JRST | WILEY

"I sit here thinking I can do this"—Developing justice-centered ambitious science teaching identities in professional learning communities

Hannah Cooke[1] | Todd Campbell[1] | April Luehmann[2] | Yang Zhang[3] | Déana Scipio[4]

[1]Department of Curriculum & Instruction, University of Connecticut, Storrs, Connecticut, USA

[2]Department of Teaching and Curriculum, University of Rochester, Rochester, New York, USA

[3]School of Education and Social Policy at Northwestern University, Evanston, Illinois, USA

[4]Graduate and Higher Education Programming, Islandwood, Bainbridge Island, Washington, USA

Correspondence
Todd Campbell, Department of Curriculum & Instruction, University of Connecticut, Storrs, CT, USA.
Email: todd.campbell@uconn.edu

Abstract

Explicitly attending to justice in science teaching and learning is long overdue. Here, we examined the professional teacher identity development of 13 science teachers as they collaborated in networked professional learning communities (PLCs) to implement and revise a culture-setting unit focused on the science of COVID and engaging in collaborative inquiry cycles to identify and refine justice-centered ambitious science teaching (JuST) practices in classrooms. These JuST practices are conceptualized as a synthesis of justice-centered pedagogies and ambitious science teaching. To accomplish our research aims, we drew on qualitative methods, where we relied on transcribed video recordings of 21 PLC meetings and three transcribed end-of-year focus group interviews of two PLCs (i.e., 13 secondary science teachers, mostly white) across a year-long period. As a result of our analyses, we identified how professional learning arranged through PLCs, culture-setting units, and collaborative inquiries supported professional JuST identity development by, among other

affordances, providing space for the critical and emotional work of learning to discuss race, affording teachers strategies for getting to know their students and the assets they bring to classrooms, and recognition and positioning of teachers as professionals capable of identifying or developing, refining, and contributing to knowledge about JuST science teaching and learning. Challenges identified included, among others, identifying how the culture-setting units could be effectively integrated into existing curriculum maps and the uneven implementation support from administrators. In the end, what is revealed helps better conceptualize how engaging teachers in PLCs around tasks like curriculum implementation and refinement or collaborative inquires support professional JuST identity development and how such experiences can be more carefully negotiated.

KEYWORDS

justice-centered teaching, professional learning communities, professional teacher identity, teacher professional development

1 | INTRODUCTION

As science teachers continue to adjust to the changes called for in the Framework for K-12 Science Education (NRC, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013), the COVID-19 pandemic illuminated several ongoing crises including police brutality, anti-CRT (Critica Race Theory) laws being passed, the disproportionate access to health care for racialized and low-wage ("essential") workers, and the continued climate crisis. While our current system of white supremacy did not originate with the onset of COVID-19, these events demonstrate the urgency of dismantling our racist system both in the context of society more generally, and in and through science teaching and learning more specifically.

Even before the pandemic, some scholars critiqued the way in which science education research interprets equity as access to a culture of power either through increasing student achievement or drawing on students interests to increase learners′ connections to science (Barton & Tan, 2020; Louis & King, 2022; Philip & Azevedo, 2017). While access is important, Philip and Azevedo (2017) pointed out how access to the "culture of power" (i.e., science as it is currently constituted) is entangled with unjust societal structures (e.g., inequalities in school funding and learning conditions). Others have problematized the objective, neutral, and binary thinking characteristic of "Western" science (e.g., Bang et al., 2018; Law, 2015; Madkins & McKinney De Royston, 2019; Nxumalo & Gitari, 2021) that contribute to domination, exploitation, power, and privilege. Further, science has been implicated in racial classification, oppression, enslavement, resource extraction, and pollution that disproportionately impact

Black, Indigenous, and People of Color (BIPOC) communities (Morrison et al., 2020). Given this hurtful and unethical reality, researchers like Morales-Doyle (2017), Philip and Azevedo (2017), Rodriguez (2015), and Tzou et al. (2021), among others, call for more expansive equity discourses in science education that challenge what is legitimated or not as science and that positions science as an intersecting disciplinary and sociopolitical pursuit (Mensah, 2013; Tolbert & Bazzul, 2017; Waight et al., 2022) aimed at social transformation capable of addressing racial inequities.

Most science teachers learned science as objective, noble, and apolitical, but this innocent version of science and science education is being contested (e.g., Melville et al., 2022; Tolbert & Bazzul, 2017; Verma et al., 2022; Waight et al., 2022). This shifting landscape repositions teachers as perpetrators or disruptors of the status quo, and many are reconsidering who they are and what they want to become as they recognize the problematic history of science and exclusionary practices of science education. Previous researchers have conceptualized these seismic transitions, like becoming a reformed-minded science teacher, in connection with professional teacher identity development (e.g., Beauchamp & Thomas, 2009; Beijaard et al., 2004; Luehmann, 2007; Moore, 2008). Here, professional teacher identity development, like identity development more broadly, has the following common characteristics: "identity is socially constituted ... is constantly being formed and reformed ... considered to be multifarious ... consisting of a number of interrelated ways one is recognized as a certain kind of person ... [and] constituted in interpretations and narrations of experience" (Luehmann, 2007, p. 827). Relevant to this current research, Luehmann (2007) described the challenges inherent in narrating a new professional teacher identity, like becoming a reform-based science teacher in her study or a justice-centered ambitious science teaching in our current study, while also hinting to possibilities for dealing with such challenges in the following:

> The initiation process of trying out one's "wings" as a reform-based science teacher is a daunting and risky process that should be supported by offering motivating and "safe" places where one can try out the new identity. (p. 835)

To deal with such daunting and risky challenges, among other possibilities, professional learning communities (PLCs) have emerged as a lower-risk space for trying out and developing new identities. PLCs represent a place where identity can develop as groups of teachers collaborate to make changes to their practice and become agents of change (Friedrichsen & Barnett, 2018; Leonard & Woodland, 2022; Nelson, 2009; Wright et al., 2019). Further, researchers like Thompson et al. (2019) and Slavit and Nelson (2009) describe how PLCs, at their best, create space and support for pursuing questions about learning goals, instructional practice, the interrogation of student data, and connecting teaching to theoretical propositions-all possible activities for trying out, narrating, and recognizing new teacher identities. Given the documented potential of PLCs to provide valuable learning spaces for teachers, and acknowledging the problematic discourses typical of science education research, we (i.e., science education researchers/authors) engaged teachers in networked PLCs as part of a multistate professional learning initiative to conceptualize justice-centered ambitious science teaching (JuST) and identify, develop, test, and refine JuST practices as part of supporting our own and our teacher collaborators' professional justice-centered ambitious science teaching identity (JuST identity) development.

We conceptualize JuST as a synthesis of justice-centered science pedagogy (Morales-Doyle, 2017) and the sets of high-leverage practices of Ambitious Science Teaching (AST)

(Windschitl et al., 2018). Justice-centered science pedagogy positions learners as agentic and prioritizes social justice science issues as phenomena to study (Morales-Doyle, 2017). In addition, and more specifically, justice-centered science pedagogy as articulated by Morales-Doyle builds on critical and culturally relevant pedagogy oriented toward social transformation. Critical pedagogy in this framework is grounded in the work of Paulo Freire and involves students understanding historical and political conditions reified in current inequitable social contexts and involving students in action and reflection aimed at social transformation (Freire, 2001 as cited in Morales-Doyle, 2017). Culturally relevant pedagogy (Ladson-Billings, 1995) is also foundational to Morales-Doyle's justice-centered pedagogy as it rests on ensuring that students (a) experience academic success, (b) develop and maintain cultural competence, and (c) develop critical consciousness to challenge the current inequitable social order. In Morales-Doyle's work, he reports how justice-centered science pedagogy assumes that inequity in science teaching and learning is the most important problem in science education and is a problem that is historically and politically rooted. In this prioritization, he identifies the following as important for justice-centered science teaching that contests this problem: (a) curriculum organized around social justice science issues at the intersection of social, political, and scientific phenomenon and relevant in local contexts, (b) equitable academic expectations connected to the canons of science to ensure further opportunities in educational institutions, and (c) students as producers of knowledge and culture in ways that are generative for producing new ways of doing things (Morales-Doyle, 2018).

AST is rooted in practice-based teacher education and offers a set of core practices for science teachers to maximize science learning (Windschitl et al., 2018). AST offers specific classroom strategies aimed at honoring students' lived experiences. Specifically, AST positions students to engage in the practices of science to make sense of natural phenomena (Kang & Windschitl, 2018). Central to AST, students' ideas and experiences are elicited and treated as valid resources for reasoning with others as part of collaborating and critiquing understandings of science concepts and explanations of how things happen in the natural world (Windschitl & Stroupe, 2017). AST and other practice-based teacher education frameworks find their value in how they provide preservice and inservice teachers concrete practices to rehearse as part of developing a vision for what ambitious forms of teaching looks like (Kang & Windschitl, 2018). While a tremendous step forward as a framework for supporting science teaching and learning, Luehmann et al. (2024) noted how, "lacking in both the Next Generation Science Standards and the AST practice framework, however, is attention to ways science is limited in its practices and science education is limited in its outcomes" (p. 322). These shortcomings are seen when science and science education typically prioritize the aims of the dominant culture, while marginalizing, misrepresenting, and invisibilizing others.

JuST builds on the advantages of practice-based teacher education connected to how concrete practices can be named, rehearsed, and shared to support developing teachers' visions about what can be accomplished in science classrooms. At the same time, in connection to justice-centered science pedagogy, JuST is committed to curriculum organized around social justice science issues connected to the canons of science, as well as pedagogy that positions students as critically conscious producers of generative knowledge and culture (Morales-Doyle, 2018). In the end, our synthesis across justice-centered science pedagogy and AST leads us to define JuST as science teaching that is grounded in critical consciousness, responsive to students' cultures and communities, dependent on teachers' interpretive power to recognize and build upon expansive forms of student meaning-making, and committed to naming and disrupting oppression and injustice in society (Luehmann et al., 2024).

Focusing on professional JuST identity development, the purpose of the current study was to interrogate the ways in which professional learning in PLCs and the tasks undertaken therein influence the development of professional teacher identity as JuST practitioners in the first year of our multistate initiative. As teachers participated in networked PLCs, they attended professional development (PD), implemented a JuST culture-setting curricular unit, and engaged in research of their own practice. Consequently, the following question guided our research: What are the affordances and challenges of PLCs and their tasks for supporting professional JuST identity development? More about our research context and design is shared after we review relevant literature about PLCs and identity development.

2 | RELEVANT LITERATURE: PLCs

Applying social learning theory to PD, teachers benefit from collaboration with their peers to make changes to their practice (Friedrichsen & Barnett, 2018; Larkin et al., 2009). PLCs are one model of collaborative PD that offer support for teachers to refine their practice and become agents of change (Friedrichsen & Barnett, 2018; Nelson, 2009), as they narrate and recognize new potential identities. To be effective, PLCs need infrastructure to support teacher collaboration and learning, rather than simply sharing anecdotes (Nelson, 2009). Drawing on research of high-functioning PLCs, Thompson et al. (2019) note that these PLCs engage in the following practices:

> systematically pursue questions of learning goals and instructional practices, reason with student data, and connect general teaching principles and theoretical understandings to specific classroom instances [and discuss] (1) working theories of teaching and student learning, (2) teaching practices and classroom tools, and (3) practical measurements using students' experiences as data. (p. 2)

Given these prioritized practices, PLCs offer teachers' time and space for productive co-learning, while reducing the isolation common in teaching.

