal of teaching and learning with students from traditionally marginalized groups "was not ultimately to see how closely students could perform White middle-class norms but to explore, honor, extend, and at times, problematize their heritage and community practices?" (Paris & Alim, 2014, p. 86).

1 | INTRODUCTION

Equitable teaching and learning are fundamental requirements of science education. Though we have made progress in explicating what a transformational understanding of equity and justice looks like in education (e.g., Mensah et al., 2018), and though we have identified core practices that support beginning teachers in enacting ambitious pedagogy that leads to deep disciplinary understandings (e.g., Windschitl et al., 2018), we have yet to bring these two conversations together in a way that supports beginning teachers' enactment of justice-centered ambitious practice. This study explores how teachers can benefit from AST's strengths in explicitly culturally sustaining and justice-centered ways.

Though we have long known about our country's problems with racism, classism, and other forms of discrimination and their painful and problematic impacts on schools, students, and their families, we have done little to address the problems (Madkins & McKinney de Royston, 2019). In addition to being a moral obligation, understanding and enacting justice-centered science education is necessary to sustain our citizenship's rich cultural diversity (Bang et al., 2013; Pomeroy, 1994; Warren et al., 2001). Further, enacting justice-centered science education serves to nurture a STEM citizenship that is expansive and diverse enough to be able to identify and address the range of challenges we currently face and will continue to face in the future (Lee, 2022; Lee et al., 2021; Zucker & Noyce, 2020). Ignorance about how to go about making these changes offers no excuse for paralysis.

While we are being called to the challenging but necessary work of social transformation in and through science education, 44 states adopted the Next Generation Science Standards or similar standards (NSTA, n.d.; NGSS Lead State, 2013). NGSS centers student sensemaking of core science concepts through students' engagement in science and engineering practices. Students engage with the same core science concepts at different stages of their educational trajectory, each time in ways designed to be developmentally appropriate. Adopting new curricular standards brings politically mandated motivations to change science teaching and learning. Given the inevitability of change, school leaders and stakeholders have the unique opportunity to also create ambitious changes to realize justice-centered science education. The pedagogy needed to enact the curricular aims of NGSS, and, in some instances, orienting toward an explicit equity commitment, is the focus of many current efforts.

Identifying "core," "ambitious," or "high leverage" practices has been the work of several scholars focused on supporting novice teachers in developing competence with a limited number of practices that will lead to effective student learning (Forzani, 2014; Lampert et al., 2010; McDonald et al., 2013). One such framework of core practices, Ambitious Science Teaching (AST), is designed to promote deep learning by engaging students with both science concepts and science discourse, where students learn to think and act like scientists (Hammerness et al., 2020; Stroupe & Gotwals, 2018; Thompson et al., 2013; Windschitl et al., 2012; Windschitl et al., 2018). AST offers a framework of four sets of practices to teach ambitiously:

1. Planning for engagement with big science ideas
2. Eliciting students' ideas
3. Supporting ongoing changes in students' thinking
4. Drawing together evidence-based explanations (Windschitl et al., 2018, p. 4)

Windschitl et al. (2012) refer to these as core practices or a "beginner's repertoire"—the practices with the highest leverage for novice teachers to learn during their teacher education programs (p. 878).

AST has been operationalized such that teachers ask students to make sense of authentic scientific phenomena, to engage with the practices of science and engineering (e.g., evaluate evidence, design experiments), and to think like scientists (e.g., make connections between observations and underlying science concepts) (Kang & Windschitl, 2018). Further, teachers treat student experiences and ideas as valid resources and facilitate discussions where students have opportunities to reason through ideas with each other, collaboratively critiquing and refining their understanding of science concepts (Windschitl & Stroupe, 2017). The AST framework is designed to provide PSTs with concrete practices to rehearse during their preservice program so that they develop a vision of what ambitious teaching can look like and accomplish (Barton, 2000; Kang & Windschitl, 2018). Note that AST, like other core practices, is not a set of unalterable, prescriptive, or overly deterministic behaviors, as Philip et al. (2019) warned; the core practices are identified as research-based footholds to engage and support novices with defining aspects of teaching, during which teachers *must* maintain a sense of responsiveness to and improvisation with youth ideas and discourse to shape instruction to be meaningful and effective for the particular students in the room.

Lacking in both NGSS and the AST practice framework, however, is attention to the ways science is limited and sometimes flawed (Abbasi, 2021)—even unethically flawed (e.g., Brandt, 1978)—in its practices and science education is limited in its outcomes. These limitations can result in dire consequences, such as a lack of trust in scientific findings, often disproportionately for the most marginalized in our society (Kazemian et al., 2021). Not understanding the weaknesses and inappropriate uses of science and science education leaves our future citizens ill-equipped to navigate resulting challenges or rectify resulting problems.

Science is often understood and taught as acultural and objective, though we know better: "…[S]cience does not occur in a vacuum. It affects society and cultures, and it is affected by the society and culture within which it occurs" (NSTA, 2020, p. 1). Science is a human endeavor and is thus impacted and shaped by culture. Particular ways of knowing and certain problem-based aims are prioritized over others, emphasizing perspectives of the dominant culture and marginalizing, misrepresenting, or invisibilizing others. The resulting science that is produced is, at best, limited and, at worst, imprecise and harmful (Seth, 2022). It follows, then, that science education, designed to engage youth in the authentic practices of the discipline, would also be limited and problematic, leaving out ways of knowing and purposes for learning that are imperative to students from non-dominant cultures.

This study takes an important step toward addressing these problems. Culturally Sustaining Pedagogy (CSP) (Paris & Alim, 2014) underscores the importance of epistemological heterogeneity and pluralism to honor and benefit from diverse ways of knowing. CSP requires dynamic and responsive engagement with youth culture while also recognizing their heritage ways of knowing. It aligns with the need to critically consider and expand how we understand the natural world (Bang et al., 2017; Harding, 1998). CSP also challenges us to consider aims beyond school performance and achievement, including focusing on ways learning can sustain local culture—especially cultures of youth and communities from marginalized groups. Using science learning to advocate for change and positively impact one's world can empower and motivate youth from marginalized groups (El-Amin et al., 2017) and lead to a more critical form of scientific literacy (Bernal-Munera, 2023; dos Santos, 2009). This study explored how teachers leaned on and took up the structures of AST in explicitly culturally sustaining and justice-centered ways. The research question guiding this study was, "How did teachers shape AST to be culturally sustaining in a minoritized community?"

2 | LITERATURE REVIEW

With the goal of equity in science education, we present the research landscape of AST and teaching science for equity. Philip and Azevedo (2017) outline the scope of research in equity work in science education with the use of four distinct discourses we paraphrase here:

- Discourse 1: Providing access to the fields of science and thus the "culture of power" (Delpit, 1988, 1995)
- Discourse 2: Engaging in authentic scientific learning experiences to nurture achievement and identity development
- Discourse 3: Expanding what counts as science—who does it, in what ways, and in what contexts
- Discourse 4: Using science to engage in justice movements

Though these discourses were originally used to summarize the literature in everyday learning, because of their usefulness, they have also been used in many formal contexts (e.g., Davis & Schaeffer, 2019; Oakes et al., 2018). Equity work within Discourses 1 and 2 may improve individual outcomes, though it does not impact (or intend to impact) macro-level inequities. The AST framework falls squarely within these first two discourses. For example, ambitious scholars use terms like promoting "equitable teaching" for "all students" (Stroupe et al., 2020, p. 3–4) from "all backgrounds" (Windschitl et al., 2018). This terminology echoes that of the NGSS, which the AST framework is well aligned to support. AST aims to provide all students access to science careers and authentic deep-learning opportunities. While this sort of unprovocative language may speak to a broad audience, as NGSS intends, this level of equity discourse does not shift power relationships or address historical structures that continue to penalize certain groups (Philip et al., 2019; Philip & Azevedo, 2017).

AST supports teachers in asking students to engage in sensemaking and practice authentic science (Hammerness et al., 2020; Kang & Windschitl, 2018; Thompson et al., 2013) and focus on anchoring phenomena that, whenever possible, connect to student interests (Windschitl et al., 2018, p. 31). Teachers elicit student ideas (Stroupe & Gotwals, 2018) and use this understanding in planning by imagining high-level student responses and ways to scaffold lessons so students can produce them (Thompson et al., 2013; Windschitl et al., 2012). Much research exists supporting the effectiveness of the AST framework in supporting preservice (e.g., Kang & Windschitl, 2018; Stroupe & Gotwals, 2018) and in-service teachers (Kang et al., 2014; 2016, Thompson et al., 2013; Windschitl et al., 2012) developing pedagogy that centers student learning through engagement in core science and engineering practices. Further, Hammerness et al. (2020) describe developing students' "agency as sense makers" as a key aspect of ambitious science teaching (p. 19). Sensemakers are individuals who engage deeply with science learning. While Hammerness et al. (2020) argue that such sensemaking challenges the status quo in science classrooms, we argue that it does not explicitly empower students to effect social change as a result of deep science learning.

The AST framework appears to foster some level of equity work where traditional science teaching has lacked. For example, the AST framework has been shown to center and support student sensemaking (Kang et al., 2014), ongoing changes in student thinking (Windschitl et al., 2018; Windschitl & Thompson, 2013), and producing evidence-based explanations (Kang et al., 2014). Collectively, these findings substantiate the AST framework's ability to support teachers in providing students with access to the field of science through engagement in authentic scientific discourse. These findings are powerful but do not advance the more rigorous equity work (e.g., Bang & Vossoughi, 2016; Morales-Doyle, 2017; Sheth, 2019). Equity work needs to incorporate more than improvements for individual students to alter the status quo in science, inside science classrooms, and in society. Some argue that the AST framework (as a discipline-specific version of core practices) cannot support teaching for social justice (Philip et al., 2019), that is, teaching that expands what counts as legitimate ways to do science or adopts transformational purposes for learning science that extends outside of the classroom. Though the AST framework has not been shown to support this higher level of equity work yet, we believe that, with intentionality, it could.

While justice-centered scholars argue for more critical versions of equity than those promoted by AST, many frameworks are more theoretical than practical. For example, within her science methods courses, Mensah (Mensah, 2022; Mensah et al., 2018) has researched the use of Banks' (2013) typology of multicultural curriculum reform, which includes the traditional reform efforts of adding representation from multiple cultures to existing curriculum, as well as the more substantive reforms of transforming curriculum and ultimately using it to take social action. In both studies, Mensah wanted her preservice teachers to develop critical conceptions of equity through learning and practicing using Banks' framework, such as using science to transform society. Mensah's (2022) study revealed that elementary preservice teachers could realize more ambitious forms of justice-centered pedagogy when supported with a multicultural framework, namely Banks's (2013), and opportunities to apply the framework to design and enact curriculum with urban youth. That said, only two of six groups of teachers moved beyond level two to the more ambitious forms labeled 3, transformative, and 4, social action.

