Preservice Teachers' Lesson Planning for Justice-Oriented Elementary Science

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Abstract

Building on the literature, we designed a practical framework to support attention to equity and justice in science teacher education coursework. This framework presents four approaches for including justice moves in elementary science lessons, from increasing opportunity and access in science, to increasing identity and representation in science, to expanding what counts as science, to seeing science as a part of justice movements. We analyzed the lesson plans of 16 preservice elementary teachers who were using the practical justice framework. In addition to extensive attention to varying participation structures to support children's science discourse, preservice teachers also took up more challenging moves such as attending to how children are positioned as scientists, inviting children's science ideas and hearing the science in their ideas, encouraging decision-making in science practices, and connecting science to issues of justice. They varied in both the number of unique justice moves they took up and the specificity with which they planned for incorporating the moves. We discuss implications for practice and theory-building in relation to supporting preservice teachers in learning to teach science toward equity and justice.

Introduction

Elementary teachers bring many strengths and assets to elementary science and advancing equity, including, for example, caring for and centering children, being inquisitive, and being able to develop both subject matter knowledge and ideas about justice in science teaching (e.g., Eick & Stewart, 2010; Haverly et al., 2020; Nixon et al., 2019; Mensah & Jackson, 2018). That said, they also face challenges. For example, science teaching may make elementary teachers particularly uneasy (Banilower et al., 2018), and some express concern about working toward justice with students, for example due to concern about alienating children's parents (Rodriguez, 2005). In our work with preservice elementary teachers, we try to build on the strengths they bring while supporting them in addressing the challenges they face. We see the worries they have about science teaching and teaching toward justice as challenges we have an obligation to address, to help prepare these dedicated teachers to become well-started beginners (Davis & Haverly, 2022; Haverly & Davis, 2023).

Given the inequities in the US and globally, antiracism and justice must be addressed in all learning-to-teach experiences, not bounded in multicultural or foundations courses in teacher education. There has been relatively little attention to supporting preservice elementary teachers in advancing equity and justice in their science teaching. We use "equity" to refer to the need for policies and practices to remove barriers to participation to work toward comparable levels of attainment, representation, and identification in science. We use "justice" to refer to actions that work to address or overturn systemic oppressions that cause those barriers, to provide opportunities for thriving and self-determination (NASEM, 2022). Issues of equity and justice always sit within systems of power (Esmonde & Booker, 2017). We have developed a practical

justice framework to support preservice teachers in attending to equity and justice in their elementary science teaching. In this paper, we explore how these preservice elementary teachers took up ideas from the framework in their early planning of science lessons.

Literature Review: Advancing Equity and Justice in Elementary Science Teaching

In developing a practical justice framework to use with our preservice elementary teachers in science-focused teacher education coursework, we build on a recent National Academies report (NASEM, 2022). This report adapts work from Philip and Azevedo (2017) and Rodriguez (2015) to put forward four "approaches to equity" for elementary science:

(1) increasing opportunity and access to high quality science instruction;

(2) emphasizing increased achievement, representation, and identification with science;

(3) expanding what constitutes science; and

(4) seeing science as part of justice movements (NASEM, 2022, p. 23).

Approach 1—*opportunity and access*—focuses on removing barriers to participation, for example by providing accommodations for learning (dis)abilities. Approach 2—*achievement, representation, and identification*—might mean that the classroom library includes books that show scientists of color, or that the teacher connects science to children's interests. With approach 3—*expanding what counts as science*—family knowledge and practices are incorporated into classroom talk, and teachers build on the multiple ways of knowing and being of children and their communities. Finally, in approach 4—*seeing science as a part of justice movements*—children ask and answer questions about justice issues relevant in their communities and examine issues using historicized lenses; furthermore, teachers recognize their own power and positionality. The approaches are not mutually exclusive, and each has pitfalls to acknowledge and account for (NASEM, 2022; Philip & Azevedo, 2017). Yet the four

approaches, *together*, reflect a spectrum of ways educators can advance equity in science teaching. Davis (2022) presents the practical justice framework in more detail, and in the sections that follow, we outline some of the literature informing our thinking about each of these approaches.