In some cases, PLCs respond to top-down measures, such as the implementation of new standards. For example, Friedrichsen and Barnett (2018) studied a PLC of biology teachers that had been effectively working together without a facilitator for years (before the study), but that needed to follow a district mandate to align the biology curriculum to the NGSS. The success of this PLC stemmed from the informally assigned, mutually agreed upon roles that each member held based on their strengths as well as the creation and use of tools. In the end, this PLC successfully altered their view of science education to be less about the memorization of facts as they revised assessments to include a focus on science and engineering practices. In their study on teachers implementing *Common Core State Standards*, Porter et al. (2015) found that PLCs provided time for needed professional collaboration. Additionally, Drew and Thomas (2022) studied PLCs consisting of science teachers, special education teachers, and other school staff to improve disciplinary literacy in secondary science classes. The study's focus was on a specific tool that the team used, the Disciplinary Literacy Observation Tool, to integrate literacy and science instruction. They argued that PLCs' strength is in the opportunity for collaborative work. Because our participants were provided with a culture-setting curricular unit intended to offer teachers a shared experience to begin the school year, we drew on the literature around PLCs collaboratively implementing curriculum. Specific to this research, we define

culture-setting units as a short unit made up of lessons used to build a critical and caring community at the beginning of the school year. Importantly, the lessons within the unit can be adapted to local contexts. More details about these units are provided in our methods section.

Other PLCs have used particular structures to explicitly support teacher research or inquiry. Slavit and Nelson (2009) found that collaborative teacher inquiry provided a rich context for teachers' learning and growth. Collaborative inquiry (CI) is a cyclical process situated in a socio-constructivist perspective (DeLuca et al., 2015). Thompson et al. (2019) created structures to facilitate "experimentation with classroom practices and school-to-school learning" (p. 2), examining the specific starting points, or "footholds," of individual PLCs and the patterns of how PLCs began their work. Drawing on literature about "network improvement communities," their networked PLCs followed learning loops to systematically investigate their focal teaching practice in the context of a linguistically diverse district. Finally, and specifically connecting the intersection of PLCs and justice-centered professional learning and identity development, Leonard and Woodland (2022) note how PLCs are an effective model of PD for antiracism, because antiracism, unlike other initiatives, requires shifts in teachers' ideology and thus a re-negotiation of their identity. While the research identified and cited here documents the effectiveness of PLCs for supporting science teacher professional learning, we were only able to locate a sparse amount of literature (e.g., Leonard & Woodland, 2022) that focused how PLCs might support professional teacher identities, especially professional teacher identity that centered social justice and equity, something this current research explores.

2.1 | Conceptual framework: Professional JuST identity development

Identity theory is not a new tool in science (teacher) education research (Avraamidou, 2014). For this study, we define identity as, "who or what someone is, the various meanings someone can attach to oneself, or the meanings attributed to oneself by others" (Beijaard, 1995, p. 282). Scholars like Lee (2017) have nuanced this further by pointing to how identity development is the ongoing negotiation between the self-narrations of individuals and the self-construal attributed to an individual by community members. Importantly, identity is multidimensional, fluid, and plural across space and time (Barton & Tan, 2010; Varelas et al., 2012).

Our conceptual framework, professional JuST identity, builds on multiple constructs of identity theory, most significantly Science, Technology, Engineering, and Mathematics (STEM) identity (Carlone & Johnson, 2007), professional teacher identity (Luehmann, 2007), and social justice science teacher identity (Chen & Mensah, 2018). Carlone and Johnson (2007) identified three core constructs: competences, performances, and recognition. Competence is having the needed scientific knowledge and skills. Performance is talking and acting on that competence so that others recognize scientific capabilities in the context of pursuits. Recognizing oneself as a "science person" is also part of recognition. In their study, Carlone and Johnson (2007) foregrounded recognition, because they, like others (e.g., Dou & Cian, 2021; Hazari et al., 2010) point out how among those constructs that shape identity, recognition is most important in the narration of self.

Relatedly, Luehmann (2007) also highlighted recognition, by drawing on Gee (2005) and defining professional teacher identity as being recognized by self or others as a certain kind of teacher based on their "professional practices, values, beliefs, and commitments" (p. 827). And, like Carlone and Johnson (2007), Dou and Cian (2021), and Hazari et al. (2010), Luehmann (2007) noted how internal and external recognition of participation in a profession's discourses

is ultimately what results in the formation of identity. Additionally, Luehmann argued that preservice teachers (PSTs) need opportunities to practice teaching in lower stakes contexts to *try on* their new identities.

Not unlike the reform-minded science teachers that Luehmann discussed, researchers like Chen and Mensah (2018) highlighted how implementing the Next Generation Science Standards (NGSS) provides another more recent example of a potentially seismic change that requires that teachers shift their thinking related to what science education looks like in practice. Thus, inservice teachers also need to develop new professional teacher identities, especially as they are confronted with new opportunities, challenges, imperatives or concerns related to what it means to learn and teach science.

Notably, Chen and Mensah (2018) drew on social justice science teacher identity, as they followed three elementary PSTs to understand the development of their science teaching identities and their trajectories in becoming social justice science teachers. In their study, they defined a social justice science teaching identity as one that involves, use of curricula and pedagogies in ways that rely on caring and engaging interactional styles and high expectations for all students. They note how social justice teachers understand the ways structural inequities disproportionately impede student learning for minoritized students based on groups marked by race, class, gender, ability, or language and seek to deconstruct these oppressive structures in their classrooms and schools. Relevant to this current study, they found that the strength of PSTs disciplinary science teacher and social justice teacher identity development was contingent on "how much and how freely they were able to practice being a science teacher in their teacher preparation coursework and field experiences" (Chen & Mensah, 2018, p. 436). This meant that those with more opportunities to engage in the reflexive practice and discourses of science teaching and social justice-focused concerns in connection to practice were found to be more fully recognized, by self and others, for their teaching identities in these areas.
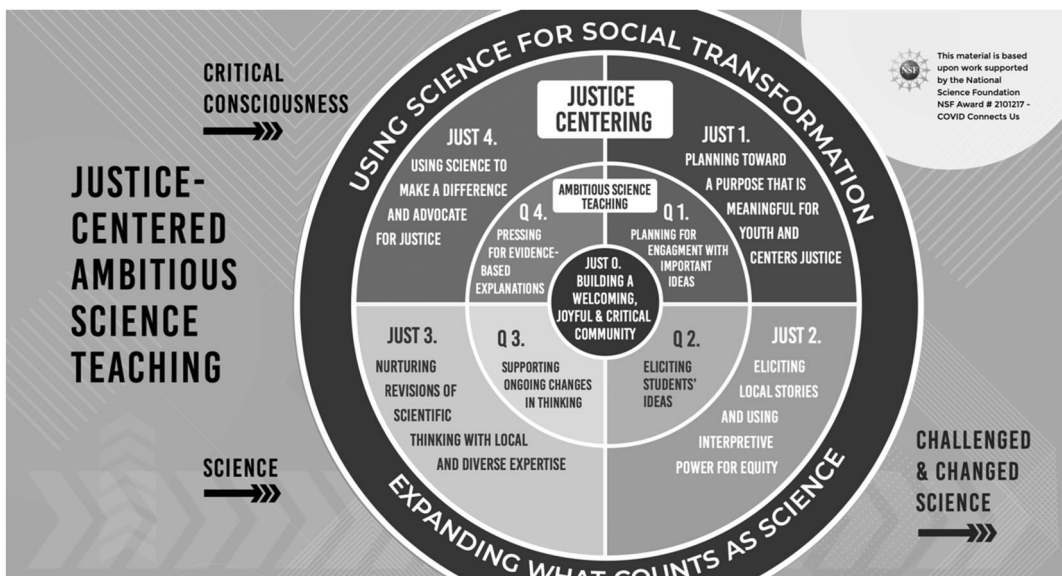

FIGURE 1 Evolving justice-centered ambitious science teaching (JuST) Framework (Luehmann et al., 2024).

In line with the social justice component of a JuST identity, practitioners continuously develop critical consciousness, which is the canvas upon which the JuST framework rests (see Figure 1, the current version of the JuST framework). According to Ladson-Billings (1995), teachers, "must help students to recognize, understand, and critique current social inequities" (p. 476). This means professional JuST identity not only includes teachers' continuing interrogation of social inequities, it also means that JuST practitioners develop competencies and performances to help students understand social inequities and empower them to plan and take actions to disrupt historical and current inequitable structures (Morales-Doyle et al., 2021), an aim of JuST practice 4 identified in Figure 1.

Further, a professional JuST identity is committed to building on and moving beyond the AST high-leverage practices by recognizing and committing to how planning for students' engagement with important ideas might be made more culturally significant (e.g., through planning instruction around explaining culturally relevant phenomena that matter to students, their communities, and society). Likewise, a professional JuST identity also manifests itself in teachers' unwillingness to stop at the AST practice of pressing for evidence-based explanations as the aim of classroom learning, and instead commits to pressing for and using evidence-based explanations for positive change (e.g., explaining the basis of local urban heat islands, identifying who is most affected by them, and proposing solutions for what can be done about it). These examples are commitments that move beyond access to high-quality learning and instruction and students' identification with science toward expanding what counts as science and seeing science and engineering as part of justice movements. In the end, this research sought to build on Luehmann′ (2007) research that explored the conditions under which PSTs were supported to navigate the development of new professional teacher identities, by exploring how within PLCs inservice teachers could be supported to develop new professional JuST identities anchored in our JuST framework.

3 | CONNECTING JuST TO PROFESSIONAL JuST IDENTITY DEVELOPMENT THROUGH PLCs

Our interests in designing and understanding the impact of deliberate learning arrangements (i.e., PLCs anchored in culture-setting unit enactments and collaborative inquiries) that could support the development of professional JuST identity, challenged us to first synthesize across justice-centered pedagogy (Morales-Doyle, 2017) and AST (Windschitl et al., 2018) literature to develop our Just Framework (Figure 1) (Luehmann et al., 2024). In this, we adapted the AST framework's sets of high-leverage practices with the aim of expanding what counts as science and using science for social transformation. From this, we then drew on PLC literature that detailed how teachers benefit, narrate, and recognize new potential identities (Friedrichsen & Barnett, 2018; Larkin et al., 2009; Nelson, 2009) as they engage with peers in collaborative work, like implementing curriculum units and engaging in collaborative inquiries (Leonard & Woodland, 2022; Slavit & Nelson, 2009; Thompson et al., 2019). Finally, we drew on research related to the intersection of critical consciousness and science teacher identity (Chen & Mensah, 2018; Rivera Maulucci, 2013) to ensure teachers work in PLCs offered them opportunities to engage in reflexive practice and discourses of science teaching and social justice-focused concerns in connection to practice to ensure they had increased chances to be fully recognized, by self and others, for their teaching identities in these areas (Chen & Mensah, 2018).