Developing novel frameworks to support justice-oriented science teaching, other scholars emphasize the classroom learning environment as a place to support student sense-making and the need to leverage local phenomena that matter to students to drive curriculum (Morales-Doyle, 2017; Morales-Doyle et al., 2021). While Morales-Doyle (2017), like Mensah (2022), also reported success with a theoretical model of justice-centered science education, the successful outcomes were documented relative to students instead of teachers. Building on this and related experiences, Morales-Doyle and Frausto articulated a curricular framework in the 2021 paper, which has yet to be enacted and explored by teachers. Similarly, Patterson and Gray (2019) articulated a curriculum framework called (W)holistic Pedagogy consisting of teacher commitments that, in addition to engaging in science for transformational purposes, pay special attention to the social and emotional care for students as they take up issues and topics that could be deeply personal and painful and, when possible, attend to undoing harm through restorative practices. This framework has also yet to be explored in practice. Sobel (2004) and others define place-based education as using the local community and environment as the core for teaching academic disciplines such as science to nurture youth's appreciation for their community, commitment to engaging as a citizen, and overall lead to improved community and environmental quality. Like place-based education in its focus on local community and culture, Paris and Alim (2014) argue for the value of a lens they call "culturally sustaining pedagogy," which will be described in detail in the analytic framework below.

Though these frameworks describe elements of justice-oriented or multicultural approaches, they stop short of defining sets of practices that teachers can enact. These frameworks more closely resemble Philip and Azevedo's (2017) four equity discourses as structured ways to conceptualize equity in and through education. None of these frameworks, including AST, is intended to be prescriptive, though the AST framework is more tangible and action-oriented than descriptive or theoretical. While we agree that the AST framework supports a limited view of teaching science for equity, we wondered whether its concrete set of practices and tools might be adapted to support an expanded vision for equity. In this study, we sought to understand ways preservice teachers used CSP to shape their enactments of the AST framework to promote more critical versions of teaching science for equity.

3 | ANALYTIC FRAMEWORK

The analytic framework used for this study primarily involved the intersection of core tenets of culturally sustaining pedagogy (CSP) with the four core sets of ambitious science teaching. We begin by describing the core sets of practices for AST followed by those of CSP.

3.1 | Ambitious science teaching

As described above, the Ambitious science teaching (AST) framework provides concrete, though not prescriptive, sets of practices that teachers can employ to create a learning environment that promotes deep learning. Because the preservice teachers (PSTs) in this study were supported in their engagement with core AST practices, we knew it was likely that we would be able to identify these components in each group's instruction. Specifically, we identified teaching practices related to AST 1 Planning, AST 2 Eliciting, AST 3 Revising, and AST 4 Constructing evidence-based explanations. This framework bracketed teachers' work into these useful, often sequential categories. More explanation of these categories will be offered in the methods section below.

3.2 | Culturally sustaining pedagogy

Arguing that schools are responsible for sustaining the culture of minoritized communities rather than forcing assimilation to the dominant culture and erasing underrepresented cultures, Paris and Alim (2014) proposed a pedagogical framework, Culturally Sustaining Pedagogy (CSP). Grounded in Ladson-Billings's (1995) culturally relevant pedagogy (CRP), CSP is a school of thought that foregrounds the need to prioritize students' heritage *and* current cultural knowledge and identities as assets and foci in the classroom. It seeks to sustain both the long-standing cultural, literate, and linguistic practices of minoritized communities and youth culture's lived and dynamic nature. Positioning cultural heterogeneity and dexterity as necessary goods, CSP views the resulting learning outcomes as additive rather than subtractive (Alim & Paris, 2017) and a core goal of schooling (Paris, 2012, p. 94). This approach challenges common hegemonic practices in education that seek to eradicate cultural differences and a plurality of points of view, which in turn diminishes the value and strengths of any particular discourse, including science education. The authors of CSP argue that a core goal of schooling is to maintain heritage ways, value cultural and linguistic sharing across differences, and sustain and support bi- and multilingualism and bi- and multiculturalism (Paris, 2012, p. 94). Thus, this view toward sustaining culture taps into students' historical and contemporary cultural and linguistic diversity as important assets for inquiry and sensemaking; further, sustaining minoritized cultures through science is a valuable end in itself.

In addition, CSP fundamentally takes a critical lens, seeking to challenge Eurocentrism and repudiate the perpetuation of white supremacy. Rather than relegate learners' cultural and linguistic strengths as tools to learn canonical curricular and academic skills, CSP aims at supporting learners in interrogating what counts as "acceptable," "standard," or "canonical" ways of knowing, critiquing the often oppressive ways these perspectives have become the dominant ones, even sometimes in our own communities. Consequently, an essential goal of CSP is to "guide learners to think about ways to disrupt, dismantle and displace these oppressive ideologies and systems by imagining, revitalizing and enacting ever-more just and equitable ways of being together in the world" (Alim et al., 2020, p. 263). One way to do this is to involve students and their local communities in decision-making about what to study and how to study in critical and expansive ways shaped by cultural and economic standpoints (Medin et al., 2014; Vakil et al., 2023). In this way, a culturally sustaining lens includes:

- Critically centering a dynamic local culture
- Recognizing and inviting expertise from the local community to which the science is held accountable

- Cultivating a reciprocal relationship with the local community and its land
- Attending to the possible internalized false beliefs that local practices and selves as minoritized people are not valued in educational settings (Paris, 2021).

Teaching can uplift minoritized and marginalized communities, expanding what counts as legitimate ways of participating in discourse and what counts as worthwhile outcomes. Our analyses consider how PSTs engaged in these varied aspects of CSP in the context of a summer science camp in a rural community.

Though Culturally Sustaining Pedagogy (CSP) explicitly draws attention to the need to sustain the culture of youth and communities of color, the authors Paris and Alim (2014) state that "CSP exists wherever education sustains the lifeways of communities who have been and continue to be damaged and erased through schooling" (np). Youth from rural communities experience documented challenges in school similar to many youth of color, namely, a lack of connection between local ways of knowing and those taught in school (Boyer, 2006), messages that local assets are not prioritized, and that important things come from somewhere else (Carr & Kefalas, 2009; Sipple & Brent, 2008). Given these challenges, it is clear that CSP could be an important and relevant analytic lens to explore how youth and local culture from a rural community could be sustained in and through science education.

4 | METHODS

4.1 | Positionalities

The authors are a team of researchers and educators committed to educational justice. We have experience teaching middle and high school science in rural and urban schools and position ourselves as co-learners and co-conspirators with teachers. Our team consists of one Asian and five white people, five identifying as female and one as male.

Each of us has experience supporting preservice teachers in the Authentic Science Education (ASE) teacher preparation program, which is a program explicitly designed to be justice-centered. In this program, preservice teachers (PSTs) are instructors of record during a science camp in the summer and an afterschool club in the fall. PSTs engage in these outside-of-school teaching experiences with students from marginalized communities as precursors to their student teaching experiences. The lead author designed the ASE program and has directed it for 20 years. The first and third authors co-taught the course during the summer of this study, and the second author was on-site as a participant observer.

4.2 | Context

4.2.1 | Science in Sorrus

This study was situated in a rural community, Sorrus (pseudonym), a 45-minute drive from a small private R1 Research University. The rural context is a crucial aspect of the study. Geography alone cannot capture a place's cultural complexities and strengths (DiCerbo & Baker, 2021). Avery (2013) explains that rural communities can provide rich environments for learning and doing science as they are enhanced by valuing and using local knowledge in the learning experience. In Sorrus, we recognized that challenges of geographic and social isolation, underfunding, and other disenfranchisement create barriers to this rich expression of science doing and science learning. Research suggests that rural schools signal to children that important knowledge cannot be found in the local community and that leaving is the only way to succeed (Carr & Kefalas, 2009; Corbett, 2007; Deitz, 2007). This framing "diminishes the cultural and intellectual capital vital to rural communities" (Avery, 2013, p. 30). The community of Sorrus shapes and informs deep ways of knowing that are context-specific. As educators in rural areas are witnessing an increase in the diversity of their students, there is an abundance of alternative ways of knowing that, when recognized and welcomed, are assets to the community (DiCerbo & Baker, 2021). Yet, these alternative ways of knowing are often overlooked because they do not fit into traditional conceptions of science and engineering practices and skills.

Rural sociologist Gene Theodori (2003) wrote, "When you've seen one rural community, you've seen one rural community. Every rural community has certain social, economic, and/or environmental issues that are unique to that particular community and contribute to its diversity" (p. 1). For this study, this means that we are allowing particular understandings of rural communities to inform our work. Still, we are also attentive to how Sorrus is distinct and unique in its strengths and challenges. Available demographics about Sorrus show that 17% of the population lives below the poverty line, higher than the national average of 12.8%. Sorrus School District has less racial and ethnic diversity than other parts of the state (DataUSA, n.d.). Approximately 65% of the students come from economically disadvantaged families. Sorrus students are academically performing in the bottom half of the state; for example, 38% of the middle school students (those in this study) achieved at or above proficiency in reading and 42% in math (U.S. News & World Report, 2022). Fewer than 1% of students take an advanced placement science course, which is significantly <6% national average. Specifically, based on test scores and measures of college readiness and student progress, "underserved students at this school may be falling behind other students in the state, and this school may have significant achievement gaps" (Great!Schools.org, n.d.). This beautiful, culturally rich, and, in some vital ways, resource-poor community is the site for our study, where teachers from outside this community considered how local culture could be centered and sustained in and through ambitious science teaching. In this way, they sought to address equity and justice-centered aims of expanding science to include these students' ways of knowing as scientific and using the science they learned for positive ends in and beyond school.

4.2.2 | Sorrus summer camp and teacher education programmatic structures

The participants of this study were nine master's students engaged in the Authentic Science Education (ASE) teacher preparation program, eight of whom are White, one identifying as having Mexican heritage, and 78% identifying as female, generally following the national trends of 80% White and 77% female (National Center for Educational Statistics, 2023). ASE is a 15-month, master's level teacher education program. As a program committed to social justice, ASE consists of five stages, the first two of which are the focus of this study: PSTs experience justice-centered science teaching as learners in a rural community; they use those experiences to design and implement a week-long summer camp for youth from that community; they design and implement a 2-month afterschool urban community; they engage in formal classroom-based field experience and student teaching; and they use evidence from these experiences and other coursework to construct a programmatic portfolio. Thus, ASE engages future teachers in learning-to-teach experiences outside of school with culturally diverse students from predominantly marginalized communities concerning race and social class as developmentally necessary precursors to learning-to-teach in the high-stakes contexts of student teaching. These outside-of-school teaching experiences are intentionally situated in communities likely unfamiliar to masters' students (i.e., a rural context in the summer and an urban one in the fall) to provide explicit instruction about what it means to teach youth from cultures different from one's own by prioritizing relationships, engagement, and student interests over standardized "achievement" measured in ways common to schools (Luehmann, 2007). While these and other non-dominant ways of being and learning are emphasized and supported, we stopped short of naming them as anti-racist and anti-oppressive. Helping PSTs understand that this approach to teaching is anti-racist and anti-oppressive and, thus, is essential to meeting the needs of students from marginalized communities (Gay, 2018; Ladson-Billings, 1995; Nieto, 2001; Paris & Alim, 2014) would likely have been more effective in explicitly supporting them in seeing these practices as important for classrooms as well as camps.