Increasing Opportunity and Access

Increasing students' opportunity in and access to science in the elementary grades is a necessary first step in terms of working toward equity with one's science teaching. To increase opportunity and access means to provide opportunities to experience and make sense of phenomena, to engage in hands-on investigation, to grapple with ideas, and to engage in science discourse; indeed, having this access to science education is a civil right (Tate, 2001). Taking this orientation means teachers view any "gaps" they notice as opportunity gaps, rather than achievement gaps (Carlone et al., 2011; Patterson, 2019), and work to remedy the opportunity gaps while avoiding "gap gazing" (Gutiérrez, 2013).

Teachers can enhance children's opportunities and access by, for example, varying the participation structures to include small group work as well as whole-class work to increase children's opportunities to talk about science. Changing participation structures and incorporating talk moves can give teachers and children supportive structures that help them build connections across ideas (e.g., Michaels & O'Connor, 2012; Patterson, 2019; Patterson Williams et al., 2020). At the same time, attending carefully to one's use of language (e.g., by using language in accessible ways and not pre-teaching vocabulary, and by using language scaffolds like sentence stems) can support emergent multilingual learners (Lee & Stephens, 2020; NASEM, 2022), though teachers must also take care not to over-scaffold and over-constrain learners' sensemaking opportunities (Suárez & Otero, 2023). Providing access to ideas

via multiple modalities, such as audio, video, or text, can support multiple ways for children to engage, making ideas more accessible. As a final example of how teachers can increase children's opportunity and access in science, orienting science instruction around natural phenomena can help to motivate children in their science learning (NASEM, 2022). Providing a shared experience with a phenomenon to launch an investigation (Windschitl et al., 2018) can help to ensure that children have equal footing, rather than assuming particular kinds of experiences such as airplane travel or downhill skiing.

Emphasizing Increased Identification and Representation

A second way teachers can work toward equity in their elementary science teaching is to increase children's identification and representation in science. Children need to see *others like them* as people who do science, and they need to see *themselves* as people who do science, too. A teacher—in particular, white women teachers, who make up the majority of the US elementary teaching force—may need to check whether they are assuming some children will not be good at science, and whether their orientation toward "niceness" (Castagno, 2019) is leading them to have low expectations for students of color (Ladson-Billings, 2022). Instead, teachers need to position children as people who do science, and—more than just as doers—as knowledge builders, thinkers, and critics of science (e.g., Carlone et al., 2014; Wright, 2019; see also Sengupta-Irving & Agarwal, 2017), to help build their identities as "science people" (Carlone et al., 2011).

Teachers might position children as scientists by privileging investigation, making connections between the science practices and the work of scientists across cultures, and/or supporting children's epistemic agency in making decisions about their investigations (Bautista & Davis, under review; Carlone et al., 2021; Manz, 2015). Manz discusses how allowing for

uncertainty can support children in this kind of meaningful decision-making. For example, just like scientists, children might make decisions based on incomplete information about how to set up an investigation or how to collect and record their data. Furthermore, simply connecting science lessons to children's lived experiences can also help to support children in seeing science as something they care about—while recognizing the many facets of children's identities and taking care to avoid or move beyond essentialism (see Gutiérrez, 2013).

The examples above help to support children's developing science identity, but equally important (and related) is enhancing representation: helping children see that science as a field is not limited to white, middle-class, cisgender men. Toward this end, teachers need to make visible a range of examples of who does science (e.g., scientists who are women of color, queer or trans scientists, or community members who engage in scientific practices in their vocations or avocations) – perhaps through books, posters, or examples in lessons (e.g., Fitzgerald, 2018). Teachers of color, themselves, can also play an important role here (Mensah & Jackson, 2018; Rivera Maulucci, 2013).