4 | METHODS

4.1 | Study design

We conducted this research using qualitative methods, relying on transcribed video recordings of PLC meetings and transcribed end-of-year focus group interviews. This approach allowed us to examine the experiences of a group of predominately white mostly secondary science teachers as they collaborated in PLCs in the first year of a larger project aimed at supporting JuST through enacting a JuST culture-setting unit and engaging in iterative cycles of CI to identify, develop, and refine JuST practices in their school contexts. We chose the qualitative research methods because they afforded rich representations and descriptions of contextual phenomena (Creswell, 2005; Patton, 2002).

4.2 | Context

Our data was collected from a group of two PLCs in the New England region of the United States as they engaged in a year-long professional learning experience as part of a larger multistate project who named themselves "Justice Jedis" and "Llamas." While additional PLCs participated in the larger multistate project in a state neighboring the New England region and another state in the Western region of the United States, we focused on the two PLCs in our own state in which Cooke and Campbell had more access to provide an in-depth look at their identity development. Our larger multistate project sought to support teachers engaged in a network of PLCs to develop and understand core teaching routines referred to as JuST practices that could serve as powerful footholds to realize cultural shifts in science classrooms. The following are a few examples of these JuST practices:

- Identity Mapping—Often used at the beginning of the school year and as part of the culture-setting unit, identity mapping supports students to name and reflect on their own, and their peers' and teacher's, intersecting identities and the role identities play in negotiations of power and privilege in science and society and in connection to the topic of the unit (e.g., how their identities might play a role in differential access to COVID-19 vaccines).
- Situating instruction in local data and phenomena—In this JuST practice, teachers sought to support students in making personal connections to data sources teachers identified. These data sources, situated in the local community, region, or state (e.g., differential asthma rates across the state), were used as an anchor for instruction across a lesson or a unit teachers planned.

The major focus of the professional learning involved PLCs learning about, revising, and implementing a culture-setting unit focused on the science of COVID and engaging in CI cycles to identify or develop, test, and refine JuST practices in their classrooms. Central also to the professional learning and all project focused PLC work, was a consistent focus on the JuST framework (Figure 1). In many ways, the framework served as a tool for all those involved (i.e., project leaders, PLC leaders, PLC members) that supported the development of common theories, codes/language, and tools (Glazer & Puerach, 2015) related to what it meant to be a justice-centered ambitious science teaching (JuST). The Framework was introduced at the beginning of the project and revisited consistently throughout (i.e., as a way of reorienting to

the work at the start of meetings or for interrogating a lesson, activity, or experience). The professional learning started in the summer, first with project leaders and teacher leaders/PLC leaders convening to co-plan a summer PD for teachers/PLC members. This was followed by PLC leaders facilitating the PD in their PLCs before the school year started. While project leaders met at least once monthly with PLCs and observed the more frequent PLC meetings, during the initial year of the project the PLC leaders were positioned as professional learning leads for their PLC and led their respective PLC meetings. The summer professional learning, as well as the PLC experiences planned across the school year (i.e., unit implementation and reflection, JuST practice development through collaborative inquiries) were designed to support PLC members' critical consciousness as part of their JuST identity development. To accomplish this in the summer and through the first half of the school year, PLC members, engaged in "learner hat" experiences whereby they were led by PLC leaders to engage in select parts of the culture-setting units (e.g., developing their own identity maps, reasoning about COVID cases in their communities). Beyond these learner hat experiences in the summer PLC members were provided additional resources to support their learning. One of the first assigned readings was Philip and Azevedo's (2017) *Everyday science learning and equity*: *Mapping the contested terrain*, which served as a point of discussion in early meetings. During the school year PLCs also engaged in a book study of Matthew Kay's book *Not Light*, *But Fire*. More details about the professional learning and how they were intended to support critical consciousness are included in Table 1. Because enacting a culture-setting unit and engaging in iterative cycles of CI to identify, develop, and refine JuST practices were the major focus of the professional learning experiences, more about each is described next.

As alluded to earlier, culture-setting units were conceptualized as short units made up of lessons used to build a critical and caring community at the beginning of the school year. Teacher participants in the neighboring northeastern state developed the COVID-focused science units for biology, chemistry, and middle school the year prior. As these units were developed so that lessons within them could be adapted to local contexts, as part of summer PD time was provided for the teachers in our study to refine the units in preparation for implementation at the beginning of the year school year in their local contexts. Table 2 provides additional details about each of the culture-setting units, including the specific disciplinary focus and the lessons within each unit. As can be seen in Table 2 a focus on race, racism, equity, and justice was elevated as part of these units as questions about how race was or was not elevated in identity maps of PLC members or their students, or in the intersection of COVID-19 and race in the COVID-19 related data highlighted in the units and the extent to which increased harm from COVID-19 was attributable to racism, as just two examples.

To engage in iterative cycles of CI, project leaders developed and provided templates that included prompts and scaffolds to support PLCs in identifying, developing, and refining a JuST practice during the second half of the school year. These templates supported PLC members to identify a practice they perceived could help them think about and introduce students to the intersections of science and justice in their classrooms. The templates both supported PLCs in fleshing out the nuances of the JuST practice they were proposing while also positioning them to interrogate their proposed practice by explaining what made it a JuST practice. The CI template also pressed PLCs to identify data/evidence they could collect to assess and improve or refine their JuST practice, including, for example, the extent to desegregated student data from exit surveys revealed differential reports of students feeling their contributions were valued in the science classroom. Table 3 details the JuST practice focus of each PLCs CI, as well as their articulation of what made the practice JuST.

TABLE 1 Professional learning community (PLC) professional learning experiences.

Experience	Learning experience	Role in supporting participants to learn about race, racism, equity, and justice
Summer	PLC Module 1—Overview of Project focused on JuST and Developing Critical Consciousness	Outlined project aims, including social justice-focused education, critical tools for addressing oppression, and community asset and identity mapping to explore power, privilege, and intersecting identities.
	PLC Module 2.1—Learning in Networked PLCs	Shared vision for effective PLCs focused on JuST commitments, including building relationships, examining racial biases, and engaging in collaborative inquiries to refine JuST practices with practical measures.
Fall	Bi-Monthly PLC Meetings	Each meeting began with a reflection on the JuST framework as a guide for professional learning, with Fall PLCs concentrating on culture setting, unit implementation support, and initiating collaborative inquiries.
	Culture Setting Unit Implementation	The culture-setting units offered PLCs resources for exploring identities, understanding COVID-19's impact on communities of color, and supporting actions to address injustices as part of social transformation.
	Book Club (Not Light, but Fire: How to Lead Meaningful Race Conversations in the Classroom—Matthew Kay)	This book offered PLCs practical strategies for fostering meaningful race dialog, distinguishing impactful from trivial conversations, creating supportive environments, and addressing unexpected challenges.
	Term Ending Cross-Site Meeting	This was dedicated to PLCs sharing initial collaborative inquiry (CI) ideas for feedback, using the JuST framework to identify practices that promote equity and justice in science classrooms.
Spring	Bi-Monthly PLC Meetings	See above description
	Collaborative Inquiry (CI) in Classrooms	The CI allowed PLCs to develop and refine a JuST practice, identify its Just Quadrant focus, and understand its alignment with JuST principles. This process helped PLCs implement JuST practices in their classrooms and gather data to guide improvements over multiple CI cycles.
	Book Club Cont. (Not Light, but Fire: How to Lead Meaningful Race Conversations in the Classroom—Matthew Kay)	See above description (Spring was dedicated to completing CIs).
	Term Ending Cross-Site Meeting	This session focused on PLCs sharing their CI results with other PLCs and reflecting together on their year-long professional learning experiences.

Abbreviation: JuST, justice-centered ambitious science teaching.

TABLE 2   The culture settings units.

Disciplinary focus	Unit focus and unit activities
Middle School	Focus: Which is worse, Cholera or COVID-19? Why is Cholera a "forgotten pandemic"? Why do some pandemics get more attention than others?—Big Idea: All living things are made of cells which contain structures that contribute in specific ways to their functions. When environmental conditions change, the functions of those cells may be affected or disrupted. When internal conditions change in ways that may harm an organism, their interacting subsystems respond to return the organism to normal functioning.
	Act. 1—Identity Mapping to Recognize Who is in the Classroom, Hear Students' Stories with the Pandemic, Position Students as experts, Recognize Who We Are as a Class Act. 2—Introduce the Anchoring Phenomenon—Compare and Contrast Cholera and COVID-19 Act. 3—How Do the Two Diseases Spread? Act. 4—How Do the Two Diseases Impact the Body's Systems? Act. 5—Learning about Body Systems Act. 6—How Do the Two Diseases Impact the Body's Cells? Act 7—Why are Scientists Studying COVID-19, but not Studying Cholera? Act 8—Advocate for Change—Writing Local, State, or National Representatives to Advocate for More Resources to Study COVID-19
Biology	Focus: COVID-19 has impacted people locally and globally in different ways. Students unpack the big idea of why the coronavirus impacts communities of color disproportionately if people all have same cellular machinery.
	Act. 1—Introducing the Anchoring Phenomenon Act. 2—Identity Mapping Act. 3—Mechanics of Viruses Act. 4—Vaccines and Herd Immunity Act. 5—Social Determinates of Health and Disproportionality in Health Outcomes Act. 6—Create a Vaccine Rollout Plan
Chemistry	Focus: Learning the science behind vaccine delivery and storage to understand the relationship between energy and matter
	Act. 1—Introducing the Anchoring Phenomenon Act. 2—Identity Mapping Act. 3—Dry Ice Investigation Act. 4—Time Lapse of H_2O Investigation Act. 5—Chicken Experiments Act. 6—Final Project: Vaccine Desert Solutions

To examine the experiences of the science teachers as they collaborated in PLCs, we examined the transcripts of video recordings of all PLC meetings that took place across the professional learning and engaged all participants in an end-of-year focus group interview that was also subsequently transcribed.

4.3 | Participants

There were 13 science teachers, most of whom were white, who participated in the PLCs (see Table 4). A majority of the teachers had collaborated with the second author (i.e., Campbell) for

TABLE 3 Professional learning community's (PLC) justice-centered ambitious science teaching (JuST) practice focus.

PLC	JuST practice focus	What made the practice JuST
Laura's Llamas	Engaging all students in conversation	This practice aimed to address the issue of creating a space for students to use their own voice (i.e., language and experiences) in conversations, especially in connection to supporting students to make sense of phenomena. This focus is connected to JuST 0 [Figure 1]—*Building a Welcoming, Joyful, and Critical Community* and JuST 1—*Eliciting Local Stories and Using Interpretive Power for Equity*
Jedis	Building a welcoming community	This practice sought to answer the question of how to make sure that every student has an opportunity for their voice to be heard by exploring a variety of structured and unstructured opportunities created for students to engage in conversations. This focus is connected to JuST 0—*Building a Welcoming, Joyful, and Critical Community*

a number of years as mentor teachers for PSTs and had engaged in PD opportunities focused on developing mentoring practices and learning about the NGSS and AST. Those few that had not collaborated with us previously were recruited since they worked in the same schools/departments as the mentor teachers. The teachers came from nine different schools across seven districts in the state. As seen in Table 4, all participants, except one, taught in middle and high school, and the teachers taught a range of science courses. The teachers had a range of experience, having taught between five and 28 years at the time of the study. Finally, all, except for two teachers were female. As noted in Table 4, the schools and districts where the teachers taught ranged from racially segregated (predominantly white settings) to racially diverse settings.