The nine masters' students worked in teams of three through two university courses over two summer quarters to design (Summer A) and lead (Summer B) a 6-day science camp for middle school youth in Sorrus. Programmatic structures were established mostly by the university teacher educators with input from Sorrus partners to support the mission of ambitious science teaching that was also justice-centered (see Table 1).

During ASE's first masters level university course in Summer A, preservice teachers (PSTs) experience justice-centered ambitious science teaching as learners in the local and social context of Sorrus. Instructors model an "anchoring phenomenon routine" (e.g., Penuel & Watkins, 2019), supporting PSTs in creating individual and consensus scientific models of phenomena local to Sorrus (e.g., how Sorrus biodiversity is evident or not through its soundscape). PSTs conduct original science investigations that they feel would be meaningful to the local community in the spaces of Sorrus. That said, knowing we are outsiders and that our relationship with Sorrus is a partnership designed to support their youth and community, we meet annually with a board of advisors that consists of former campers, school board members, parents, Sorrus teachers, local business owners, farmers, and others to ask their advice on what phenomena they would like us to focus on this year (Luehmann, 2022). Running parallel to these place-based experiences, PSTs also read and discuss chapters of the Ambitious Science Teaching book (Windschitl et al., 2018) as well as readings that inform justice-centering (e.g., Avery, 2013; Brown, 2006; and Settlage & Southerland, 2012). In these and other ways, masters' students are supported in experiencing and learning justice-centered ambitious science teaching practices, such as choosing an anchoring phenomenon that would be meaningful to the community. Before the camp, other programmatic elements include engaging in a member check of science camp ideas with Sorrus sixth graders and participating in a round-table teacher conference with Sorrus teachers focused on drafts of camp plans. The camp plan that masters' students design is to be guided by the notion of T.E.A.M. (Teens Engaged in Action that Matter).

Supported by a second six-week university course during Summer B, PSTs implement the camp. Sorrus practicing teachers serve as teaching assistants and collaborators for the masters' students. After each camp day, each team debriefs pluses (successes) and arrows (intended changes for next time). The implementation of the camp follows a temporal arc similar to the authentic work of ballet studios or science labs (Heath, 2001): setting goals, iterations of practice and revisions with reflections, and intense preparation for and implementation of a final public performance, in this case, of the science and its implications for the community where

TABLE 1 Programmatic structures of the summer components of the authentic science education teacher preparation program.

Programmatic structure (academic context; timing; and ambitious science teaching quadrant)	Description	Purpose
Camp preparation		
Science in Place (various Sorrus locations; mid-May, Summer A, AST1)	PSTs designed and conducted a short-term empirical study related to something they believed might be important to the community in the physical spaces of the community.	Nurturing a thoughtful choice of topic that might be meaningful and developing familiarity and appreciation for places in Sorrus as sites of scientific and social inquiry
Community Advisory Panel (Sorrus administration building, late May, Summer A, AST1)	Engagement with a group of 12 community members including youth, school board members, community stakeholders, Sorrus youth program leaders, and others. PSTs share their ideas for summer camp phenomena through "Posters of Possibility" and invite a gallery walk and graffiti wall writing in which all in attendance add their ideas for 1) relevant places; 2) community resources and expertise; 3) empirical data that could be collected; 4) related contributions youth could make to the community using the science they will learn.	Listen to stories of local residents to cater science foci, develop understandings of and appreciations for local culture, and develop a nuanced perspective of what it means to choose a culturally sustaining ambitious science focus.
Sixth-grade member check (Sorrus classroom, mid-June, Summer A, AST1)	PSTs share their ideas for camp along with the findings from their locally based empirical study in interactive ways with small groups of sixth-grade students at Sorrus Junior High School. One format used is the sharing of a PowToons video PSTs created highlighting the science they conducted in Sorrus so far.	Develop more nuanced understandings of the group of youth they will serve through summer camp—including things like their energy, interests, and ways of being together. Continue to learn about local culture through student ideas and stories.
Round-table teacher conference of camp plans (Sorrus, late June, Summer A, AST1)	PSTs share their camp plans with diverse stakeholders for feedback including local Sorrus teachers, administrators, community members, former program PSTs, and others.	Explain the storyline of camp in a way that continues to invite local feedback and catering from people who know the youth and the culture.

(Continues)

TABLE 1 (Continued)

Programmatic structure (academic context; timing; and ambitious science teaching quadrant)	Description	Purpose
Professional Development Day (Well-loved Farmer's Market in Sorrus, half day, two days before camp starts, mid-July, Summer B; AST1)	Teachers partner with local Sorrus science teachers as co-leaders of each camp team to collaboratively wrestle with what culturally sustaining and ambitious pedagogy looks like day to day in their camp plans and future implementation.	Collaboratively share the vision for camp that PSTs have been developing the previous 6 weeks and work collaboratively to make final preparations for camp.
Camp implementation & reflection		
Expo Day (Sorrus school yard, Day 1 of camp, Summer B; AST2)	Day one of camp involves each group of teachers leading all campers in interactive stations around their lab team's focus. After youth experience all possible options, they are invited to rank order a) their favorite science to work on, b) their favorite fellow scientists to work with, c) which of these two matters most to them. These preference cards are used to assign youth to teams for the remainder of camp.	Nurture enthusiasm and a sense of intrinsic motivation for the science that will be the focus of the camp. Elicit a broad range of student ideas, prior experiences and knowledge related to the science that can be used to continue to shape lesson plans and implementation in culture-setting ways.
Field Experiment Day (Various Sorrus locations, Day 2 of camp, Summer B; AST3)	Day two involves all participants traveling to a location in Sorrus that holds prominence and meaning to the community. Each team plans empirical investigations for youth to conduct in these spaces, the data from which will continue to be used for the reset of the week.	Begin camp with a team of particular youth in spaces where they are the experts; places of which they likely have different stories and experiences. Being outside a classroom invites diverse participation that allows PSTs to see youth as having varied and important differences in the ways they express themselves and engage in the work. The outdoor space and hands-on nature of empirical work can foreground relationship-building and creativity.
Public Showcase and T.E.A.M.—"Teens Engaged in Action that Matters" (Sorrus school gymnasium, Day 6 of camp, Summer B; AST4)	On the last day of camp, camp teams engage the public in interactive stations to share and teach others about the science and action they took in the community. The camp mantra of *T.E.A.M.* challenged	Supporting youth in authoring the what, why, how, and "so what" of science requires connections to be made across activities as well as stages of science. PSTs are given the opportunity through a showcase to

TABLE 1 (Continued)

Programmatic structure (academic context; timing; and ambitious science teaching quadrant)	Description	Purpose
	campers to go beyond scientific findings to enact and share a positive change using those findings. Attendees to the showcase include family members, local school personnel, community members who became collaborators in the work, former PSTs, families of PSTs, local press and others.	experience the important role that recognition plays in science learning for youth as well as for their own identity development.
Daily Teacher Debrief (Sorrus classroom, each day after camp, Summer B)	Every day after the camp, the PSTs and local practicing teachers participated in teacher debriefings. Naming the strengths and possible ways to improve, each participating teacher reflected on trends in their team as well as across teams.	Have support from peers and faculty to interpret practice using JuST as a lens as well as deliberate implications for changes in future practices.
Final Zoom Recording Reflection (Zoom, early August, Summer B)	The co-teachers of each camp meet on Zoom a week after camp to debrief the overall experience. Individually, they prepare for this recorded conversation by collecting evidence to share in response to the question, "In what ways were you able to effectively implement ambitious science teaching that was culturally sustaining?"	Collaboratively sensemaking about their abilities to capitalize on this out-of-school teaching experience to enact JuST practice. Accountability to professors related to understanding and evidence of both ambitious science teaching and culturally sustaining practice.

guests, including local members of the press, were invited. At the end of the camp, a full group teacher reflection and celebration is held over a meal at a local landmark restaurant. A week following camp, teacher teams use recorded video calls to share evidence and their interpretations of their efforts to implement justice-centered AST lesson plans and develop authentic connections with students. They also reflect on their experiences by creating blog posts about their experiences (Luehmann & Borasi, 2011).

4.3 | Data collection

In this multi-case study (Yin, 2014), data were collected throughout teachers' engagement with authentic activities of the teacher education program. Specifically, as mentioned, as PSTs puzzled over how to center and sustain local culture through the different sets of AST practices and tools, they engaged in place- and community-based scientific inquiry, lesson planning, and debrief sessions with in-service teachers and course instructors. Throughout this process, the research team amassed a large collection of qualitative data sources, including (1) recordings of conversations among teachers and their supporting personnel (approximately 1 h for each of six sessions), (2) daily lesson plans created on shared Google Docs, including comments and revisions from multiple stakeholders in the process, (3) artifacts from teaching in the field including photographs, quotes from student participants, and audio recordings of student dialogues, (4) recorded video calls of debrief sessions for each teacher team, highlighting program successes and needs for improvement from each teachers point of view, and (5) community feedback, including a local news story, gathered through a community showcase day. We used recorded video debrief sessions and lesson plans as primary data sources in the data set. The video debriefs involved the participants reflecting on how they perceived their camp to be equitable, using supporting evidence collected from their teaching to support their claims. They responded to the questions: (1) How did you include culture and students' home lives? (2) How did you use technology (including for equity)? and (3) What are your three overarching pluses and arrows? Other data sources were utilized as secondary data for data triangulation. While the PSTs used the debriefs to share their camp highlights, the lesson plan allowed us to understand how they planned and enacted their teaching daily.

4.4 | Data analysis

Digging into the work of sensemaking and storytelling, the research team began analysis with thematic coding of the data using a focus on the four core sets of AST practices (see Table 2) as well as emergent codes related to culturally sustaining pedagogy, which allowed us to quickly identify the data relevant to the research questions (Saldaña, 2016. p. 98). For instance, AST 1-PLAN (Ambitious Science Teaching quadrant one—planning) was used to capture PSTs' practices related to identifying an anchoring phenomenon, describing goals and objectives, or designing and organizing activities.

Emergent codes for CSP included units of action in which teachers created opportunities to engage youth in disciplinary learning by capitalizing on their unique identities and framed community assets as specific resources for scientific investigations. "Resources-Linguistic," for example, was used when students were able to use Spanish, a minority language in the town, to engage others in their speech community around the work of scientific data collection and communication. "Disciplinary engagement and recognition" drew our attention to moments when teachers or students recognized youth's unique contribution to their own or collective science learning. A set of codes around "Change" identified ways teachers supported youth in using the science they were learning to make a difference in the community. These codes were used to label extensions of scientific study in service of community work, such as the student-led design and creation of a sign meant to explain a lake ecosystem and deter littering.