Expanding What Constitutes Science

A third way teachers can work toward more equitable science teaching is through taking a more expansive stance on what constitutes science. Because science has historically been the realm of white men, as noted above, many future teachers have limited perspectives on what can "count" as science. Yet individuals from a huge range of backgrounds, cultures, and identities have contributed to understanding the natural world. Beyond representing those contributions, as emphasized in the previous approach of increasing identification and representation, teachers also must *value* and *listen for* the range of ways of knowing and being that can contribute to science – among adults in their broader community and among the children in their classroom

(Bang et al., 2017; Wright et al., 2018). The intent is twofold: to help children to develop a more expansive perspective themselves, and to use the full range of ideas and practices children bring with them to the classroom, toward the class's collective sensemaking. (This, in turn, serves the larger good of potentially bringing a more diverse range of ways of thinking to professional science, strengthening the science that can be done.) Being cognizant of these goals is important because even teachers who have a strong commitment to equity can succumb to a narrow, excluding, limiting stance, due in part to the culture of teaching in the US and decades- or centuries-long systems of oppression (Louie, 2017, 2018).

Most centrally, in the classroom this more expansive stance entails being able to "hear the science" in what children say, write, draw, or do (Bang et al., 2017; Rosebery et al., 2016). Teachers need to invite a range of ideas into classroom conversation and encourage expression of those ideas in ways that build on children's unique knowledge, skills, and experiences (Suárez, 2020; Suárez & Otero, 2023). Ideally, teachers can recognize and promote multiple scientific ways of knowing that stem (for example) from Indigenous ways of knowing or heritage agricultural practices with African roots, as well as ways of engaging in science discourse that allow for use of nonstandard (i.e., non-white, non-middle class, and non-male) expression of ideas (e.g., Bang & Medin, 2010; Gunckel et al., in press; Medin & Bang, 2014; Wright, 2019). At the same time, having an expansive perspective on what counts as science entails connecting to children's out-of-school experiences, and in particular, the knowledge and practices of the families and communities of children that are scientific or connect to science knowledge and practices (Bang & Medin, 2010). This, in turn, means teachers need to take care to recognize the assets and funds of knowledge children bring, rather than making deficit-based assumptions

about their homes or prior experiences (Ladson-Billings, 2022; McLaughlin & Calabrese Barton, 2013; see also Carlone & Davis, 2023).

Teachers can also do other, more prosaic things too, to help children to recognize a more expansive perspective on science. For example, by using non-traditional student roles for small group work – roles that move beyond "timekeeper" and "recorder" and could position children as "ethicists" or "scientific artists" – teachers can help to acknowledge more competencies than are usually valued in science (Louie, 2017; Mercier & Carlone 2021). By integrating science with English language arts, mathematics, or social studies, teachers can help children see how science connects to other things they may care about (NASEM, 2022; Stevens et al., 2005). Connecting to local phenomena and even having children document science in their own lives can help to broaden this perspective, as well (Cody & Biggers, 2020; Tzou & Bell, 2010).

Seeing Science as a Part of Justice Movements

A fourth way teachers can move toward more equitable science teaching is to help children recognize how science can support them in developing a more equitable and just community. "Community" here may be as proscribed as the classroom community. For example, Calabrese Barton and Tan (2020) describe how a class of sixth graders used what they were learning about electric circuits to design and build an alarm system to indicate when someone was using the classroom restroom, as a way of curbing a student-identified bullying problem. One of our own preservice teachers framed a kindergarten lesson on germs around keeping the children in the classroom healthy, so in turn the babies and grandparents in their families could stay healthy. Or, "community" can be much broader, such as when environmental justice issues are the focus, and the community stretches to a neighborhood, town, or region.

In essence, teachers who take on this approach to equity emphasize connecting the science in the classroom to real-life justice issues that are at play in children's lives, such as water quality, soil contamination, climate change, or health disparities (e.g., Davis & Schaeffer, 2019; Morales-Doyle, 2017). Teachers may be able to partner with local farms, museums, or zoos to establish meaningful contexts for this work. For example, Penniman (2020) describes their work as a Black Kreyol farmer, helping Black youth to develop or rekindle relationships with the land that have too often been severed due to long-term, intergenerational traumas of enslavement. Teachers might also help children ask and answer "should we" questions (Learning in Places Collaborative, 2020) to explore ethical decision-making informed by both science and community input.