4.4 | Data collection

As alluded to earlier, data collected for this research included video recordings of 21 PLC meetings and three end-of-year focus group interviews. More specific information about the video recordings and focus group interviews (i.e., how many PLC meetings were recorded and transcribed per PLC, as well as how the end-of year focus group interviewers were organized) can be seen in Table 5. Summer PD and project-wide meetings were not used in the analysis.

4.5 | Data analysis

We, all authors, were involved in co-planning and co-leading the larger multistate project, while the lead (i.e., Cooke) and second author (i.e., Campbell) were involved in data collection and analysis for the current study. Importantly, our positionalities (i.e., of the two authors involved in data collection and analyses) influenced the analyses of the data. Cooke is a white female doctoral student, who taught high school science at a racially diverse 6–12 school before becoming a full-time doctoral student. She went to school and taught in the state where the research took place. Raised in a family of educators who also taught in the state, she grew up with some

TABLE 4 Participants' professional learning community (PLC) and demographics.

Pseudonym	PLC	Classes taught	Years taught	School demographics (A = Asian; B = Black or African American; H = Hispanic; T = two or more; W = White)
Laura	Laura's Llamas	7th and 8th Grade General Science	5	7.5% B; 6.67% H; 79.17% W
Margeaux	Laura's Llamas	8th Grade General Science	18	9.5% A; 18.05% H; 4.75% T; 64.37% W
Sarah	Laura's Llamas	4th and 5th STEM	28	14.48% A; 3.79% B; 17.24% H; 61.03% W
Tanya	Laura's Llamas	8th Grade General Science	5	14.29% A; 4.85% B; 7.82% H; 1.89% T; 71.16% W
Evelyn	Laura's Llamas	High School Biology	5	7.59% A; 25.99% B; 35.65% H; 3.05% T; 26.91% White
Abigail	Jedis	Advanced Placement Biology	23	3.54% A; 31.92% B; 53.69% H; 2.96% T; 7.54% W
Alexa	Jedis	Biology	21	3.54% A; 31.92% B; 53.69% H; 2.96% T; 7.54% W
Mark	Jedis	Integrated Science	15	7.59% A; 25.99% B; 35.65% H; 3.05% T; 26.91% W
Jackie	Jedis	Biology	8	3.54% A; 31.92% B; 53.69% H; 2.96% T; 7.54% W
Kylie	Jedis	Anatomy and Physiology	20	3.54% A; 31.92% B; 53.69% H; 2.96% T; 7.54% W
Vicky	Jedis	Integrated Science	11	6.47% H; 3.53% T; 85.88% W
Robert	Jedis	High School Biology	18	8.0% A; 51.5% B; 22% H; 4.5% T; 13% W
Kristen	Jedis	High School Integrated Science	10	1.18% A; 18.92% B; 75.17% H; 1.52% T; 2.36% W

Note: School demographics from EdSight for 2023–2024 school year. Percentages do not equal 100% due to data being suppressed for confidentiality. Evelyn and Mark work at the same school, and Abigail, Alexa, Jackie, and Kylie work at the same school.

understanding of racial segregation in schools. Despite an academic background in the "achievement gap," she began her teaching career with ideologies of white saviorism and race-evasion. While her school prioritized equity, many of the policies perpetuated the status quo. In grappling with this tension, she reflected on her complicity in white supremacy and her own journey toward antiracism during data analysis. Campbell is white male professor at a predominately white institution, a science teacher educator/researcher and a former science secondary science teacher. He was raised in a Southern state in the United States and taught in predominately white K-12 settings in the Midwestern US before completing his doctorate in science education. Like Cooke, he too held color-evasive assumptions as a K-12 science teacher and early career science education researcher and because of his lack of experience in diverse school settings, is only over the last decade better able to recognize the vestiges of systemic racism and its impact of schools and schooling. In engaging in this research, he reflected on his own developing critical consciousness and insights from literature focused on justice-centered aims for teaching and learning as a mechanism for challenging the assumptions he brought to

TABLE 5 Data collection.

Time	Number of meetings/data collected via video and transcription	Approximate number of hours of recording
Fall 2021 (August–December)	5/5 Llama PLC meetings (5 participants) 5/2 Jedi PLC Meetings (8 participants) 3/3 Whole Group meetings with PLCs in breakout rooms (13 participants)	14
Spring 2022 (January–May)	3/3 Llama PLC meetings (5 participants) 3/2 Jedi PLC meetings (8 participants) 3/3 Whole Group meetings with PLCs in breakout rooms (13 participants)	12
June 2022	3/3 Focus Groups (teacher leaders, Llama PLC, Jedi PLC) (4, 4, 3 participants, respectively)	1.5

Note: Differences in the number of professional learning community (PLC) meetings across the two PLCs were a result of technical difficulties we had capturing video that could be transcribed for the Jedi PLC, as both PLCs met approximately the same number of times in both Fall and Spring. Only a subset of participants was available for the end of year focus group interviews.

data analysis as part of this research. Furthermore, all authors recognize their privileges and share a commitment to shining a light on the complicity and transgressions of science, as well as disrupting hegemonic whiteness in teacher education. We also recognize that our understanding of identity is shaped by predominantly white scholars, who operationalize identity absent of racial identity.

Before the data analysis's initiation, we collaborated to develop an initial a priori coding scheme developed with the goals of the larger project, the current study's research question, and the literature on identity in mind. More specifically, we used high-level codes to identify data that could inform our understanding of how the implementation of the culture-setting unit and how engaging in the networked PLCs supported professional JuST identity development. A priori sub-codes for identifying data related to the unit's implementation included any data related to implementation and adaptation of the unit. Further we created additional subcodes to identify challenges teachers encountered implementing the unit and how their administrators responded to their implementation of the unit. Examples of these subcodes included identifying how the sharing of resources and how the CI process unfolded to support or constrain teachers' professional JuST identity development. The following is an example of a segment of transcription from a PLC meeting that was coded in connection to how administrators supported teachers' professional JuST identity development through recognition in connection to the implementation of the culture-setting unit: When describing her administrator's response to the unit, Vicky shared, "I sent the whole unit to my admin and said, 'This is what I'm doing.' They were for it." [Jedis, September 23, 2021].

Further, as part of our data analysis, previous research on identity helped inform our additional high-level and subcodes. More specifically, Carlone and Johnson's (2007) components of science identity were added: competence, performance, and recognition, and modified to be "JuST performances" and recognition after Cooke and Campbell read through three of the transcripts.

We, Cooke and Campbell, coded the same transcript and discussed similarities and differences. We added examples to the codebook for clarification. After coding a second transcript,

we established interrater reliability (>80%). After coding the rest of the transcripts, we identified episodes containing codes and reorganized these in a new document based on emerging themes. We present the findings below.

5 | FINDINGS

The findings section is organized by our research question: What are the affordances and challenges of PLCs and their tasks for supporting professional JuST identity development? This is accomplished by first outlining how the experiences in the PLC more broadly provided support for professional JuST identity development. This is followed by a more nuanced look at how implementing a culture-setting unit and CI to refine a JuST practice impacted participants' development of a professional JuST identity.

5.1 | PLCs support the development of teachers' professional JuST identity

The following are three ways teachers' participation in a PLC focused on JuST supported their professional JuST identity development (italicized throughout the findings): *PLCs supported teachers in developing JuST competencies and performances*; *PLCs provided space for the critical and emotional work of learning to discuss race and challenging, pushing, and holding one another accountable*; *PLCs provided space for internal and external recognition as a JuST teacher*.

In relation to *PLCs supporting teachers in developing JuST competencies and performances*, teachers in the PLCs shared ideas about JuST performances they drew on in their classrooms in ways that informed other teachers' ideas about engaging in JuST. An example of teachers sharing ideas about JuST performances can be seen in the following discussion about the use of identity maps that emerged as one teacher reflected on what she appreciated about their previous PLC meeting:

> Laura: ... we looked at how to use identity maps in the classroom. How I really liked Tanya's idea last time of using it [student-created identity maps] sort of as an initial model that students can refine throughout the year. And also with Margeaux talking a lot about why didn't you, or did you include race as part of your initial model [identity map].
>
> [Llamas 8/30 Mtg]

Not only did teachers share ideas about JuST performances in their PLCs, these opportunities to share often positioned teachers to articulate what about the performance made it a JuST performance, an indication of how JuST competencies and performances are entangled. As an example, in the following PLC meeting as part of PLCs being encouraged by project leaders to connect their proposed collaborative inquiries with Philip and Azevedo's (2017) equity discourses, one PLC discussed why student talk in the classroom was important:

> Kristen: So, I was thinking, reading that first one, approach one [Equity Discourse #1], increasing opportunity and access, just the idea that we are trying to embrace more talk in our room ... Like, Hey, we're not only going to accept written or

something that you created in full sentences. We're shifting, it's like, hey, if you can say something in a conversation, to me that's almost just as valuable as if you wrote that as a response or as a written response. So being more accepting of the different forms of learners and what they can produce, if that makes sense.

Alexa: Yeah, I think that's a lot in approach three [Equity Discourse #3] as well, expanding what constitutes science and engineering. Talking about that it's not all about knowing the vocab words, right? [2.28 Jedis]

In this exchange, Kristen and Alexa connected supporting student talk in science classrooms to increased opportunities and access and attempts to expand what counts as science in their classrooms. Relatedly and central to the JuST competence of expanding what counts as science (i.e., Philip & Azevedo's Discourse #3), teachers expressed interest and began to learn to think about science in new ways. This can be seen in the following as a teacher described what she had hoped to learn more about after hearing discussions among teachers in her PLC:

Sarah: Well, that kind of leads me to the thing that I am hoping to learn. Because where I felt underwater, where I felt out of my depth this year, among other things. But one of the things was, we kept having this conversation about, I would like to be open to other students' ways of seeing the world. I would like to provide examples of other ways of looking at the world. And Margeaux, I remember you shared one about, I think about a Native American way of looking at the world in science, and that was helpful to me … because I'm having a hard time … allowing myself to be open to other ways of thinking about science without examples … I would like to read about how does a non-western person looks at the world. [Llama focus group June 2022]

When considering the theme *PLCs provided space for the emotional and critical work of learning to discuss race and challenging*, *pushing*, *and holding one another accountable*, teachers often shared their fears of facilitating discussions of race and injustice in their classrooms with their PLC members. In the following, Laura voices her fear and appreciation of the space for learning afforded by the PLC:

Laura: I'm excited to kind of work through and stumble through some of this stuff with you guys. I have a lot of good ideas in my head, but never can get them to like, I can't ever say the right thing. So I'm excited to kinda work through that with you guys … I just don't know what to say. Sometimes I freeze up. [Llamas 8/25 Mtg]

Based on the conversation, the "stuff" Laura refers to is justice-centered teaching in general, and responding to problematic comments made by students, more specifically. Additionally, teachers shared how their engagement in this emotional work with their PLC supported them to feel reassured and less isolated. This can be seen in the following shared as a reflection at the end of the year as part of a focus group interview:

Sarah: So one thing that I … Obviously, it was a struggle for all of us, right? And it was a little bit reassuring that it was a struggle. Because I sit here thinking I can do this and to know we all thought really too big at a moment and then we're like,

"How do we fix it all?" And then we came back to like, "Okay, this team helped me learn how to take a little bite and then do a thing and then interrogate that a little bit, and then do the next thing."