Using this codebook, the team evaluated transcriptions of multimodal teacher debriefs and reflections. We divided our research team into two pairs who worked on coding different categories. Within the pair, the two researchers worked separately and then came together to compare their codes, after which the whole team checked and negotiated the coding again. Through this coding structure, our team identified moments in which teachers overlapped AST practices with the work of culturally sustaining pedagogy. We searched for ways that teachers

TABLE 2 Ambitious science teaching codes and examples.

Code	Definition	Sample coded text
AST1-PLAN: Planning for engagement with important science ideas	Three core practices make up this quadrant: identifying big ideas; selecting an anchoring event and essential question; and sequencing learning activities	"I think the first way we did that *was through our anchoring phenomenon*. What we chose to study was through a question the students asked when a couple other teachers went to Sodus to talk to them. They were interested in studying why Stink Bugs were in their community."
AST2-ELICIT: Eliciting Student Ideas	Three core practices make up this quadrant: Eliciting ideas and activating prior knowledge; helping students represent their thinking publicly; and adapting further instruction.	"My thought was that *we were using the students' questionings while they were doing that activity to drive us toward our anchoring phenomenon*, students were discussing if they saw stink bugs indoors, which allowed us to investigate where they are inside and why they are there."
AST3-REVISE: Support ongoing changes in thinking	Three core practices make up this quadrant: introducing new ideas; engaging students in activity and sense-making; and collective thinking.	"One of the teachers told us early on or I had heard from one of the teachers at collaborative conversations that some of the older kids called the water in drainage ditch Jesus Water [Air quotes] … Better than Gatorade? electrolytes? This is a little bit worrisome given that this water coming from parking lot and off of an orchard… *But I did try to point out, especially to these older kids that might have been on these sports teams, hey, we are testing this water … is this water good to drink? Nooooo, no its not…*"
AST4-USE EVIDENCE: Pressing for evidence-based explanations	Three core practices make up this quadrant: co-constructing a gotta-have checklist; pressing for gapless explanations and models; and assessing for understanding.	*"In pressing for evidence, we asked them to draw on their own opinions and experiences to support or negate the claims they were making*. Like in the debate, students were bringing up, "In my garden, this happened… Or, my dad told me this… they had to build upon their own observations. We were not just giving them the information; they had to build upon that."

were able to engage science content, teaching strategies, and a meaningful approach to community engagement within the same lesson and exploration. As we identified moments of conjunction between AST and CSP, threads of stories began to emerge.

In each team project, we created a case study that enabled us to see how teachers negotiated the complexity of science teaching in situ. Then, through comparative analysis across cases

(Lichtman, 2013), we located the commonalities across the three cases to identify sets of core practices that build on and extend AST in culturally sustaining ways.

5 | FINDINGS

Teacher teams designed the steps of each camp team's learning journey in ways that connected with local people, places, and things that held meaning for the student's lives. We present the findings first as narratives for each of the three camp team's learning trajectories, capturing how teacher teams worked with their campers to realize their understandings of ambitious science teaching that was culturally sustaining. Following the overviews of each camp team's experience, we present findings from cross-team analyses to identify practices common across the three teams that built on ambitious science teaching practices in ways that were culturally sustaining.

ExStream Team: On the ExStream Team, the journey began at the home base of the schoolyard. Pre-service teachers (PSTs) led open-ended discussions with students about why water quality might matter to town life. Students listed activities that connected to the valuable resource of clean water. Mina, a PST, described this process as deliberately "eliciting students' ideas." In a reflection activity, she recounted students' responses to her eliciting question:

> 'Is there a reason you'd want to know if water was polluted or clean?'… Some of the things they were thinking about were fishing, swimming, [and] a lot of students want to know if we could drink the water, even though that wasn't something that we were exclusively talking about, and so that was … bringing students' background knowledge from their everyday culture into the reason why our investigation mattered.

The responses revealed students' knowledge and gaps in knowledge about Sorrus's water supply.

Soon, open-ended conversations about local uses of the water uncovered a critical mystery for students at the school. As it turned out, water from a nearby drainage ditch had been dubbed "Jesus Water" by a group of middle-grade students on the school's competitive sports teams. Students had heard about a ritual of hazing in which student-athletes drank this water—deemed to be "better than Gatorade"—to embolden their performance on the sports field. The PSTs talked to local practicing teachers and soon corroborated the rumor. This story set the stage for the camp's investigation. Susan, one of three teachers, explained how a complex stance of double inquiry, merging local culture with scientific implications, required a delicate balance, a balance between validating students' experiences and validating scientifically accurate ideas with research.

> This is a little bit worrisome given that this water coming from the parking lot and off of an orchard… so I tried not to talk about this too openly around the whole class because I didn't want to give the younger kids the idea to drink it if they haven't already. But I did try to point out, especially to these older kids that might have been on these sports teams, "Hey, we are testing this water … is this water good to drink? Nooooo, no, it's not"… And I was explicit about that because I was aware of it as an aspect of their culture.

Not all local culture is worthy of sustaining (Paris & Alim, 2014). In this case, a scientific perspective shaped teachers' commitment to supporting youth in challenging an element of local culture for the safety of themselves and their future students.

Teachers led youth to take a step back and explore this scenario from a watershed perspective. As they evaluated GIS maps and engineered contraptions to send a GoPro up in the air for aerial photography, they studied the flow of water and drainage. From these experiences, students began to see local water from new perspectives, informed by the practices of science and their identities as scientists. Susan explains,

> They really loved the opportunity to see… "Oh! Let me see if I can see my own house; oh, that's what school looks like from the sky." All of that kind of perspective they don't normally get… [Aerial photography] also was able to show us that the drainage ditch fills right here, and it ends right here.

Students soon found that the so-called "Jesus Water" actually contained a variety of roadwork and agricultural bi-products due to the position of the ditch and process of run-off rainwater collection. Water quality testing work positioned students of the ExStream team as local experts.

The journey of the ExStream team was both virtual and real. Students traced their fingers across watershed maps and built aerial rigs to take their photos (virtual), as well as walked out of the classroom to local destinations to try new tools for evaluating water quality (physical). Instead of entering the group as experts, teachers learned to use the scientific probes alongside their students, co-constructing identities around scientific points of view situated in local spaces and stories. The teachers learned that facilitating inquiry within a framework of student experiences and local phenomena meant using deliberation and observation (studying watershed maps and using scientific probes) to come to collaborative, informed answers about the campers' "Jesus Water" mystery.

Their journey's pathway soon led to Miller Pond, a local fishing site, where the group began to "see" the water in a new way. Mina described this process as a design challenge of making the work "not just hands-on, but minds-on." The team worked together again, using probes to understand how water data connects to the local practice of fishing. In reflection, Susan explains:

> [A] very important piece that I want to discuss was the Vernier lab quest … a field-testing piece of equipment. You've got this little monitor, and you can use probes of different kinds. We used the turbidity probe. You just put a vial of water in, and it measures the turbidity or clarity of water. High turbidity means not very clear. And then here is our optical DO [dissolved oxygen] probe, which … tells us how much oxygen is in water based on light that can go through it, which blows my mind … So, we were testing the macroinvertebrates and looking at the plant communities.

Soon, teachers and students together found that Miller Pond, unlike the "Jesus Water" drainage ditch" was home to a healthy ecosystem. Together, they renamed salient aspects of the ecosystem. "Fish food" became shorthand for macroinvertebrates, and students realized that community action for clean water would support the fish yield for the whole town. One teacher reported:

> When we got there, they saw some trash that was along the bank, and so they saw the trash and also found that the water was relatively clean, and didn't come up as polluted in our tests, and had pretty sensitive organisms living in it … So the kids really wanted people to keep it clean, and we really wanted to support that as a main goal. And I'm really proud of that. And we're looking forward to getting this sign up that's kind of the work of the next couple of weeks, the closing up work that we really need to make sure that we do is get that sign up … so yeah [reads] "We don't trash your home, so don't trash ours. We live here." We put a picture of the Ex-Stream Team as well as a picture of the organisms.

Together, the ExStream Team took up their camp charge to be "Teens Engaged in Action that Matters" by designing and posting a sign for Miller Pond to encourage collaborative action around clean water.

Every journey requires a home base and a destination, but the journey itself has the potential to change our understanding of what we see and our ways of seeing along the way and at the finish line. In other words, culturally sustaining science can lead to powerful surprise endings. A common complaint of the students was that Sorrus, a small agricultural community, was not an important or interesting place. However, the process of enacting scientific inquiry changed the value of the place in the students' perspective. Teacher Susan explained:

> All of our locations and sample sites were in Sorrus. Something that [local teacher] Candy, our cooperating teacher, said at one of the end-of-the-day meetings was that she thought some of the kids can't wait to get out of this town and don't like Sorrus. So, seeing Sorrus as fun, where you can do something and make a difference—and actually see the cool parts of the town like the beach or the pond, or seeing that you can do science there is—like-useful. And I think that is kind of the planning and engagement side of our teaching.

Science engagement in their community challenged and positively changed their relationship with their hometown, so much so that they positioned themselves as advocates for its care.

Stink Squad: The second team in our program embarked upon a global journey to understand a local phenomenon: stink bugs were causing damage in gardens and crop plants. *Halyomorpha halys*, commonly known as stink bugs, are an invasive species hailing from Asia. They were discovered in New York state in 1998 and quickly spread through the mid-Atlantic region, feeding on a variety of crop plants. The annoying pests also release a distinctive smell likened to the smell of coriander. Not only is their stink annoying, but it's also been estimated that stink bugs have led to the destruction of about $40 million in U.S. apple crops per year (Roberts, 2012).

The work of the teacher team involved beginning with a local anchoring phenomenon identified by local farmers, namely how an invasive species functions in a new environment, and deftly directing students' curiosity toward research questions that could lead to the next steps for research design. Students, already familiar with the species, had many questions about the bugs. As Natalie, one of the PSTs, explained:

> The overarching phenomenon we observed, prompted by Sorrus's student questioning, was that different bugs live in different places. We steered students from initial

> questions such as "Why do stink bugs smell bad?", "What do stink bugs eat?", and "Why are there so many stink bugs in Sorrus?" toward a more investigable question: "How are stink bugs affecting Sorrus, and what can we do about it?"

Natalie's reflection highlights a key consideration for culturally sustaining scientific investigations: anchoring phenomena tied to local stories and cultural meaning allowed for braiding together concepts from disciplinary science with meaningful local questions to apply the science understandings in service of community-wide discussions about a particular problem. This braiding move facilitated a process in which students' experiences, and the experiences of their families and friends, became points of evidence in the ongoing investigation.