It is crucial that these efforts not just focus on identifying problems in communities (Davis & Schaeffer, 2019), but rather, that strengths in communities are identified, too, and that children are positioned as agents of change. This latter might occur by having them write letters to community leaders, or inviting those leaders to come to the classroom to hear about what children have learned (Calabrese Barton & Tan, 2010). These efforts also need to historicize inequities in communities, taking an explicitly sociopolitical approach (Gutiérrez, 2013; see also Esmonde, 2017; Ladson-Billings, 2022), by helping children see (in age-appropriate ways) how systemic racism and centuries of policies and practices have led to inequities that are still very much with us today (e.g., Davis & Schaeffer, 2019; Patterson Williams et al., 2020).

Theoretical Framework

We build from Cochran-Smith's (2010) theory of teacher education for social justice. This perspective emphasizes that teaching for justice requires an amalgam of knowledge, interpretive frameworks, teaching strategies or moves, and advocacy, and our practical

framework incorporates these elements, with an emphasis on interpretive frames and teaching moves. We also draw on other literature related to practice-based teacher education and social justice and antiracist teacher education (e.g., Ball & Forzani, 2009; Milner & Laughter, 2015; Sleeter & Owuor, 2011). In practice-based teacher education (such as in the program in which this study took place), novices engage with decompositions, representations, and approximations of practice to support their entry into professional work (Grossman et al., 2008). These pedagogies of practice serve to provide incremental opportunities to learn new practices – here, practices that attend to power structures and challenge oppressive systems (Esmonde & Booker, 2017), and support justice-oriented science teaching. By drawing together these multiple theoretical perspectives, this work interweaves theories around justice, practice, and knowledge.

These organizing ideas assume that learning to teach is sociocultural and situated in experiences, and over time what is learned—knowledge and practice—can be generalized across contexts (Esmonde, 2017). Further, learning to teach requires orchestrating skill, knowledge, and identity to work toward a communal goal (Esmonde, 2017; Grossman, 2018), such as teaching science well and equitably. Thus, this learning-to-teach also involves identity work: here, in addition to one's personal identities, this refers to identity as seeing oneself as a teacher committed (or not) to enhancing justice through one's elementary science teaching—thus learning is a process of becoming.

These perspectives, then, provide a foundation for a practice-based teacher education program like ours: activity, knowledge, beliefs, identity, and practice all come to be interconnected. In this case, the knowledge, beliefs, identity, and practice are related to justice commitments and understandings as well as teaching moves that can enhance equity and justice

in teaching. We see these collectively as building blocks to support the teachers' readiness for justice-oriented elementary science teaching (Haverly & Davis, 2023).

The activity of focus here is lesson planning, scaffolded within a teacher education program and shaped by pedagogies of practice. Frameworks and other forms of scaffolding can support lesson planning, enactment, and reflection (Patterson Williams et al., 2020), serving as cognitive and cultural tools for learning (Wertsch, 1998). Through the mediation of tools and frameworks (Esmonde, 2017), including our practical justice framework, novice teachers begin to develop their knowledge and practice—here, related to justice-oriented science teaching.

In sum, we braid these theoretical and practical elements together in our conception, enactment, and study of learning to advance equity in science teaching. In this study, we look at novice teachers' lesson plans at one moment in time—indeed, the first science lesson plans they develop—to provide insight into very early knowledge and practice with regard to justice-oriented elementary science teaching. Later research will build from this early snapshot to sketch a trajectory of development across time (Davis & Palincsar, 2023; Kang & Zinger, 2019; Thompson et al., 2020). Recognizing the strengths in these teachers' early work allows us to take an asset framing in our work with beginning elementary teachers (Zembal-Saul, Carlone, & Brown, 2020).