[Llama focus group June 2022]

Not only did the PLC provide a space for teachers to share and work through emotions, like fear, the PLCs also provided space for teachers to challenge, push each other, and hold each other accountable. Beyond pushing each other, teachers in the PLCs helped each other think about problematic framings they heard other teachers using or had previously used themselves and were now trying to avoid. This can be seen in the following from Kristin reflected with PLC members about how they were supporting students to engage in discussions with peers and the language that they were using in the following:

Kristen: But then, it made me also think about, and maybe this is being too sensitive, but I was wondering if 'policing your voice' was the best word choice to use or would that be potentially triggering? I feel like, a lot of times in schools, we think of policing, like policing girls' bodies, that urban schools are more policed than suburban schools. We use that term, I think, in a not-good way or it's negatively perceived, so I was interested and/curious that he chose to use that as the saying. And Alexa, I saw you saying, "Yes." I was wondering if you were feeling similarly. [Jedis 10.18]

Finally, professional JuST identity authoring was supported as *PLCs provided space for internal and external recognition as a JuST teacher*. Categorized with this theme, teachers were recognized in PLCs both for the justice-focused approaches they shared with the group. Beyond internal and external recognition, the PLCs also supported teachers to reflect on and recognize their own growth as JuST teachers, as one teacher shared what had been happening in her classroom recently with PLC members and how she could recognize her own developing facility and performances as a JuST teacher in the following:

Laura: Being a newer teacher, I always used to get super scared when these things happened ... Where it's kind of like, "Yeah, just stop saying that so nobody gets in trouble." And like I love the work that we're doing and sort of the movement now of being able to recognize, let's pause for a second and separate the student from their comment and really try to get them to understand. [Llamas 9/20]

Consequently, PLCs provided a collaborative space to share and reflect JuST performances, emotional and critical work, and recognition of growth.

In connection to how we conceptualized professional JuST identity and in how identity is authored more generally, the development of competences, performances, and recognition noted in these findings in relation to teachers' engagement in PLCs go far in supporting professional JuST identity since they represent key identity constructs (Carlone & Johnson, 2007) that position these teachers to be recognized by self or others as a certain kind of teacher (i.e., JuST teacher) (Gee, 2005). Furthermore, and in alignment with what Chen and Mensah (2018) and Rivera Maulucci (2013) found, our finding that the PLCs provided space for the critical and emotional work of learning to discuss race served an important role in the development of critical consciousness and science teacher identity for these teachers.

The findings shared next provide a more nuanced look at how the two main professional learning tasks across their first year of engagement in the PLC (i.e., implementing a culture-setting unit; engaging in CI to identify, enact, and refine a JuST practice) influenced participants' professional JuST identity development.

5.2 | Affordances and challenges of adapting and enacting a culture-setting unit as a PLC task for JuST identity development

The focus of the PLCs at the beginning of the academic year was learning about, revising, and implementing a culture-setting unit focused on the science of COVID. As alluded to earlier, the participants in this current research were not engaged in the initial development of the units; however, as part of their participation during the time-period investigated, these units were provided to them, and time was set aside within PLCs for them to learn about and revise the units as needed prior to their implementation. As part of this PLC task identified to support teachers' JuST identity development, teachers implemented one of the three possible units that most closely aligned with their teaching assignments within their schools at the beginning of the school year. Analysis of the data revealed implementing the unit supported and challenged the teacher participants' development of professional JuST identities. We first share the affordances and challenges of this PLC task connected to participants experiences as they refined and implemented the culture-setting units. Additionally, the data highlighted the importance of administrator support, especially connected to the PLC task of implementing the unit and how administrative support or lack thereof played a role in teacher recognition as part of JuST identity development. Before sharing specifics of this PLC task, it is important to note that, few teachers worked to implement the entire units as designed, instead most teachers adapted the units with the collaborative help of their PLCS. This can be seen as one teacher Margeaux shared in a PLC meeting focused on learning about and readying to implement the culture-setting unit, "so let me see. So I pretty much took all of the lessons and I flip flopped them all around" [Llama 8/30 Mtg].

5.3 | Implementing the culture-setting unit—affordances

The following were identified as important affordances of PLCs implementing the culture-setting units: *units afforded teachers strategies for getting to know their students and the assets they bring to classrooms*; *units provided a common set of resources for elevating discussions about race and ethnicity in classrooms*; and *units served as springboards for conversations in PLCS focused on what makes curriculum JuST*. Related to how *units afforded teachers strategies for getting to know their students and the assets they bring to classrooms* one teacher shared the following at the end of the year when reflecting back on the benefits she recognized about the culture-setting unit:

> Margeaux: So, the COVID unit I taught early in the year, … I so appreciated the focus on examining your identity and what do you bring to the classroom? What are your things that you feel good about bringing in? And defining that as the science work that we're going to be doing, that we have kids like, "Oh, I can talk, I can communicate well." That's great. "I'm really good at math. I'm good at art.

I watch a lot of videos about science." And that helped throughout. I think it was just calling on that self-identification and what they could bring into the class. Justice centered teaching in my class, first I tried to create this environment where everybody feels like we are contributing. And that when they're modeling, it's low risk. So, we talked about creating an environment for them to share their ideas … It's a lot of getting to know them as students and talking to them about their experiences. And bringing those into the classroom as ways of helping them make sense of the relevance and their responsibility as citizens of the world. So, trying to solicit kids and how they connect to it, there's a lot of that. [Llama focus group June 2022]

Beyond offering strategies for centering student identity and creating spaces where students felt they could contribute; the *units provided a common set of resources for elevating discussions about race and ethnicity in classrooms*. This was accomplished as the units highlighted the disproportionate impact of COVID on racially and ethnically minoritized communities. The following quotes are a few examples of teachers describing how they drew on the units to engage students in discussions about race and ethnicity in connection to COVID in their science classrooms. These examples all emerged from dialog PLC members were engaged in during their PLC meetings early in the year when they were engaged in supporting each other to implement the culture-setting units or collaboratively reflecting on how implementation of the units went in their classrooms:

> Evelyn: I kind of tried one of the things in the bio [biology] unit is looking at, if people have the same cells and organs, why are they affected by COVID differently? And so, we had a really good discussion in all three of my bio [biology] classes … I gave them more scaffolding for the activity just to get them started with some ideas about different factors about a person that might contribute to how they're impacted by disease … Yeah, so that was just really good, because we talked a lot about, they brought up race and ethnicity, because we had looked at graphs showing percentages of vaccinations for different people … So, I was just excited about that. [Llamas, 9.20]

Evelyn was encouraged by the class discussion that sparked from the unit. While her students brought up race and ethnicity as part of engaging in the identity mapping activity planned at the beginning of the culture-setting unit, Margeaux introduced the topic directly:

> I started right away with the identity mapping, what do you think you contribute to the science classroom? And then went into Mae Jemison's story [first black woman to travel in space]. And we've just been talking about, what does science look like and who is a scientist these days? And it's in contrast to some of the later work where we're just always seeing white dead men and remarking, "Well, why are these all white men, in the 1600s and 1700s?" So, I was happy for that experience of just creating this culture. We created a class identity map as well to share what we all have to contribute to this work. Then I introduced the phenomena [comparing Covid and Cholera] by having them analyze the [COVID] data, both from maps and tables on race and ethnicity data. And the number of [COVID] cases for hospitalization and deaths for people of color … [Llamas, 9.20]

Finally, *units served as springboards for conversations in PLCs focused on what makes curriculum JuST*More specifically, the units prompted teachers to think with one another about how the aim of justice-centered instruction is beyond just teaching science devoid of context. This realization can be seen in the following reflection, where a focus on making learning relevant to students' lives and experiences was identified as a criterion for JuST, as Abigail reflected with her PLC members soon after she had implemented the culture-setting unit:

> Abigail: I think that also gets at what we're trying to do here. Where like the justice-centered teaching. Having them think about their own communities and the things that they need in their community, right? Isn't that a really important piece? ... It seems to me that you want to disrupt the typical, this is a cell, this is how it works and ... make it more relatable to them. I think that's a really good piece and that was in part of the original unit too. I think it's great. [Jedis September 23, 2021 PLC meeting]

Relatedly, the PLC conversations led to more general reflections about what makes curriculum JuST, something Margeaux recalled at the end of the year in a focus group interview, as she reflected on the importance of setting the culture at the beginning of the year:

> Margeaux: I also think that it's our responsibility not to make the curriculum so white-centric, in terms of the scientists that we feature, and in the use of vocabulary that is totally unfamiliar. That, we encourage and ... I don't know if the word is promote, but this idea that you're going to use words that are relevant to you. And what I choose as curriculum is relevant to your everyday life, rather than something that happened in the 19th Century with a white man. [Llama focus group June 2022]

Here, Margeaux, in discussion with her peers, had begun to reflect on and articulate important features of JuST (see Figure 1) in her JuST identity development. More specifically, in her reflection, she sought to connect science teaching and learning to students "everyday life," which, according to our JuST framework, aligns with planning for engagement with important ideas that have cultural significance and Equity Discourse 3 (i.e., expanding what counts as science). As well, Margeaux's reflection hints of a level of critical consciousness (awareness and action) of the "white-centric" hegemony that is portrayed in the historical narratives of great discoveries and figures in science and suggest a desire to contest this narrative with and for students.

Overall, these findings point to how the affordances of culture-setting units in supporting teachers to take up and practice JuST performances as part of professional teacher JuST identity development. This can be seen in how the units provided strategies for getting to know their students and resources for elevating discussions about race and ethnicity in classrooms.

5.4 | Implementing the culture-setting unit—challenges

Some of the challenges teachers encountered when being asked to implement the unit related to *making sense of the design of the culture-setting units* and *identifying how the units could be effectively integrated into existing curriculum maps* (not connected to the lack of administrative

support discussed in a subsequent section). This initial challenge, *making sense of the design of the culture-setting units*, seemed most attributable to how teacher participants were not engaged in the initial development of the units. Instead, as stated earlier, teachers in the neighboring Northeastern state participating in the larger multistate project a year prior to when the data was collected for this research developed and refined the units. Even though the units were designed by practicing teachers, it was challenging to implement the unit as written. This challenge of making sense of the units is highlighted in the following teachers' questions about one of the units. This reflection from Margeaux occurred as she engaged with her PLC members to think about how she was struggling to understand the culture-setting unit she did not develop, but was working to prepare herself to implement with her students:

> Margeaux: Is it because they're unvaccinated? Is it because their mask laws are lax? Is it because it was hot and they were all in air-conditioned rooms, but this is not the teaching. This is still in the initial modeling. I think … that's your crux of it. So, when do we start teaching and how do they learn? Where are those lessons? [Llama 8/30 mtg]

Over time, teachers navigated these questions in their PLCs and beyond as they could contact the authors of the culture-setting units to ask questions; however engaging in this initial meaning making about the units presented challenges to PLCs trying to ensure they had a sense of goal of including specific activities or lessons and the logic behind why particular activities were organized sequentially in the ways they were across the units.