Teachers designed Day One's Expo station work to involve youth working with natural materials found around Sorrus to build the ideal habitat for a stink bug. The station space included colorful materials about invasive species. While building, teachers sat next to campers and probed their understandings and stories related to stink bugs specifically and invasive species more generally. Smiles, laughter, and other evidence of relationship-building emerged, such as using names and having extended conversations.

Next, the student scientists and their teachers engaged in a hands-on project that focused on investigative design. Leaving the schoolhouse for the afternoon, students embarked on their journeys to collect bugs at locations around the town and in their backyards. Students set bug traps at areas with which they were familiar: a crop field next to the school, a science lab inside the school, and sporting fields. Then, using a bug collection jar, they brought their process of data collection home with them after camp, and many returned the next day with collected specimens and reports of how they engaged their family members in conversation about the bugs and the bugs' impact on their backyards and gardens.

Movements around the community were soon followed by a journey into a novel community, that of citizen science. The teacher team set up the iNaturalist app (iNaturalist, n.d.), a crowdsourcing network that allows citizen scientists to upload images of species, as well as observations and discussions. These uploads then become part of a larger data set collected and analyzed by all app users. Sorrus campers each took and uploaded five photographs of their samples to the app. In so doing, they and their local data contributed to ongoing conversations between botanists and entomologists engaging in projects to study and control the invasion. This virtual journey supported the students' awareness of the movements of the species population across the United States. Through contributing to a larger citizen-science investigation, their research was not just a matter of their learning but also a connection point to the world of experts and novices. Pre-service teacher Natalie describes this shift—from bystander students to engaged scientific investigators and communicators through their work with iNaturalist:

> The most interesting thing that I could see was that students in Sorrus could connect to a greater scientific community through the app. Through that connection, they could see themselves as scientists, I hope. Just by logging pictures they were taking and observations they were making and seeing some of the data collection that goes into the actual science they were doing.

In this project, a physical journey of species sampling and data collection led to a new digital community for them.

As the students gathered new stink bug samples and acquired new expertise, teachers invented participation structures that facilitated new forms of knowledge exploration and use.

Working together, the class created multimedia data charts to map the different ecosystems and where the stink bug lives. As a team, the teachers decided on the shared goal of engaging every student in scientific argumentation around a potential intervention to address the stink bug population growth. Using a teacher-created cartoon to communicate key elements of a published scientific study, the teachers led a "popsicle stick debate," in which each student was given three wooden sticks representing one turn of speech. Each student had to voice arguments for either the for or against teams on the question: "Should Sorrus introduce a natural predator, a species of wasp, to try to control the spread of the stink bugs?" The debate structure enlivened participation from every student scientist, including the shyest and most boisterous students equally, to the local mentor teachers' joy and excitement. One teacher recounted:

> And then, in pressing for evidence of the students, we asked them to draw upon their own observations and experiences to support or negate any of the claims we were making. Like when we were, like with the debate, and the students brought up things like "Oh, in my garden..." or "My dad told me this." So, they, you know, they had to build upon, again, their own observations. We weren't just handing them information; they had to build it for themselves. I feel like we did a really great job on that.

Student experiences counted as data and were used alongside other scientific understandings as evidence to support claims and arguments.

Throughout their journey, the student scientists of the Stink Squad team explored real and virtual communities and learned how scientific knowledge gained through direct experience could lead to powerful community communication and informed strategies for improving the local economy. The connections of people (campers) to their places (e.g., fields, backyards) were scientific, personal, and relational. These connections, driven by the priority of understanding and minimizing the harmful impact of non-native species, drew on the insights gained through local experiences to motivate and inform both local and global understandings.

Loyal to Soil: On team Loyal to Soil, students and teachers turned a tasty local treat into the object of scientific inquiry. The camp planning process began during a pre-program advisory panel with potential summer camp students and other community members. One potential camper asked the group, "Why do strawberries purchased at the grocery store taste chemically?" The teacher team took up this question as their camp focus and immediately engaged local mentors in helping them find accessible sites where this initial question could be converted into a full-scale experiment. The team drew upon community connections to engage the staff of Beauford's Farms, a well-known local farm and farmer's market. This place was home to many personal experiences for the campers and adults alike—a restaurant for meals, a store for local fruits, vegetables, and honey, an active strawberry farm, and a pillar of the community.

The local community, rich with agricultural resources, offered many meaningful possibilities for designing student science. In a reflection moment, one teacher stated:

> I felt we did prioritize students' home culture. Farming is such an important industry in Sorrus, and working with the Beaufords showed students that science can take place in their home culture where they live... Their farms are valuable, and they are lucky to have such fresh fruit right by them.

Following the lead of one young person's question led teachers' designs to industries and businesses that were important to the community.

Day two of camp involved spending the day in the different strawberry fields of Beauford's Farms. Here, student scientists were able to use their role as cultural insiders in Sorrus to connect with local experts, including the farm staff.

> The next thing is that, while we were on the farm throughout the day of the camp, we asked students for their experience with knowledge of farming. And because we came here, some other students had farming experience, we capitalized on that. And ... particularly able to serve as an expert, just include some of the knowledge they were sharing about why strawberries in one place can taste different from others (Riley).

Farming experience and expertise were that of the community, including the youth. This expertise was not shared by the teachers who approached the context as scientists in a new lab space. After flipping the typical power structures of classrooms on its head, teachers were ready, even eager, to listen to, learn from, and build upon student expertise to shape future aspects of the curriculum.

As the farm manager explained the process of planting the field and nurturing the strawberry crop, Arturo, an immigrant hailing from Mexico, apologized to the students, saying, "My English isn't so great." Eustice, a bilingual student in the camp, began to engage Arturo in an animated fashion using Spanish. During the tour of the farm and fields, the duo had a lengthy interaction using Spanish about the practice of farming cherries, highlights of which Eustice offered back to the group. Through accessing their cultural knowledge, such as language fluency, as core to culturally sustaining scientific work, students were able to braid together their identities in the community with their identities in science learning. In this way, the bilingual students on the team brought collective assets to the life of the project and supported their mono-lingual teachers and the whole class in achieving a greater understanding. As Buxton and Lee (2023) write, "Student engagement in varied forms of classroom discourse, interactions, multi modalities, and registers while doing and learning science points to the sweet spot where science and language intersect in mutually supportive ways" (Buxton & Lee, 2023, p. 296). The camp team's multilingual learners brought all of the team into this "sweet spot."

Students' braiding of community and science cultures and identities allowed them to see new possibilities. Teacher Oliver highlighted how students took up the place-based science and imagined future possibilities:

> When we visited Beauford's Farms, students were explicitly saying, 'You can do this in your backyard.' There were moments where the science became extremely connected to both Sorrus and potentially what they have at home, which was really, really cool.

It is important to note that this type of student agency can either be encouraged, discouraged, or ignored by teachers, the result of which can have powerful implications for students' science identity (Bang, 2021; Suárez & Otero, 2023; Warren & Rosebery, 2011). In this case, Oliver's enthusiasm assures us that student agency was met with appreciation and support.

This lab team collected soil samples from different fields on the farm and brought them back to camp for further analysis. While donning lab coats, the youth evaluated each of two soil samples collected from opposite sides of the farm to measure pH, phosphorus, nitrogen, and potassium. They compared their findings to the range of ideal levels for strawberry growth the teachers provided:

> Students felt like scientists at multiple stages of our experience, whether it was in the field, in the lab, or wearing lab coats. We consistently aimed to reinforce this by calling them scientists or referring to other students in their group as scientists or lab team members (Oliver).

One student was seen using her phone to video record herself conducting the analyses. When asked why she was recording, she said she wanted to show her mom how she was doing science.

As a complement to the soil tests, Loyal to Soil engaged in a more personal form of data analysis. Soon after tabulating the findings from a blind taste test in which Beauford's Farms' "great" strawberries competed against those from the grocery store, the results of the study were in, and it was time to report back to the community. The team found that the local Beauford's strawberries were sweeter, the clear preferred choice of a blind taste test. Findings were "published" at the public showcase on the last day of camp, a room filled with school administrators, families, local media, and many others whose identities were unknown to the students. A local television news outlet picked up the Loyal to Soil students' research and profiled the work of student researchers and the farm itself. With the compelling headline "Sorrus Science Students Explore Why Some Strawberries Taste Better Than Others" and lively photographs of the students conducting research on the farm, the work of the team was celebrated by local reporters.

> The work we did mattered to Sorrus, and one of the cool takeaways is that it is now published by [local news station]. That taste test revealed that Beauford's food is better than store-bought food. That might be obvious to people living in Sorrus. I thought that was really awesome action we didn't even anticipate happening.

This novel human interest story may have encouraged local consumers to visit Beauford's and buy local produce as a superior tasting option to that which was shipped in from far away. In this way, students honored their new science connections with the farm staff, local teachers, and collaborators with expertise to share.

5.1 | Cross teams findings

Looking across the team data, we now consider how teachers' commitments to culturally sustaining pedagogy shaped their implementation of each of the core sets of Ambitious Science Teaching (AST) practices. Table 3 highlights the braiding work that emerged as PSTs were supported in enacting Ambitious Science Teaching in ways that were culturally sustaining.

5.1.1 | Core practices set one: Planning for engaging with big ideas (AST1) and developing local networks to learn and center local culture (CSP1)

Instructional planning that meets the aims of AST involves identifying big ideas, deciding on anchoring phenomena that motivate students' learning, and sequencing lessons in a way that builds specific explanations (Windschitl et al., 2018). Considering this charge through the lens of being culturally sustaining was realized by identifying important science ideas for students to engage with that were also important to the community. In addition, teachers anticipated ways students could use their science to make a positive difference.

TABLE 3 Emergent practices that braided ambitious science teaching with culturally sustaining pedagogy.

Ambitious science teaching (AST) (Windschitl et al., 2018)	Culturally sustaining pedagogy (CSP) (Paris, 2021; Paris & Alim, 2014)	Braided practices
Planning for engagement with important science ideas Eliciting and working with students' ideas Supporting ongoing changes in students' thinking Pressing for evidence-based explanation	Centering local culture Intentionally sustaining or enhancing that culture Recognizing individual contributions to the community Critiquing cultural norms and values to take actions that matter to the community. Critically centering a dynamic local culture Recognizing and inviting expertise from the local community to which the science is held accountable Cultivating a reciprocal relationship with the local community and its land. Attending to the possible internalized false beliefs that local practices and selves as minoritized people are not valued in educational settings.	Planning for important science ideas that are also important to the community and anticipating ways students could use their science to make a positive difference. Using connections to local places to elicit student ideas embedded in stories of their experiences. Using these experiences to shape future inquiries and legitimize the stories as data for scientific argumentation and sensemaking. Supporting ongoing changes in thinking through place-based scientific engagement done in collaboration with local stakeholders. Highlighting scientific expertise from the community and the value of other aspects of local cultural wealth to nurture students' local pride and care. Expanding the audience for science to include and center the community. Scaffolding youth scientific storying by using creative strategies that merge their cultural resources as youth, their community resources as insiders, and their scientific resources as investigators; encouraging students to use their scientific experiences to enact positive change and care for their community. Building relationships with youth and community to center culture while maintaining criticality when needed.