Methods

Our central research question is, *How do preservice teachers plan for advancing equity in elementary science?* Toward answering this research question, we ask two analytic questions:

a) *What justice moves are used most and least often, as preservice elementary teachers modify existing lesson plans?*

b) *How do preservice elementary teachers vary in the ways they employ these justice moves?*

Participants, Instructional Context, and Data Sources

Our participants included 16 preservice elementary teachers in their second semester of a four-semester undergraduate elementary teacher education program at a large public university in the US. During this study, they were taking a class focused on teaching with curriculum materials in elementary mathematics and science. The program is a practice-based elementary teacher education program. In this course, the emphasis is on the practice of lesson design. This was the preservice teachers' first experience with planning a full lesson and their first experience with lesson planning in science.

We selected five focal participants—Shayna, Lana, Skye, Teri, and Leo—because they used justice moves frequently and used a range of moves, across several approaches to equity, as described more fully in the Findings. Thus, they are not selected to be representative of all of the preservice teachers in the class, but rather, to illustrate a range of approaches to incorporating justice moves. These cases, together, provide us with a window into how the justice framework might be taken up.

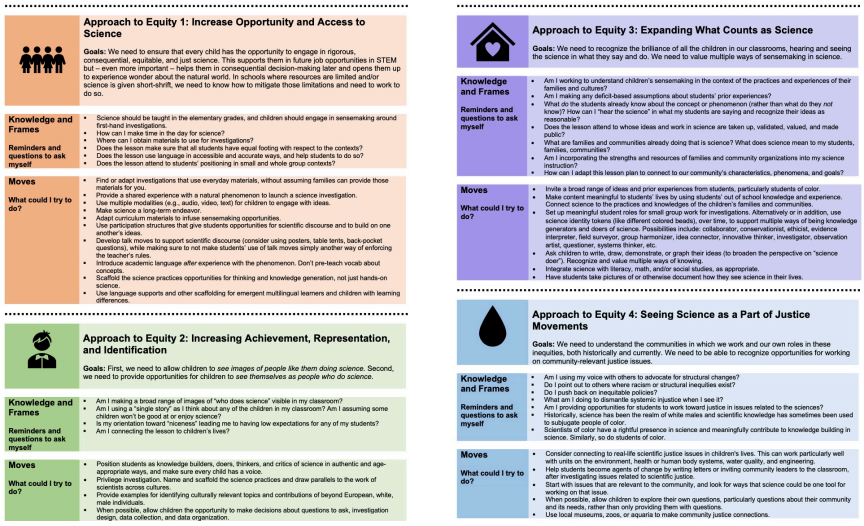
Most preservice teachers in the class identified as white women. Among our focal participants, three identify as white women (Shayna, Lana, and Skye—all names are pseudonyms), one as a Black woman (Teri), and one as nonbinary and Hispanic (Leo). Leo uses they/them pronouns and the other participants use she/her.

The first author was the instructor of the class and the second author assisted with the instruction. The authors both identify as white, cisgender women, with the second author

identifying as racially white and ethnically Hispanic. As white women with social privilege, we approach this work with preservice teachers, and this research, with caution and care.

As a routine part of the class, preservice teachers were asked to use existing lesson and unit plans and make principled adaptations to them in their design of lesson plans, which served as the data corpus for this study. The practical justice framework, used throughout the class in a variety of ways, is one key tool guiding those adaptations. The color-coded framework is organized around the four approaches to equity explored above, and provides thinking frames and teaching moves for each approach. Figure 1 presents a snapshot of the framework, which is available in its entirety in Davis (2022).

Figure 1: The practical justice framework (see also Davis, 2022)



The instructional planning template used by the program is structured with sections for three forms of input relevant in this study: a section where preservice teachers describe how they will make the lesson accessible for learners, a section where they explain how their classroom management will support a more equitable learning environment, and a section running alongside the instructional sequence where they annotate instructional moves as working toward particular justice goals. We used all three of these sections in our coding. Thus, the data sources

for this exploratory study were the 16 annotated science lesson plans generated by the preservice teachers, using the practical justice framework for guidance and the instructional planning template for structure.