In relation to the challenge, *identifying how the units could be effectively integrated into existing curriculum maps*, several teachers struggled to identify how the culture-setting unit could fit coherently in the context of their existing curriculum in ways that may not have arisen as a challenge for those teachers who designed the unit and could take their school's curriculum maps and contexts into consideration when creating the culture-setting units. Specifically in the following example, Laura puzzled about how she was going to implement the unit in the context of an existing curriculum that was already comprised of seven instructional units:

> Laura: So I guess if I could kind of pause here and think about timing and I know we also have our units, like I have seven units I already have in my curriculum and I'm being pushed to make sure I get through all my curriculum this year. [Llama 8/30 mtg]

Taken together in the context of thinking about developing professional JuST identity, these challenges with implementing the culture-setting units appeared to potentially trouble notions of competence, performance, and recognition, as core constructs of identity and JuST identity for teachers, especially if the teachers struggled to make sense of and implement them in ways helped them demonstrate competence and performance or to be recognized as capable of negotiating the implementation of JuST focused units.

5.5 | Administrative influence on the implementation of culture-setting units PLC task

According to the teachers' accounts, their administrators' responses to the culture-setting units played a significant role in their recognition and confidence in implementing the units.

These responses led to teachers feeling recognized and supported in some cases, while in other cases the opposite was true. The following reveals the recognition and autonomy and support one teacher experienced, which she felt confident in sharing with her PLC, "I sent the whole unit to my admin and said, 'This is what I'm doing.' They were for it." [Vicky, Jedis, September 23, 2021]. This was the response of most administrators who had previously been approached by teachers about participating in the larger project and whose schools had, to varying degrees sought to support teachers in the current sociopolitical context (e.g., disproportionate effect of COVID-19 on racialized groups in the United States, the Black Lives Matter Movement). Opposite of this, however, was the following episode whereby an administrator forbade a group of teachers (both with approximately 20 years teaching experience) from proceeding with the implementation of the culture-setting unit they had previously given the teachers permission to implement. This experience happened mid-way through their implementation of the unit and, as is evident, was jarring for Alexa and Jackie who were both at the same school:

> Alexa: Well, and I also said, we haven't said, but when we say we got pushed back, she said, "You need to shut this down—
> Vicky: Oh, boy.
> Alexa: —you cannot go forward with this."
> Vicky: Wow.
> Alexa: Those were her words, so that—
> Jackie: We pretty much got to the data points and she was like, "You're basically pointing out to them how numbers are saying how they're gonna fail in the future and they're all gonna get sick because all the cards are stacked against them, so we can't talk about it anymore."
> Alexa: Yeah. She wouldn't even like—and usually, she's pretty supportive of this, she's never done anything like this but that part was, again—I was like, I told her in a meeting, it was hard because she didn't even let us try to fix things or modify things to work and it was a really tough start of the year.
> Abigail: Yeah, I agree.
> Alexa: -and we didn't know. Then we were like hanging out in space like, what do we do and then we just cut it and we were like, okay, whoa.

Teachers' discussions were reminders that they work in systems, their recognition is bound up in responses to their instruction from others (e.g., administrators), and significant parts of their work in systems resides beyond their control. Important in these interactions with administrators around the implementation of the culture-setting units, is the powered position administrators are in to provide or withhold recognition or opportunities for recognition grounded in JuST practice that is critical for professional JuST identity, especially when scholars (e.g., Carlone & Johnson, 2007; Dou & Cian, 2021; Hazari et al., 2010) point to the preeminence of recognition among other constructs that shape identity.

5.6 | The influence of CI to identify, enact, and refine a JuST practice

The focus of the PLCs beginning mid-way and continuing through the end of the academic year turned to engaging in CI composed of plan, do, and act cycles to identify or develop, test, and refine JuST practices in their classrooms. In this, PLCs were asked to identify instructional

practices connected to one or more features of the emerging project-wide JuST framework (see Figure 1). To do this, teachers drew on project-wide readings (e.g., Matthew Kay's 2018 book, *Not Light*, *but Fire*: *How to Lead Meaningful Race Conversations in the Classroom*, purchased and shared with all PLCs) and other resources (e.g., STEM Teaching Tools—see https://stemteachingtools.org/) to identify or develop practices PLC members could concurrently try out as an opportunity to center justice in their science classrooms. In the two PLCs examined in this current research, one PLC focused on "empowering student voices in their classrooms through listening and speaking" while another focused on "scaffolding student talk as sensemaking." Each PLC worked to refine their chosen JuST practice across the plan, do, and act cycles of design, whereby they were prompted to plan the implementation of their practice, do or implement their practice and collect data, and analyze their data to act or refine the practice for either the next design cycle or for sharing at the end of the three cycles as a practice brief with other PLCs across the project. The following are ways teachers' participation in CI supported their professional JuST identity authoring: *CI supported both the recognition and positioning of teachers as professionals capable of identifying or developing*, *refining*, *and contributing to knowledge about JuST science teaching and learning*; and *CI supported self- and group-reflection and clarification about how to act and understand JuST work in classrooms.*

In relation to *CI supporting both the recognition and positioning of teachers as professionals capable of identifying or developing*, *refining*, *and contributing to knowledge about JuST science teaching and learning*, this was exemplified in the following quote shared by Laura worked to recount for her peers what they were focused on as they reconvened for a PLC meeting after some had recently returned from their school's spring break:

> Laura: A couple of reflections that we had after our last cycle … Our big focus that we had was getting all of our students to feel safe and comfortable enough to contribute. A big barrier that we think our students have is kind of feeling like they shouldn't share their ideas if they're wrong or kind of always feeling too anxious to share because they're going to be wrong. A lot of what we were talking about focused on, how do we allow for students to make mistakes? What kind of body language, what things should we say in response to kind of elicit those ideas, even if they are wrong? … Along with some of our initial practices, we kind of added in a few things here, nonverbal talk moves per se, consistency of being non-reactive to those things and not saying, "wrong," or having our body language say that, but more of kind of pressing them, … "Did I hear you right? Is this what I said?" … We talked a lot last time about "do nows" and sort of different activities that we can structure at the beginning of class so that students talk science in a more informal way using their own language. Other than that, a couple of things that we thought we could try are things like true false questions at the beginning of class, breaking apart a word, real world context, creating word maps, using a GIF/GIF and using words in a new context, creating an Instagram caption, all those fun things. I kind of wanted to touch base with each of you guys, how is it going, things you've tried …? [Llamas, 3.30]

In this excerpt, it can be seen how teachers in the PLCs were positioned as professionals as they identified or developed and worked to refine practices they believed would help them achieve their JuST aims. As an example, in the excerpt, Laura shared how her PLC identified the "big focus" of their work. In the context of this project, teachers were not told that this would be

their "big focus", instead as professionals they were positioned to identify JuST related challenges they faced in their classrooms. For this PLC, the challenge was for, "students to feel safe and comfortable enough to contribute." To accomplish this, teachers in the PLC proposed and tried out practices (e.g., monitoring their body language as students shared, proposing strategies). Beyond this positioning, all PLCs created and shared practice briefs detailing the JuST practices they focused on, including the plan, do, and, act cycles they undertook, and the refined practice they thought other teachers beyond their PLCs might also find useful. These practice briefs were shared in a final cross-site meeting with PLCs both in the state within the New England region where this research took place, with PLCs in a state neighboring the New England region, with project leaders, and nationally known researchers in science education serving as advisory board members of the project, one of whom was able to attend the end-of-the-year cross-site meeting. Creating the practice briefs and sharing them with other PLCs, leaders, and researchers positioned teachers to contribute knowledge about JuST science teaching and learning as a form of recognition supportive of professional JuST identity development.

When considering the theme *CI supported self- and group-reflection and clarification about how to act and understand JuST work in classrooms*, one PLC, the Jedis, whose JuST practice focus was titled "Empowering student voices in their classrooms through listening and speaking" focused on providing a variety of structured and unstructured opportunities for students to engage in conversations. Because of sharing their JuST practice with another PLC in a cross-site meeting, one teacher was found reflecting with her PLC in the following about why the JuST practice they identified and worked to implement and refine mattered as they reconvened after the cross-site meeting to continue their CI:

> Abigail: So just going to the discussion that we were having previously thinking about why this matters. And, that was definitely a question somebody had asked when we had one of our sessions [at the cross-site meeting] ... Why do you think that this matters? Why is this going to lead us to equity? ... For me I feel like the reason why this is important in terms of equity is making sure that everybody's voice can be heard. And so thinking about talking about issues that are important to the kids and that matter to them. Talking about social justice issues that affect them and letting everyone have kind of agency about what we're discussing or what we're doing or talking about. I think this kind of gets at all of those things. So that for me is why this is, I think, tied into the idea of equity and justice-centered science teaching. [Jedis, July 2, 2022]

In this excerpt, Abigail reflected with her group about why she thought the practice her PLC selected as a focus of their DBR was important and was connected to how she thought to act and understand their JuST work in classrooms. The importance of DBR in supporting reflection within the PLC was also recognized by another teacher, Kylie, in the following as she was asked in the focus group interview to reflect on and share whether there were structures of the collaborative inquiries she found particularly helpful:

> Kylie: I guess doing the DBR [collaborative inquiry] allowed us to ground ourselves and reflect upon what we actually got out of the whole thing. It was kind of a reflective process ... [it] provide[d] the structure and the opportunity to reflect. [Jedis Focus Group June 2022].

Like the example excerpt from Abigail, Kylie also recognized how engaging in CI cycles supported reflection and consequently professional JuST identity development.

6 | DISCUSSION

Our findings reveal the advantages and challenges of participation in PLCs for JuST identity development. Here, we reveal more about how our findings can be understood, contribute to, and raise new important questions for future research about professional teacher identity more generally, and professional JuST identity more specifically. In each subsection that follows, we explicitly attend to how our findings align with, are different, or are new in the context of prior work documented in existing literature and the strengths and limitations of what we were able to understand.

6.1 | PLCs as communities of practice for collaboration and the Co-negotiation of professional JuST identities with peers

Our findings align with that of Leonard and Woodland (2022) who claimed that PLCs are an effective model of PD for justice-focused professional learning, because a PLC can provide "teachers with time, space, and support for critical dialogue about identity, implicit biases, and systemic oppression, so they can recognize and transform racist beliefs and practices" (p. 220). Additionally, this research supports Friedrichsen and Barnett's (2018) study of a biology PLC developing competence with NGSS, where the participating teachers collaborated to make meaning of the changing standards. They found, "teachers' identities were shaped by their participation and their experience of competence within their community" (p. 1017). Beyond this, our research provided additional insights about the how PLCs developed performances specifically connected to science teaching and learning, made space for negotiating emotions and holding one another accountable, and supported internal and external recognition as teachers who aspired to and were becoming JuST practitioners.

Gee (2001) noted how identity development or who one is seeking to be a particular kind of person (e.g., JuST teacher) is intricately shaped by the extent to which an individual is capable of and recognized for leveraging needed competencies (e.g., critical consciousness) and performances (e.g., facility engaging students in interrogation of the inequitable social order), which support the accomplishment of valued group-level pursuits (e.g., science as an expansive pursuit for social transformation). In the PLCs, we observed teachers developing JuST competencies and performances like using identity maps to learn about and seek to connect science teaching and learning with students' intersecting identities and interests in ways that were recognized internally and externally recognized ways.