Programmatic structures (see Table 1) that supported this work included the PSTs conducting a science investigation in local places, pitching and integrating ideas for anchoring phenomena to a community advisory, and planning for campers to make meaningful and relevant contributions to the community through science. Centering scientific and cultural phenomena that were motivated by local priorities and places positioned teachers and the science lessons they created to be accountable to culturally sustaining ambitious science teaching.

For Stink Squad, an adult advisory panel member who was a local pesticide supplier guided the team to plants and places likely to be affected most by stink bugs that were also within walking distance from school. It's important to note that the networks PSTs built served to link people (e.g., pesticide suppliers and campers) with places (e.g., particular sections of fields that bordered forests) through particular priorities (e.g., reducing the impact of stink bugs as an invasive species). Another resource for this team was the county's Soil and Water Management team, specifically one specialist who worked with a teacher team in the same camp a few years before address a different invasive species problem affecting Sorrus, the water chestnut. Thus, through this person and organization, teacher teams from across years and cohorts connected. Using the expertise of their expanded group of local learning partners, youth wrestled with the complicated factors of addressing one invasive species problem without causing new problems.

ExStream Team's networks were youth-centric. After hearing the "Jesus Water" story from youth and having that story confirmed by teachers, the team centered on the drainage ditch as the geographical focus of the study. Exploring the local watershed using Google Earth (n.d.) (http://earth.google.com) added camper's homes and points of interest to considerations of water flow and quality. From there, one camper described Miller Pond as his hang-out place and wondered if the pollution around it impacted the quality of the water. The team took up this inquiry, and after cleaning up the litter and testing the water, they found a healthy ecosystem. Having invested in the importance of the water in Sorrus, the campers tapped into the passion for Miller Pond and its health by creating signs for visitors advocating for them to care for this valuable part of the ecosystem of which the campers were a part. Network-building for this team, again, connected places, people, and priorities, nurturing historical and interconnected understandings of science and culture. Science learning was motivated by something more meaningful than creating evidence-based explanations (AST4); it was motivated by using those evidence-based explanations to sustain, even produce, local culture in youth caring for local waters.

Loyal to Soil's phenomenon identification incorporated a mix of youth and adult community input. While the question about why grocery store strawberries tasted chemically was presented by a youth member of the advisory panel, the selection of Beauford's Farms as the place chosen for the lab team's scientific work was the result of a community leader agreeing to share her property and expertise. This particular farmer and land owner then facilitated the development of an inquiry-driven social network that included her parents (former owners and soil specialists) as well as a long-time hired worker, all of whom shared expertise for different elements of the overall inquiry. One valuable result of the inquiry was a public honoring and acknowledgment of the contributions of the farmer, her business, and thus, the community.

Teachers who do not share the same cultural background with their students, like those in this study, must first be learners of local culture. Teachers in this study began by learning from local people, places, and practices. Using what they learned, they either selected an anchoring phenomenon that was locally meaningful (i.e., stick bugs or soil studies) or connected a more general anchoring phenomenon (i.e., the importance of water to Sorrus) in ways that were personally meaningful to youth (i.e., "Jesus water"). Connecting to local priorities naturally introduced a purpose for the science youth would learn, offering them potential ways to use their science to make a positive difference.

5.1.2 | Core practices set two: Eliciting student ideas (AST2) and legitimizing local stories (CSP2)

Eliciting students' ideas involves activating learners' prior knowledge, helping learners present their ideas and stories publicly, and using what is shared to tailor further instruction

(Windschitl et al., 2018). All learners have experiences and ideas that connect to any given science instructional goal; drawing out these experiences and ideas invites both learners and facilitators to use these resources for sensemaking (e.g., Moll et al., 1992; van Niel, 2010). Considering this charge through the lens of being culturally sustaining was realized by physically and conceptually engaging students with local sites and artifacts to elicit their ideas embedded in stories of their experiences. Using these experiences to shape future inquiries and legitimize the stories as valid and valuable resources for scientific argumentation and sensemaking, teachers underscored the usefulness of local experiences for science while expanding what counts as science in important ways, in ways that include often silenced populations.

Teachers in this study first elicited campers' prior experiences with the phenomena through the programmatic structure of the Camp Expo. Expo Day included hands-on stations with microscopes to investigate local water, taste tests of fruit grown in neighboring soil, and gathering materials from the town's state park to build a potential stink bug habitat. As campers rotated through each station, they experienced a sampling of all three teams from which they could choose to join, while teachers elicited the widest possible collection of student stories and ideas. Place-based artifacts (sticks from local trees, fruit from the farmer's market, and water from the nearby lake) held cultural connections for youth. Teachers engaged each group of campers with energy and attentiveness, sitting next to them, using names, asking probing questions, and documenting what they learned.

Teachers used what they learned from youth to shape future inquiries. In Loyal to Soil, the conversation between the camper and the farm worker laid much of the foundational, site-based knowledge the team would draw from as they made sense of their soil study findings the next day in the lab. In ExStream Team, one camper's stories of his favorite fishing pond became the destination for a walking field trip and water quality study. Stink Squad campers used their local knowledge to choose sites for their study of the prevalence of different insects in different locations.

Beyond using student stories to inform how teachers approached or scaffolded instruction, teachers welcomed them as valid and useful sensemaking tools. Specifically, campers used their own experiences as data to support arguments for an invasive species debate, as relevant background to justify decisions when designing a soil experiment, and as claims in the construction of explanations for what may have contributed to water testing results. Expanding what traditionally counts as "evidence," teachers' recognition of student experiences in this way served to honor their value in and for science, expanding and thus enriching the science that was learned.

5.1.3 | Core practices set three—revising thinking across inquiries (AST3) by drawing on local place and expertise (CSP3)

The third set of AST practices involves teachers in supporting students' ongoing changes in thinking by introducing new ideas, engaging students in activities and sensemaking as well as collective thinking (Windschitl et al., 2018). Considering this charge through the lens of being culturally sustaining was realized by designing and conducting science investigations in local spaces and drawing on community-based expertise. Teachers supported campers' ongoing changes in thinking through place-based scientific inquiry done in collaboration with local stakeholders. Highlighting scientific expertise from the community and the value of other aspects of local cultural wealth did more than effectively support the development of scientific understandings; it served to nurture local pride and care.

Loyal to Soil partnered with Beauford's Farms to learn soil chemistry from a 40-year expert. Collecting soil samples from different fields, they followed up with their own empirical investigations. ExStream Team began with a Google Earth-supported study of their local watershed to investigate the myth of a student-driven phenomenon of drinking from the "Jesus Water" drainage ditch. Concluding that "Jesus Water" was unhealthy, they set out to explore Miller Pond based on the recommendation of a camper who lives near it. Using probeware and other water quality measures, they concluded Miller Pond was healthy despite the trash they encountered. Finally, leaning on the expertise of a local pesticide provider alongside a soil and water conservation expert, Stink Squad collected and identified insects and their habitats around the school building and their homes. These shared place-based experiences and data collection efforts afforded future investigations that were physically (through samples), intellectually (through investigative design), socially (through the networks of shared expertise they developed), and culturally (through the language and priorities of Sorrus) connected to the community (Saracino, 2010), positioning youth (Thompson, 2022) as well as community members as experts. During varied learning experiences, the campers' local community changed campers' scientific understanding, and, in turn, their scientific understanding changed their respect and care for the community.

5.1.4 | Core teaching practices set four—constructing Evidence-Based explanations (AST4) in Service of Making Positive Change (CSP4)

The final set of AST practices involves teachers helping students draw together evidence-based scientific explanations (Windschitl et al., 2018). Considering this charge through the lens of being culturally sustaining was realized by expanding the audience for the science to include and center the community and challenging teams to use their science to make a difference in their community. Teachers in this study scaffolded youth scientific storying for an outside audience by using creative strategies for youth to share science in ways that merged their cultural resources as youth, their community resources as insiders, and their scientific resources as investigators. In addition, they encouraged students to enact positive change and care for their community based on the implications of their science.

Creating evidence-based explanations implies an audience for those explanations. The focus of the camp's public showcase was T.E.A.M.—Teens Engaged in Action that Matters. This focus defined the core of this audience to extend beyond teachers or other camp participants. Family members, local youth, including those from the program, teachers, and administrators, were familiar faces at the public showcase, while university graduate students, former camp teachers, and members of the local press comprised the broader "public" in attendance. Thus, campers' scientific work was recognized by a broad array of "significant narrators," people whose opinions matter to them (Sfard & Prusak, 2005). Thus, science was held accountable to the community instead of the other way around.

Not unlike a performance for a dance studio, preparing to share one's work publicly involves a certain amount of intense preparation and readying (Heath, 2001). The showcase of both science and cultural sustainment required teachers to prioritize instructional time and resources to scaffold youth science storying for an outside audience, specifically their community and beyond. Storying is a natural way of creating connections across ideas while also considering the needs and interests of the listeners. The showcase for all three teams involved youth leading interactive experiences that they had experienced as learners. These sets of stations communicated the components of a larger storyline including what was studied, what was learned, why it mattered, and what could be done with what was learned. Evidence-based explanations were mediated by youth-created artifacts, merged youth with scientific language, and were communicated through interpersonal interactions.

In addition to the science, campers from two groups left a physical mark on their community. For the ExStream Team, this was a sign at Miller Lake. For Loyal to Soil, this was a thank you poster displayed at Beauford's Farms and a local article featuring the strengths of this local resource. Science invited youth to see what was familiar to them with new eyes and positioned them to be advocates for their local places and communities.

5.1.5 | A practice that cut across quadrants

Teachers committed time and energy to building trust and relationships with youth to open and facilitate ongoing lines of communication and intellectual risks taking. Separate from any of the core quadrants of AST, teachers described intentionally using "downtime" to get to know about learners' lives. "Talking to them as people," teachers inquired about how many siblings they have and what they do for fun. Teachers described this practice as resulting in what they referred to as "teacher capital," a resource they could draw from during instruction in the future. As students shared their experiences and expertise, teachers used their interpretive power (Rosebery et al., 2016) to mark, legitimize, and celebrate youth stories and identities as meaningful and worth knowing. It is important to note that while centering culture and community was important to teachers, they also maintained criticality when needed (i.e., ExStream Team teachers related to drinking "Jesus Water" from the drainage ditch).