Data Coding and Analysis

Our coding scheme incorporates the justice moves identified in the class justice framework. Using the four approaches to equity as categories, we drew on the literature discussed above (e.g., Bang & Medin, 2010; Calabrese Barton & Tan, 2020; Carlone et al., 2011; Kang, 2021; Patterson, 2019; Rivera Maulucci, 2013) to develop codes to capture elements visible in planning. Table 1 presents sample codes. See Appendix A for the full set of codes.

Table 1: Sample codes for justice moves

Definition (from justice framework)	Indicators
Attending to students' positioning (a move within approach to equity #2)	
• Position students as knowledge builders, doers, thinkers, and critics of science in authentic and age-appropriate ways, and make sure every child has a voice.	• Focuses on students as sensemakers • Includes attending to power, respect, competence. • Includes being explicit about how students engage in science practice from standpoint of positioning.
Encouraging decision-making about science practice to support identification as a science person (a move within approach to equity #2)	
• When possible, allow children the opportunity to make decisions about questions to ask, investigation design, data collection, and data organization.	• Includes giving students choice about how to engage in science practices; the intention of this move is that the student is taking on the role identity of scientist. • Does not include giving choice about how to express ideas more generally or about choosing their partner or group job.
Inviting students' ideas and hearing the science in students' ideas (a move within approach #3)	
• Invite a broad range of ideas and prior experiences from students, particularly students of color. • Does the lesson attend to whose ideas and work in science are taken up, validated, valued, and made public? • What *do* the students already know about the concept or phenomenon (rather than what do they *not* know)? How can I "hear the science" in what my students are saying and recognize their ideas as reasonable? • Ask children to write, draw, demonstrate, or graph their ideas (to broaden the perspective on "science	• Includes giving students options for how to share or express their ideas in lesson or assessment (e.g., through writing, drawing, or making a video). • Includes idea of "rightful presence" in science. • Includes ideas like "bringing in students' prior experiences" or probing students' ideas in ways that signal valuing those ideas.

doer"). Recognize and value multiple ways of knowing.	
Connecting science to justice issues (a move within approach to equity #4)	
• Consider connecting to real-life scientific justice issues in children's lives. This can work particularly well with units on the environment, health or human body systems, water quality, and engineering. • Am I providing opportunities for students to work toward justice in issues related to the sciences? • Start with issues that are relevant to the community, and look for ways that science could be one tool for working on that issue.	• Includes reference to justice issues, even when ill-specified. • Includes mentioning the environment, even when tie to environmental *justice* isn't made explicit.

We analyzed the coded data by developing matrices to capture patterns and trends. For example, we: determined the number of occurrences of each code ("instances"), determined the count of unique teachers who employed any particular code and the count of unique codes a given teacher used ("counts"), determined the most and least frequent codes used, and sorted teachers by who had the most to least coded instances and by the highest to lowest count of unique codes. The number of coded *instances* and the *counts* of unique codes and unique teachers were all of interest to us. The number of coded instances allows us to assess how many statements in a teacher's lesson plan was coded for having something to do with a justice move or idea. This allows us to make a rough and imperfect characterization of how extensively each teacher oriented toward justice. (It is a rough and imperfect measure because the number of instances also depends simply on how lengthy or verbose the plan was; our five focal interns were roughly similar on this front, with Leo's lesson being lengthiest.) Similarly, the number of unique teachers who used a given code helps us see how prominently that code was taken up. The number of unique codes, in turn, allows us to assess how widely the teacher was thinking about justice moves. If a teacher had 10 coded instances, but only a count of 2 unique codes, that would mean that they consistently used two justice moves or ideas. If, on the other hand, they had 7 unique codes, it would mean they were trying more things out in their planning. A higher

count is not necessarily better, but it does potentially indicate a broader range in the uptake of ideas and moves in the justice framework.