Beyond developing competencies and performances in PLCs, the emotional work of becoming a JuST teacher was supported. Rivera Maulucci (2013), drawing and building on the work of Chubbuck and Zembylas (2008), recognized the importance of the expression of emotions for sustaining or changing action. Related to the expression and experience of emotion, Luehmann (2007) described the risks that teachers assume when they try out new practices and "the need to provide safe and supportive contexts" (p. 828). Mensah (2022) echoes this need in her study with future teacher educators of color, highlighting the need for providing space for critical conversations. In our research, teachers in PLCs expressed emotions that could have easily

redirected their actions connected to their attempts at becoming JuST teachers. As an example, teachers exhibited fear of, among other things, "not saying the right thing." However, the course of action was not redirected, at least not away from the broader aim of JuST teaching, because teachers reported how the PLCs provided support in dealing with these emotions. In Rivera Maulucci's (2013) research, coping strategies were identified as ways to avert the abandonment of the broader aims of becoming a social justice-centered science teacher. While coping strategies could have been used by teachers in our research, it was the PLC support in reaffirming JuST aims that stood out as a mechanism for avoiding the abandonment of becoming a JuST teacher in the precarity of, among other things, political environments that resisted elevating justice as an aim in science classrooms.

Finally, teachers' participation in PLCs afforded them opportunities for internal and external recognition. Researchers like Carlone and Johnson (2007), Dou and Cian (2021), Hazari et al. (2010) foregrounded recognition as among, if not the most important dimensions of identity development, while Luehmann (2007) did the same with considering professional science teacher identity development. We identified recognition occurring in the space of PLCs like the following internal form of recognition referenced in the title of our manuscript, "I sit here thinking I can do this." This instance of recognition was found connected to entangled competences and performances (Gee, 2001) like teachers understanding the effectiveness of how pausing in the moment can be needed to "separate the student from their comment and really try to get them to understand" as a way in which this particular teacher was becoming a JuST teacher.

6.2 | Adapting and enacting curriculum as a PLC task for professional JuST identity development

While researchers like Friedrichsen and Barnett (2018) and Larkin et al. (2009) recognize the affordances of the social nature of PLCs and the necessity of collaboration among peers to make changes to practice, researchers like Nelson (2009) and Thompson et al. (2019) focus on the importance of infrastructure or footholds around which teacher learning and changes in practice can be anchored in the context of PLCs. In our research, working to learn about, adapt, and implement culture-setting units that embodied commitments in the JuST framework (Figure 1) served as one of the pieces of infrastructure that was examined. In our findings related to these units, we identified both affordances and challenges teachers experienced. We also recognized the role that administrators played in their attempts to implement units that included a social critique of how COVID-19 surfaced systemic racism that, for the most part, has typically gone un-questioned in science classrooms (Tolbert & Bazzul, 2017; Verma et al., 2022).

More specifically, when implementing the culture-setting units, teachers were afforded specific strategies for both learning about and supporting their facility in building relationships with students and identifying their assets. The units also provided a common set of resources for elevating discussions about race and ethnicity in classrooms and served as springboards for conversations between teachers in PLCs focused on what makes curriculum JuST. In their study, Chen and Mensah (2018) identified how the experiences within the science teaching methods course supported PSTs by helping shift what they came to understand about teaching science as they learned about the benefits of providing visual, hands-on experiences to students and asking open-ended questions. Somewhat like how the science teaching methods course supported PSTs in Chen and Mensah's study, in this current research, the culture-setting

units provided valuable resources (e.g., activities and ways of orienting to science teaching and learning as a sociopolitical endeavor) for the inservice teachers in PLCs to help shift what they came to understand of their role in becoming JuST teachers. More specifically, these units, among other activities and foci, included activities whereby students created and shared identity maps as a powerful foundation for building relationships and for identifying student assets. Additionally, each of the units focused on the differential impact of COVID-19 on racial and ethnic groups in ways that supported the elevation of discussion about race and ethnicity as, for example, students worked to explain the disproportionate number of cases, hospitalizations, and deaths of people of color during the pandemic. Finally, the units served as a foothold around which teachers could reflect on and articulate what made a specific feature or task of the curriculum JuST.

While the task of implementing culture-setting units brought with them benefits, challenges also emerged, mainly in connection to teachers in the PLCs not taking part in the design of the units. For teachers in the two PLCs investigated in this research, this distance from the design led to challenges in understanding the aims of tasks within the units or negotiating how the unit could fit into, in many cases, an already overcrowded previously designed department-, school-, or district-level curriculum teachers were already expected to teach. Researchers like Penuel and Gallagher (2009), identify how access to high-quality curriculum materials can support teachers in making principled adaptations for local contexts in ways that support teacher planning and coordination of instruction. As is evident in the affordances we have shared in connection to anchoring PLC learning around the units, teachers benefited from access to curriculum that supported them in planning for JuST practice (e.g., by drawing on activities that fostered relationship building, by having access to reasoning tasks oriented toward interrogating differential harm from COVID-19). However, like others (e.g. Edelson et al., 2021; Miller et al., 2021; Reiser et al., 2021), we also noted how challenges can come alongside the affordances that providing access to high-quality curriculum can bring. Here, we identified the time it takes teachers to learn and adapt curriculum and the complexity of negotiating the fit of any high-quality curriculum within an existing and potentially overcrowded curriculum. In the case of our current work, these challenges meant that many of the teachers could not make the time to implement the unit in its entirety. Beyond these affordances and challenges, we identified interactions among teachers and their administrators as a potentially important factor influencing our participants attempts at becoming JuST practitioners.

We had not originally planned to explore the interactions between administrators and teachers, since our PLCs were not school-based and instead were made up of teachers from several different schools and districts. However, our data analyses revealed how administrators played different roles in either supporting or challenging teachers' participation in the project, while also sending messages to teachers that we believe either affirmed or challenged their professional JuST identity development. In some cases, administrators supported teachers' participation in the project as they reviewed and signaled their approval of the enactment of the culture setting curriculum units. In both cases, we believe that recognition, among the most important of identity constructs for narrating self (Carlone & Johnson, 2007; Dou & Cian, 2021; Hazari et al., 2010), was happening as teachers were being recognized by their administrators as either capable of engaging students in JuST or not. In the end, while we were not able to explore further the sensemaking teachers were making about administrative support (or lack of support) beyond what was captured in the meeting transcripts, based on other studies (e.g., Carrier et al., 2017), there is reason to believe that the teacher-administrator interactions

documented did play a role in shaping, positively or negatively, who teachers in our project were becoming in relation to JuST.

6.3 | CI in PLCs as spaces for recognition and positioning and self and group-reflection

In addition to curriculum adaptation and implementation, CI cycles also served as tasks within PLCs for the identification, enactment, and refinement of JuST practice and identity development. More specifically, CI supported both the recognition and positioning of teachers as capable of contributing knowledge about JuST teaching and learning, while also supporting self- and group-reflection about JuST work in classrooms. In this regard, our findings align well with that of Slavit and Nelson (2009) as they recognized CI as a rich context for teachers' learning and growth. In our study, the rich context was related to JuST identity development as CI supported recognition, positioning, and reflection, key features of identity development which we sought to support. The recognition, positioning, and reflection was born out of how DeLuca et al. (2015) described CI as a cyclic process situated in a socio-constructivist perspective where we found identity construction occurring in the social settings of PLCs engaged in both the development of JuST practices and the narrations of themselves as JuST practitioners. Finally, like Thompson et al. (2019), our research has helped demonstrate how PLC tasks like CI can serve as infrastructure or footholds for "experimentation with classroom practices and school-to-school learning" (p. 2) like JuST practices that are essential for accomplishing JuST aims and supporting teachers in becoming JuST practitioners. Additionally, the CI supported PLCs to contribute meaningfully to our JuST Framework as the practices they identified, enacted, and refined informed the frameworks iterative and ongoing development while also ensuring that it was grounded in JuST practices that other teachers can begin to explore as footholds in their own journeys of becoming JuST.

7 | CONCLUSION

The moment in time in which this research took place found science teachers challenged with societal ills emanating from systemic racism as they were still adjusting to changes in teaching and learning prompted by the release of the Framework for K-12 Science Education (NRC, 2012) and the NGSS (NGSS Lead States, 2013). The Covid-19 pandemic and subsequent racial uprising led to a renewed sense of urgency to reflect on what it means to teach science in ways that countered injustice and sought social transformation (Morales-Doyle, 2017; Philip & Azevedo, 2017; Rodriguez, 2015; Tzou et al., 2021). Further, science teaching and learning as an apolitical pursuit was being contested (Melville et al., 2022; Tolbert & Bazzul, 2017; Verma et al., 2022; Waight et al., 2022). This led us to propose JuST as science teaching that is grounded in critical consciousness, responsive to students' cultures and communities, dependent on teachers' interpretive power to recognize and build upon expansive forms of student meaning-making, and committed to naming and disrupting oppression and injustice in society (Luehmann et al., 2024), even as we recognized how taking up JuST meant teachers would need support negotiating new versions of themselves and their professional JuST identity. With these events and priorities as a backdrop, the contribution of this research lies in the nuance we have detailed about how PLCs, with their importance anchored in social learning theory, can provide

space for teachers to develop professional JuST identities. From what we have revealed, not as prescriptives but as guides, teacher leaders and administrators can engage teachers in PLCs around tasks like curriculum implementation and refinement or collaborative inquires as spaces for professional JuST identity development, where JuST competencies and performances are practiced alongside opportunities for recognition and reflection so that teacher's expertise, identities, and basic needs as learners are met. Culture-setting curriculum implementation and collaborative inquiries can be further considered in informed ways as PLC tasks or footholds supportive of socio-constructivist learning and development (DeLuca et al., 2015), while influences like teacher-administrator interactions, like those we identified, can be better anticipated and cultivated in ways that lead to positive affirmation of teachers' JuST work. With research like we have undertaken here as a beginning, future research can add to what we know about what professional JuST identity development might look like as PLCs work together around adaptions of curriculum implementation, collaborative inquires, or other meaningful tasks. As well, building on what we have learned in this research, future research might also consider how a professional JuST identity develops in relation to other teacher identity markers such as race and gender. Finally, while not the primary focus of our research in this current study, we expect a more refined version of our JuST framework to emerge in subsequent research as we continue our collaborations with the teachers in our PLCs and with other science education researchers nationally who are involved in similar work.

DATA AVAILABILITY STATEMENT
Research data are not shared.

ORCID
Todd Campbell ⬤ https://orcid.org/0000-0001-6844-5303

REFERENCES
Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145–179.

Bang, M., Marin, A., & Medin, D. (2018). If indigenous peoples stand with the sciences, will scientists stand with us? *Daedalus*, *147*(2), 148–159. https://doi.org/10.1162/DAED_a_00498

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *Journal of the Learning Sciences*, *19*(2), 187–229.

Barton, A. C., & Tan, E. (2020). Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher*, *49*(6), 433–440. https://doi.org/10.3102/0013189X20927363

Beauchamp, C., & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*, *39*(2), 175–189. https://doi.org/10.1080/03057640902902252

Beijaard, D. (1995). Teachers prior experiences and actual perceptions of professional identity. *Teachers and Teaching: Theory and Practice*, *1*(2), 281–294.