6 | DISCUSSION

6.1 | Toward a justice-centered framework

Returning to Philip and Azevedo's (2017) articulation of the four equity discourses (EQD1 Access, EQD2 Authentic Science, EQD3 Challenging Science, and EQD4 Using Science for Positive Change and Justice), it becomes clear that culturally sustaining ambitious teaching offered an opportunity to move past the version of equity promoted by AST alone and toward social justice. Specifically, the ways in which the teachers enacted AST in culturally sustaining ways offer powerful examples of ways in which science was conducted to sustain local culture. This braiding of the cultural and scientific ways of knowing resulted in three team investigations that were place-based, community-informed, and publicly recognized. The programmatic camp element of "Teens Engaged in Action that Matters" challenged teams to consider ways in which science served a greater purpose than academic learning. These findings demonstrate that more radical and transformative science education is possible, though there is always more to do. Combining these findings with the critical work of justice-centered science educators cited earlier, we offer a justice-centered ambitious science teaching (JuST) framework that provides a set of core practices for planning and implementing rigorous and authentic science education while importantly aligning with the theoretically more critical elements of equity work.

Ambitious Science Teaching effectively addresses Philip and Azevedo's (2017) Equity Discourses 1 and 2, namely giving all students access to effective and rigorous learning (EQD1) through engagement in authentic science and engineering practices that can nurture science identity development (EQD2). The framework we describe builds on the strengths of AST and extends this framework to support the critical work of expanding what counts as science and using science and science learning for positive change. Identifying the strengths and limitations of teachers' implementation in this study in light of the research on justice-centered science teaching, we share core elements of this structure as a JuST framework. Note that, like AST, the JuST Framework is not intended to be a prescriptive set of steps for teachers to follow; instead, it is shared as core sets of justice-centered teaching practices to support the realization of transformational changes for the benefit of marginalized communities and the world as a whole.

6.1.1 | JuST 0. Building a community that is welcoming, joyful, and critical

The foundation of justice-centered teaching, present in both these findings and the literature on justice-centered teaching, is building a learning community through joy-filled interactions and relationships—a community in which youth know their voices, ways of being, values and feelings are valued. Building a learning community that was welcoming, joyful, and critical began through Expo stations on the first day of camp. Laughter was prioritized through taste tests, silly promotional videos, and circle-up recognitions. A recent study by Leung and Cheng (2023) reminds us of the importance of emotions in learning, especially as they relate to sociscientific issues such as the concepts our camp teams took on. Relationships were built as PSTs sat next to youth and encouraged them one-on-one using students' names, attending to youth emotions, engagement and reactions. Justice-centered science teaching requires developing a community with both one's "classroom" of students but also with the community they call home. Teachers in this study demonstrated the ongoing and emergent development of social and place-based networks that allowed them to understand local culture and, when necessary, critically engage with it (e.g., drinking the "Jesus Water" from the drainage ditch). As Ballard and colleagues (2023) highlight, the peopled work of community-based science serves to transform what counts as science: "As the practice centers the relational work of learning from people and place, doing science expands beyond doing knowledge and practice" (p. 1618). We refer to this focus on relationship-building in service of understanding, sustaining, and, when needed, critically considering local culture as the groundwork of all JuST practice, and as such, name it JuST 0 (see Figure 1, center).

Another important understanding of "critical" is the need to develop and support students' development of critical consciousness (Freire, 1970). In this case, the inequities of the group were those faced by rural communities, many families of whom live in poverty, the collective of whom have been marginalized in science and science education (Eppley, 2017). Having course readings and discussions (e.g., Avery, 2013) to honor the unique strengths typical of rural communities while warning of stereotyping "common" characteristics of the non-existent "typical" rural community, teachers complemented their strength-based perspectives of Sorrus by learning from community leaders who truly love their community and their youth.

6.2 | Equity discourse four (EQD4): Science for positive and just change

The top hemisphere of the JuST Framework focuses primarily on Philip and Azevedos'(2017) EQD4, as teachers plan for and enact science learning that students use to make a positive difference and enact social transformation. These practices establish the purpose of science

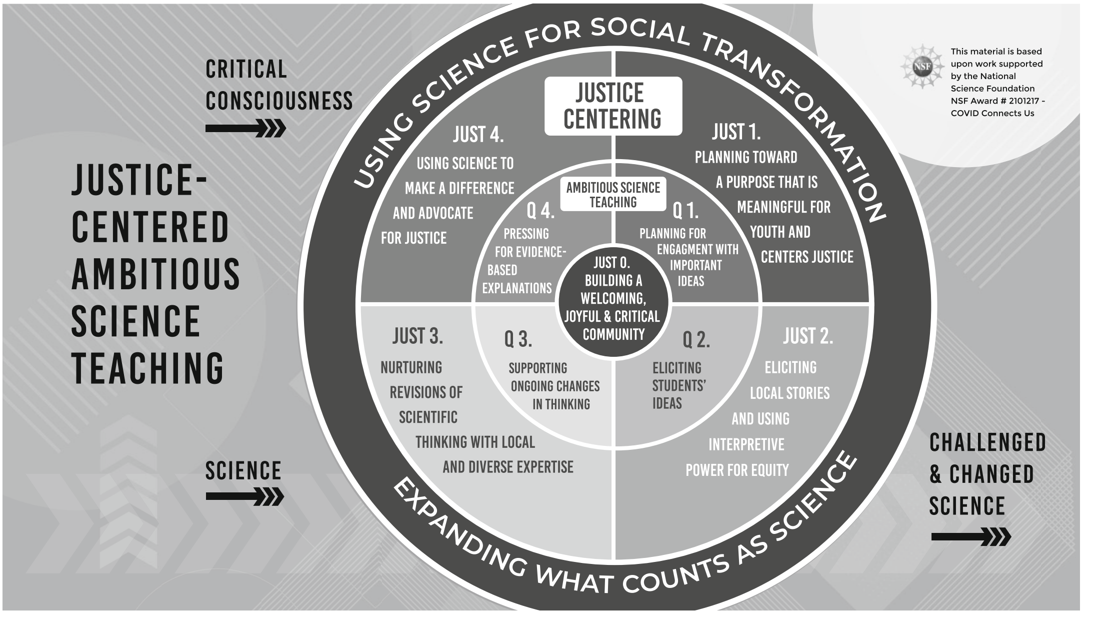

FIGURE 1 Justice-centered ambitious science teaching framework about here.

education to extend beyond the accountability measures of a classroom, erasing the need for students to plead for answers to the age-old question, "Why do we have to learn this?" Science and science education can and needs to be used for positive change.

6.2.1 | JuST 1. Planning for engagement with important ideas in ways that are meaningful to youth and center justice

Teachers in this summer program planned to end the endeavor of teaching science in ways that were notably different from AST. PSTs embarked on a double inquiry of cultural learning and science learning, braiding the two together. This braiding practice required teachers to seek out ways of learning culture from the people, places, and histories of Sorrus, discerning pedagogically valuable footholds for further study (Kang, 2022). Sometimes, these footholds came from youth (e.g., "Why do grocery store strawberries taste chemically?") and other times from community leaders (e.g., stink bugs are a local, problematic invasive species) or local places (e.g., the main form of recreation and tourism in the water around Sorrus).

In addition, a commitment to community action as the primary curricular aim (i.e., a particular kind of performance-based assessment) sensitized teachers to critically and thoughtfully consider ways in which the science education experience could be used to sustain local culture. The commitment to identifying ways to reduce the impact of invasive species such as the stink bug as well as caring for the invaluable resources that water and soil are to Sorrus were evident in the three team names: Stink Squad, ExStream Team, and Loyal to Soil.

Though a shortcoming of this study, this change work needs to engage youth in identifying and addressing related justice-related concerns. Youth need support in seeing injustices in the world and the role that science does or could play in addressing these injustices. Nurturing students' critical consciousness is an important aspect of preparing them for participation in civic reasoning and discourse (Lee et al., 2021; Zucker & Noyce, 2020). Research has shown that taking on justice-related issues can be a powerful support for both motivation and achievement for students from marginalized communities (El-Amin et al., 2017).

6.2.2 | JuST 4. Pressing for and using evidence-based explanations for positive change and social transformation

At the end of camp, students cycled back to larger narratives embedded within meaningful local and regional networks. They did more than sustain local culture; they helped to produce culture by contributing meaningful story points (e.g., debunking the myth of the power of "Jesus Water") to the mesh of ongoing narratives about local life and the resources that sustain it. The final showcase stood in stark contrast to typical science school-based assessments, building and extending beyond the evidence-based explanations AST supports. Posters of graphs, re-creations of empirical investigations, and demonstrations of scientific data collection tools supported youth in communicating their science to people who matter most to them, nurturing their identities as scientifically competent. A common question asked of the youth was, "So what does this science mean for the problem you chose to study?" By moving beyond conclusions, youth were prepared to consider implications and act on them. Through investigating the local and grocery strawberries, Loyal to Soil told a story about how Sorrus strawberries tasted better, which was covered in the local news. ExStream Team found out that the Miller Pond was a perfect home for the ecosystem, so the youth created and put up a sign to call people's attention to protect the local water as a production of their learning. For Stink Squad, their utilization of the app iNaturalist allowed the young scientists to contribute to a conversation among a broader scientific community engaging in projects to study and control the invasion by sharing local science stories. Considering implications and acting on them positioned youth as the transformational intellectuals they are (Morales-Doyle, 2017), people who are capable of contributing meaningfully to their culture.

Through their braiding of the needs and resources of the community with the affordances that science could offer, PSTs engaged and involved their youth in the "taking action" parts of critical consciousness. In this way, the work of advocating for rural communities was shared between "culturally powered" (local administrators and school board members, university graduate students and faculty) and youth. Sustaining culture—sustaining minoritized and often invisibilized cultures—is an important form of social transformation. Focusing on and amplifying the scientific and cultural strengths of the rural community of Sorrus is certainly its own form of activism. In this case, the youth's scientific understanding and action for their community resulted in a sense of community pride that was unexpected by the local teachers who have worked with these youth for many years. This, itself, is arguably an important form of social change. In addition, youth using science to celebrate local culture in very public ways could also have powerful impacts on families, the school, the community, and beyond.

That said, teachers' critical consciousness, in this case, stopped short of calling out the inequities many rural communities, including Sorrus, face in the larger discourses of science and society. Rural communities often suffer from documented health disparities, educational disparities, and a lack of multilingual resources for the community (Rural Health Information Hub, 2022). Though the teachers in this study were successful in honoring and using local culture to shape science in meaningful ways, they did not support youth or families in developing their own critical consciousness as advocates for Sorrus in the larger science or societal landscape. The phenomena teachers chose did not have a clear connection to justice. Morales-Doyle (2017) writes about the importance of working with the community to identify social justice science issues (SJSI) (dos Santos, 2009) that invite students to use science for justice. Sheth (2019) found that though an in-service teacher focused a science unit on a critical phenomenon, namely investigating science related to the impact of a Superfund site (toxic waste dump) on local water systems, he chose to stay very close to the science content, missing opportunities to support youth in critically considering the health and economic costs to the communities of Color that live near these sites. Thus, even when teachers can identify a meaningful SJSI, they may need support to know how to use science learning for justice-focused work.