Findings

We present the findings organized around our analytic questions, turning first to the justice moves preservice teachers used in their lesson planning.

What justice moves are used most and least often, as preservice elementary teachers modify existing lesson plans?

In their plans, the 16 preservice teachers used an average of a total of 7.5 unique justice moves each. Specifically, they used an average of 2.3 unique justice moves associated with approach to equity #1 (increasing opportunity and access), 2.6 justice moves associated with approach #2 (increasing identification and representation), 1.9 justice moves associated with approach #3 (expanding what counts as science), and 0.7 justice moves associated with approach #4 (seeing science as a part of justice movements). Thus, approach #4 was the least prominent across these data.

Table 2 summarizes how often preservice elementary teachers used specific justice moves that were supported by the justice framework. *Varying participation structures* was, by far, the most commonly employed justice move; all 16 preservice teachers used this move multiple times. Providing different ways for children to participate in science lessons – for example, through individual work, think-pair-share structures, small group investigative work, whole class discussions, and the like – is important because it gives children different kinds of opportunities for sharing their ideas and hearing other children's ideas. That said, this move is also inherent in any "good teaching." Because of its near ubiquity in the data, we set it aside for

now and focus on the other justice moves, some of which are likely more consequential for children and certainly are more challenging for preservice teachers to plan for (and enact).

Table 2: Number of preservice teachers employing justice moves (* indicates a focal move)

	Approach to equity #	Used by *n* preservice teachers
Used most frequently (used by between 13-16 teachers)		
Varying participation structures	#1	16
Making real-world connections	#2	13
Attending to students' positioning *	#2	13
Inviting students' ideas and hearing the science in students' ideas *	#3	14
Attending to families and communities	#3	13
Used somewhat frequently (used by 5-7 teachers)		
Ensuring shared experience	#1	5
Supporting talk moves for science discourse	#1	5
Scaffolding science practices	#1	6
Supporting representation of scientists from non-dominant groups	#2	9
Encouraging decision-making about science practice to support science identity *	#2	7
Connecting science to justice issues *	#4	7
Used rarely (used by 1-3 teachers)		
Employing multiple modalities	#1	3
Providing supports for emergent multilingual or learning differences	#1	2
Attending to a "single story" or implicit bias	#2	2
Attending to assumptions about prior experiences	#3	3
Supporting students to be change agents	#4	1
Making connections to community organizations	#4	3
Never used (used by 0 teachers)		
Making science a long-term endeavor	#1	0
Supporting academic language through use	#1	0
Attending to "niceness" and low expectations	#2	0
Developing meaningful roles as "science people"	#3	0
Supporting integration of science with other subjects	#3	0
Encouraging documentation of science in real life	#3	0
Asking and answering own community justice questions	#4	0

Toward that end, we focus on four justice moves: (a) *attending to students' positioning*, (b) *encouraging decision-making about science practice to support science identity*, (c) *inviting students' ideas and hearing the science in students' ideas*, and (d) *connecting science to justice issues.* We choose these as our foci here because they were used either frequently or somewhat frequently by preservice teachers (see Table 2), suggesting that there is some reason to believe

that novices find them accessible. We also select them as foci here because we suspect that they are particularly important in genuinely working toward justice (indeed, we opted not to include any moves from approach 1, to push our analysis toward potentially more challenging moves).

How do preservice elementary teachers vary in the ways they employ these justice moves?

Preservice teachers varied in their uptake of the justice moves in terms of the count of how many unique justice moves they employed in their lessons. This ranged from a low of 4 unique justice moves for Grace and Ariel, to highs of 12 unique moves for Leo and 11 for Shayna. Tables 3-6 present samples of how our five focal preservice teachers incorporated the four focal justice moves.