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education*, *20*(2), 107–128. https://doi.org/10.1016/j.tate.2003.07.001

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218. https://doi.org/10.1002/tea.20237

Carrier, S. J., Whitehead, A. N., Walkowiak, T. A., Luginbuhl, S. C., & Thomson, M. M. (2017). The development of elementary teacher identities as teachers of science. *International Journal of Science Education*, *39*(13), 1733–1754. https://doi.org/10.1080/09500693.2017.1351648

Chen, J. L., & Mensah, F. M. (2018). Teaching contexts that influence elementary preservice Teachers' teacher and science teacher identity development. *Journal of Science Teacher Education*, 29(5), 420–439. https://doi.org/10.1080/1046560X.2018.1469187

Chubbuck, S. M., & Zembylas, M. (2008). The emotional ambivalence of socially just teaching: A case study of a novice urban schoolteacher. *American Educational Research Journal*, 45(2), 274–318. https://doi.org/10.3102/0002831207311586

Creswell, J. W. (2005). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (2nd ed.). Merrill.

DeLuca, C., Shulha, J., Luhanga, U., Shulha, L. M., Christou, T. M., & Klinger, D. A. (2015). Collaborative inquiry as a professional learning structure for educators: A scoping review. *Professional Development in Education*, 41(4), 640–670. https://doi.org/10.1080/19415257.2014.933120

Dou, R., & Cian, H. (2021). The relevance of childhood science talk as a proxy for college Students' STEM identity at a Hispanic serving institution. *Research in Science Education*, 51(4), 1093–1105. https://doi.org/10.1007/s11165-020-09928-8

Drew, S. V., & Thomas, J. (2022). Reframing literacy in the discipline of science with the disciplinary literacy observation tool (DLOT). *Learning Disabilities Research & Practice*, 37(1), 64–79. https://doi.org/10.1111/ldrp.12270

Edelson, D. C., Reiser, B. J., McNeill, K. L., Mohan, A., Novak, M., Mohan, L., Affolter, R., McGill, T. A. W., Bukc Bracey, Z. E., Deutch Noll, J., Kowalski, S. M., Novak, D., Lo, A. S., Landel, C., Krumm, A., Penuel, W. R., Van Horne, K., González-Howard, M., & Suárez, E. (2021). Developing research-based instructional materials to support large-scale transformation of science teaching and learning: The approach of the OpenSciEd middle school program. *Journal of Science Teacher Education*, 32(7), 780–804. https://doi.org/10.1080/1046560X.2021.1877457

Freire, P. (2001). *Pedagogy of the oppressed*. Continuum. (Original work published 1970).

Friedrichsen, P. J., & Barnett, E. (2018). Negotiating the meaning of next generation science standards in a secondary biology teacher professional learning community. *Journal of Research in Science Teaching*, 55(7), 999–1025. https://doi.org/10.1002/tea.21472

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education*, 25, 99–125. https://doi.org/10.2307/1167322

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method* (2nd ed.). Routledge.

Glazer, J. L., & Puerach, D. J. (2015). Occupational control in education: The logic and leverage of epistemic communities. *Harvard Educational Review*, 85(2), 172–202.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, 47(8), 978–1003. https://doi.org/10.1002/tea.20363

Kang, H., & Windschitl, M. (2018). How does practice-based teacher preparation influence Novices' first-year instruction? *Teachers College Record: The Voice of Scholarship in Education*, 120(8), 1–44. https://doi.org/10.1177/016146811812000803

Kay, M. R. (2018). *Not light, but fire: How to lead meaningful race conversations in the classroom*. Stenhouse Publishers.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32(3), 465–491. https://doi.org/10.2307/1163320

Larkin, D. B., Seyforth, S. C., & Lasky, H. J. (2009). Implementing and sustaining science curriculum reform: A study of leadership practices among teachers within a high school science department. *Journal of Research in Science Teaching*, 46(7), 813–835.

Law, J. (2015). What's wrong with a one-world world? *Distinktion: Journal of Social Theory*, 16(1), 126–139. https://doi.org/10.1080/1600910X.2015.1020066

Lee, C. D. (2017). Expanding visions of how people learn: The centrality of identity repertoires. *Journal of the Learning Sciences*, 26(3), 517–524.

Leonard, A. M., & Woodland, R. H. (2022). Anti-racism is not an initiative: How professional learning communities may advance equity and social-emotional learning in schools. *Theory into Practice*, 61(2), 212–223. https://doi.org/10.1080/00405841.2022.2036058

Louis, V. N., & King, N. S. (2022). Emancipating STEM education through abolitionist teaching: A research-practice partnership to support virtual microteaching experiences. *Journal of Science Teacher Education*, *33*(2), 206–226. https://doi.org/10.1080/1046560X.2021.2012957

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education*, *91*(5), 822–839. https://doi.org/10.1002/sce.20209

Luehmann, A. L., Zhang, Y., Boyle, H., Tulbert, E., Merliss, G., & Sulivan, K. (2024). Shaping ambitious science teaching to be culturally sustaining and productive in a rural context: Toward a justice-centered ambitious science teaching framework. *Journal of Research in Science Teaching*, *61*, 319–357. https://doi.org/10.1002/tea.21917

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

Melville, W., Verma, G., Campbell, T., & Park, B.-Y. (2022). Challenging the hegemony of Western scientism in science teacher education. *Journal of Science Teacher Education*, *33*(7), 703–709. https://doi.org/10.1080/1046560X.2022.2112130

Mensah, F. M. (2013). Theoretically and practically speaking, what is needed in diversity and equity in science teaching and learning? *Theory into Practice*, *52*(1), 66–72. https://doi.org/10.1080/00405841.2013.743781

Mensah, F. M. (2022). Educating future teachers of color to talk about race in teacher education. In C. D. Gist & T. J. Bristol (Eds.), *Handbook of research on teachers of color and indigenous teachers*. American Educational Research Association.

Miller, E. C., Severance, S., & Krajcik, J. (2021). Motivating teaching, sustaining change in practice: Design principles for teacher learning in project-based learning contexts. *Journal of Science Teacher Education*, *32*(7), 757–779. https://doi.org/10.1080/1046560X.2020.1864099

Moore, F. M. (2008). Positional identity and science teacher professional development. *Journal of Research in Science Teaching*, *45*(6), 684–710. https://doi.org/10.1002/tea.20258

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

Morales-Doyle, D. (2018). Students as curriculum critics: Standpoints with respect to relevance, goals, and science. *Journal of Research in Science Teaching*, *55*(5), 749–773. https://doi.org/10.1002/tea.21438

Morales-Doyle, D., Varelas, M., Segura, D., & Bernal-Munera, M. (2021). Access, dissent, ethics, and politics: Pre-service teachers negotiating conceptions of the work of teaching science for equity. *Cognition and Instruction*, *39*(1), 35–64. https://doi.org/10.1080/07370008.2020.1828421

Morrison, D. L., Bell, P., & Rhinehart, A. (2020). Focusing science and engineering learning on justice-centered phenomena across PK-12. STEM Teaching Tool. https://stemteachingtools.org/brief/67

Nelson, T. H. (2009). Teachers' collaborative inquiry and professional growth: Should we be optimistic? *Science Education*, *93*(3), 548–580. https://doi.org/10.1002/sce.20302

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.

NRC. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.

Nxumalo, F., & Gitari, W. (2021). Introduction to the special theme on responding to anti-blackness in science, mathematics, technology and STEM education. *Canadian Journal of Science, Mathematics and Technology Education*, *21*(2), 226–231. https://doi.org/10.1007/s42330-021-00160-8

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Sage Publications.

Penuel, W. R., & Gallagher, L. P. (2009). Comparing three approaches to preparing teachers to teach for deep understanding in earth science: Short-term impacts on teachers and teaching practice. *Journal of the Learning Sciences*, *18*(4), 461–508.

Reiser, B. J., Novak, M., McGill, T. A. W., & Penuel, W. R. (2021). Storyline units: An instructional model to support coherence from the students' perspective. *Journal of Science Teacher Education*, *32*(7), 805–829. https://doi.org/10.1080/1046560X.2021.1884784

Philip, T. M., & Azevedo, F. S. (2017). Everyday science learning and equity: Mapping the contested terrain. *Science Education*, *101*(4), 526–532. https://doi.org/10.1002/sce.21286

Porter, R. E., Fusarelli, L. D., & Fusarelli, B. C. (2015). Implementing the common Core: How educators interpret curriculum reform. *Educational Policy*, *29*(1), 111–139. https://doi.org/10.1177/0895904814559248

Rivera Maulucci, M. S. (2013). Emotions and positional identity in becoming a social justice science teacher: Nicole's story. *Journal of Research in Science Teaching*, *50*(4), 453–478. https://doi.org/10.1002/tea.21081

Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices? A critique of the next generation science standards. *Journal of Research in Science Teaching*, *52*(7), 1031–1051. https://doi.org/10.1002/tea.21232

Slavit, D., & Nelson, T. H. (2009). Supported collaborative teacher inquiry. In D. Slavit, T. H. Nelson, & A. Kennedy (Eds.), *Perspectives on supported collaborative teacher inquiry*. Routledge.

Thompson, J., Richards, J., Shim, S.-Y., Lohwasser, K., Von Esch, K. S., Chew, C., Sjoberg, B., & Morris, A. (2019). Launching networked plcs: Footholds into creating and improving knowledge of ambitious and equitable teaching practices in an rpp. *AERA Open*, *5*(3), 233285841987571. https://doi.org/10.1177/2332858419875718

Tolbert, S., & Bazzul, J. (2017). Toward the sociopolitical in science education. *Cultural Studies of Science Education*, *12*(2), 321–330. https://doi.org/10.1007/s11422-016-9737-5

Tzou, C., Bang, M., & Bricker, L. (2021). Commentary: Designing science instructional materials that contribute to more just, equitable, and culturally thriving learning and teaching in science education. *Journal of Science Teacher Education*, *32*(7), 858–864. https://doi.org/10.1080/1046560X.2021.1964786

Varelas, M., Martin, D. B., & Kane, J. M. (2012). Content learning and identity construction: A framework tostrengthen African American students'mathematics and science learning in urban elementary schools. *Human Development*, *55*(5–6), 319–339.

Verma, G., Campbell, T., Melville, W., & Park, B.-Y. (2022). Science teacher education and a sociopolitical turn: The implications for democratic citizenship, and environmental and social justice. *Journal of Science Teacher Education*, *33*(5), 459–465. https://doi.org/10.1080/1046560X.2022.2082639

Waight, N., Kayumova, S., Tripp, J., & Achilova, F. (2022). Towards equitable, social justice criticality: Reconstructing the "black" box and making it transparent for the future of science and technology in science education. *Science & Education*, *31*, 1493–1515. https://doi.org/10.1007/s11191-022-00328-0

Windschitl, M., & Stroupe, D. (2017). The three-story challenge: Implications of the next generation science standards for teacher preparation. *Journal of Teacher Education*, *68*(3), 251–261. https://doi.org/10.1177/0022487117696278

Windschitl, M., Thompson, J. J., & Braaten, M. L. (2018). *Ambitious science teaching*. Harvard Education Press.

Wright, C. G., Likely, R., Wendell, K. B., Paugh, P. P., & Smith, E. (2019). Recognition and positional identity in an elementary professional learning community: A case study. *Journal of Pre-College Engineering Education Research (J-PEER)*, *10*(1), 1–12. https://doi.org/10.7771/2157-9288.1214