6.3 | Equity discourse three (EQD3): Expanding what counts as science

The practices in the bottom hemisphere of the JuST Framework focus primarily on Philip and Azevedo's (2017) EQD3. As teachers elicit students' stories and learn from student experiences and local places as cultural elements that can be used as resources for ongoing inquiry, teachers can support students in expanding currently limited perspectives of what counts as science. In addition, learning from youth allows the learning community to sustain both youth and heritage cultures.

6.3.1 | JuST 2. Eliciting local stories and using interpretive power for equity

When pressed and supported to engage in AST in ways that aligned with CSP, teachers needed to learn more than science ideas from their students; they needed to learn about the cultural contexts in which those science ideas were understood. During the Expo on Day 1 of camp and beyond, teachers created scenarios and activities that invited student storytelling about what stink bugs need in their habitats, how students know when soil is considered good for planting, or what water around town is safe to drink. These stories provided more than an isolated science idea. Noticings and wonderings, a common approach in phenomenon-driven inquiry, is an approach to elicit student ideas, but if they remain abbreviated as something that can be captured on a post-it note, the cultural context will likely be lost. This contextual richness and its connection points can be lost. Thus, such abbreviations for minoritized youth can be far worse than unfortunate—they can be damaging and dangerous.

Warren and Rosebery (2011) tell a powerful and illustrative story about a white teacher who confessed that when a young Black student in her class offered a wondering about the possible cause for a particular germinating bean being magic, she initially considered that his form of engagement might have been inappropriate, possibly disrespectful. Instead of dismissing or correcting him, something told her to ask him to "tell me more." Drawing out more context allowed this teacher to identify rich conceptual insights that meaningfully contributed to collaborative sensemaking. Highlighting this "interpretive power" that teachers have in deciding how much energy and time to invest in any given contribution, the authors of the paper underscore the importance of using this power with extreme care and intentionality to elevate and learn from the ideas, insights, and experiences that students, especially those who have been marginalized by schools, are willing to share, with sufficient sensitivity to ensure that they are not further victimized in schools.

6.3.2 | JuST 3. Nurturing revisions of scientific thinking with local and diverse expertise

A commitment to CSP-shaped AST3 practices focused on "supporting ongoing changes in thinking" by both physically and conceptually honoring local culture. Place-based science investigations for all three teams naturally blended science aims with those of elevating and sustaining local culture. ExStream Team's scientific study of Sorrus water nurtured a sense of community pride and activism that shocked local teachers who knew the youth to have an attitude of disdain for the community. Formal recognition of place-based scientific expertise for Loyal to Soil, which included local farm workers, both owners and hired staff, can nurture students' enhanced appreciation for the excellence found in one's own backyard, literally and figuratively. Local stakeholders, including "my dad," the county's conservation department, and a long-term farm worker, all shaped the scientific claims that campers made. Engaging local culture (place, people, history, and other aspects) in the ongoing investigations holds science accountable to lived experiences and offers science educators more resources to support youth in navigating understandings from their different communities.

6.4 | Alignment among Equity-Focused frameworks

Existing equity-focused theoretical and curricular frameworks intended to inspire, guide, and support justice-centered science education align with the core elements of the JuST pedagogical framework that we put forth in this paper. Ensuring access to the "culture of power" (Delpit, 1988, 1995), the JuST Framework explicitly builds on Ambitious Science Teaching and thus supports teachers in engaging youth in collaborative sensemaking through science and engineering practices to develop rigorous scientific understandings and positive identities. In addition, the JuST framework offers teachers practices to engage their students in honoring diverse ways of knowing as they critique and potentially expand what counts as science, as well as use science learning for positive change, including in service of explicit justice projects in the classroom, community, and beyond. The core practices of the JuST framework explicitly align with the theoretically more critical elements of equity work outlined in the theoretical and curricular frameworks of Morales-Doyle (2017), Morales-Doyle et al. (2021), Banks (2013) used by Mensah (2022), Mensah et al. (2018), and Patterson and Gray (2019) described earlier, who, in turn, ground their work in the foundational works of Freire (1970), Gee (2003), Ladson-Billings (1995) and others. Thus, by centering transformational equity practices, the core practices of the JuST framework address Philip et al.' (2019) critique that core practices do not explicitly center justice.

In addition, the practices of the justice-centering aspects of the JuST framework come from PSTs' braiding of the *theory* of culturally sustaining pedagogy with the *practices* of ambitious science teaching. In this way, the JuST Framework also addresses the critique that many equity frameworks are primarily theoretical and lack actionable footholds for teachers new to justice-centered teaching to enact and practice. The JuST Framework is unique in its attempt to identify core justice-centered teaching practices that are theoretically grounded, empirically supported, and actionable.

7 | IMPLICATIONS

The work described in this study is the result of a long-term community-university partnership that was thoughtfully nurtured (Luehmann, 2022). Though many core programmatic structures remain constant year after year (e.g., advisory board meetings to choose a camp theme, PSTs doing science in Sorrus and sharing their work with sixth graders, and the one-week camp), others are adjusted as needed by either partner. The programmatic structures supported PSTs in learning a culture unfamiliar to them from the youth and other Sorrus community members as well as local places, helping them center this culture in their instruction. Adopting the learner role before the teacher role required PSTs to adopt a sense of cultural humility that is necessary if, as O'Neill et al. (2023) argue, science learning is to "move beyond building new doorways to old knowledge systems." These authors argue for driving the culture of STEM education to focus on

> (1) strengthening teachers' and students' sense of belonging by building a connection to place(s) that tethers them to the *'āina* [land/earth]], (2) developing a sense of humility that enables participants to elevate the knowledge of the place and its people first, and (3) empowering learners to engage in real-world problems solving as a reciprocal rather than transactional process (p. 1781).

Some of the programmatic structures outlined in Table 1 emerged as much more important than others for these three teams. Specifically, the advisory panel of diverse Sorrus stakeholders, as well as the time spent in the places and with the people of Sorrus during Summer A, allowed PSTs to develop social- and place-based networks that they were able to honor, sustain, and draw on for resources and expertise during camp. The science and pedagogy were centered on the priorities of the community. Starting camp with Expo Day was an important opportunity for PSTs and youth to do active, physical things together, which proved to be valuable for relationship-building. Finally, the mantra of "Teens Engaged in Action that Mattered" sensitized PSTs as well as campers to work with the community to identify how the work done through the camp could sustain, even produce, local culture.

As Morales-Doyle (2017) points out, "Out-of-school science offers more expansive and authentic experiences than is possible within classroom settings" (p. 5). This study demonstrated some of what is uniquely possible in an out-of-school context, including spontaneous trips to Miller Pond, a large adult-to-student ratio, and the opportunity to truly follow emergent leads like the study of "Jesus Water" without consideration for state-level expectations. Building on the work of Nasir and Hand (2008), the ASE program was intentionally designed to capitalize on the rich identity-building resources uniquely available in authentic work that most often occurs in outside-of-school time (Luehmann, 2009, 2016). These learning experiences simultaneously support youth development of science identities and teacher development of justice-centered and ambitious professional identities, both of which expand on and challenge what is available through school science. That said, as Morales-Doyle (2017) has demonstrated in his work with high school classrooms and Mensah (2022) showed in her work in elementary classrooms, authentic justice-centered work that partners with the community is also possible in the classroom. Though it is more challenging given time and accountability constraints, challenges that need to be faced institutionally and not left to individual teachers to navigate, one might argue that it is only through JuST practice in schools that true transformation in and through science education can be realized. Students engaged in compulsory education wisely call their teachers to task with the reasonable and essential question, "When are we ever going to use this?" Learning has important purposes; it's time we connect the practices with purposes in schools that youth find meaningful and that prepare them for civic discourse now and for their futures (Lee et al., 2021; Zucker & Noyce, 2020).

Regarding teacher education, this study agrees with a finding by Mensah (2022) regarding the importance of merging methods courses with field placements. PSTs in this study were supported in planning, interpreting, and reflecting on justice-centered pedagogy in this field experience through simultaneous coursework during which they studied asset-based approaches to science education. It is also important to remember that this study is only the beginning of a 15-month science teacher education program centered on social justice. In the Authentic Science Education (ASE) program, this study spotlighted the first two of five stages of JuST development: namely, experiencing JuST practice as learners in a culture typically marginalized and one that is different from one's own (stage 1), and engaging in JuST practice as teachers in a low stakes, highly supported context (stage 2). The next three stages are just as critical: engaging in JuST practice as teachers in an urban afterschool club where one must negotiate new norms for science in a classroom space and learn the culture of students more quickly than the summer (Stage 3); student teaching that builds on confidence and commitments gained so far, where university support is decreased but still present and accountability is increased (stage 4), and the authoring of one's beliefs, accomplishments and commitments with evidence from their rich array of experiences in the ASE program in the format of a professional portfolio (stage 5; Author). Camp is but one step of many in setting a teacher's professional compass firmly on JuST identity; follow-through is necessary for other field experiences, including student teaching and, ideally, into and through induction years and beyond.

8 | LIMITATIONS OF THIS STUDY

As teacher educators, we did not explicitly center race and language, two core aspects of culture and pillars of CSP. As it was the preservice teachers' first experience with JuST practice, the priority of camp instruction centered on hearing and honoring youth and community voices and using science in service of projects deemed meaningful by community members, including youth. PST teams explicitly and intentionally countered many white supremacy norms by prioritizing process over product, honoring a broad diversity of forms of communication, supporting the demonstration of learning through performance-based methods instead of perpetuating the over-privileging of writing, engaging in relationship-building, team identity, and collaboration over individual accountability, nurturing joy over academic gains, and prioritizing nature-culture relations (Sanchez, 2023) over the need to label things such as water as good or bad. Though race and racism shaped the interactions in other ways as well, given the early stage of this work for preservice teachers, we chose to focus on the culture of youth and their community living in a rural area.

Another limitation of the study has to do with the science-centric focus of the camp. The projects in Authentic Science Education (ASE), not surprisingly, center on science; "We are doing science!" campers chant multiple times a day in a circle-up. Though we explicitly take on social justice science issues, we could more intentionally explicate the limitations of science to address complex, often global challenges such as "why strawberries from the grocery store taste chemically."

9 | CONCLUSION

The justice-centered practices of Culturally Sustaining Pedagogy shaped Ambitious Science Teaching in ways that required teachers to thoughtfully braid canonical science with community culture. Teacher education support for community-driven science provided tools for teachers' engagement and positioned them as listeners of local stories, locators of local science, and collaborators with local expertise. Building relationships with both the people and places of Sorrus was central to the work. As the teachers drew upon the AST framework using CSP theory, their camp teams collaboratively imagined and enacted investigations that were valuable to and valued by a diverse rural community, expanding their understanding of what science is known, how it is conducted, and for what purposes. Using CSP to shape the AST framework allowed us to propose a JuST framework that could support the challenging tasks of transforming science, science education, and social inequities at large. The teachers' creative braiding of local culture with science in service of equity aims offers important insight into the ways in which the AST framework can center justice.

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CONFLICT OF INTEREST STATEMENT

There are no known conflicts of interest to disclose.

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