Table 3 presents examples of how the focal preservice teachers incorporated the justice move of *attending to students' positioning*. The examples emphasize the importance of affirmation; in fact, Leo, Lana, and Teri all explicitly used the word *affirm* or *affirming*. Leo hoped students will identify as "people who do science" and Teri wanted to ensure that "every student is a scientist." (Leo's connection to an "I can" statement took this routine pedagogical move—which in our experiences is typically enacted in a mindless and rote manner, often with children simply chorally repeating the learning goal the teacher has projected on a slide—and made it into something potentially meaningful and identity-supporting for children.) Lana elaborated on how she can provide feedback that highlights "specifics of [students'] competence." Skye's comment was unique in the data set; Skye connected children's engagement in the science practice of modeling to their positioning as scientists and mentioned that she would tell children that "we [w]on't and shouldn't be right on our first try," and instead should engage in model revision. These are all important ways of increasing children's identification with science (an aspect of approach to equity #2), and the affirmations of students'

science identities (without reference to specific science practices, as Skye did) were typical of other preservice teachers' uses of this justice move.

Table 3: How focal preservice teachers used *attending to students' positioning* (approach #2)

Preservice teacher	Sample instance
Leo	Students write the *I can* statement to affirm their identification as people who do science and so they can look back at all the learning they have done.
Lana	During this process, it is very important that my response to students' work is carefully crafted feedback that mentions the specifics of their competence and highlights their own experiences in an affirming and grateful way. This will make all students feel heard in the classroom, and valued as sensemakers and scientists who all bring equally important, though different, viewpoints and experiences to our classroom. …
Skye	stating that revision is a part of science (we don't and shouldn't be right on our first try)
Teri	Increasing Achievement, Representation, and Identification: It is important to have enough materials for each student to prevent hogging and affirm that every student is a scientist. However, if resources are short, set a timer for each student in a pair to have the hand lens for an equal amount of time.

Of these focal participants, only Teri incorporated moves related to *encouraging decision-making about science practice to support science identity* (see Table 4). For example, Teri planned to offer children the choice between generating an argument in the form of a claim supported by evidence and reasoning, and drawing a scientific model, and noted that the teacher would "still be able to assess their understanding". In fact, Teri consistently wrote about listening to children's thoughts about "how they work and perform best" throughout her lesson plan. Giving kids decision-making power, at least some of the time, as Teri argues, helps them to see themselves as science people (an important aspect of approach to equity #2). This relinquishing of some responsibility to students was typical of the entries that were coded this way; for example, several preservice teachers (though not the other focal participants) offered children choices about how to design an investigation and noted that doing so may help children identify as people who do science.

Table 4: How focal preservice teachers used *encouraging decision-making about science practice to support identification as a science person* (approach #2)

Preservice teacher	Sample instance
Teri	Offering students an option in how they will be assessed will take up a range of their ideas in ways that publicize their strengths. Students know how they work and perform best, so allow them to show you. Through a model, you will still be able to assess their understanding. Ask them to make annotations on the model about evidence and reasoning to support their model (claim).

Table 5 shows examples of how the focal preservice teachers incorporated the justice move of *inviting students' ideas and hearing the science in students' ideas.* This was a frequently used code (second in frequency after *varying participation structures*; see Table 2) and was wide-ranging in how preservice teachers incorporated it. In fact, statements were often dual-coded as both *attending to students' positioning* and *inviting students' ideas and hearing the science in students' ideas.* A typical comment in the data corpus overall considered to be *inviting students' ideas and hearing the science in students' ideas* would simply note the importance of providing students with opportunities to express their ideas in a range of ways (e.g., writing, drawing); while this is an important thing to do, it does not press justice efforts forward in the same ways as some of the focal participants' contributions do. All three of the examples shown in Table 5 – illustrating bringing in nondominant perspectives on science (Leo), connecting to children's own cultural practices vis-à-vis science (Skye), and ensuring that students have a voice in the sensemaking of the class (Shayna) – represent important ways of inviting children into the work of science and expanding what counts as science (approach to equity #3), going beyond the more typical move of encouraging children to express their ideas using multiple vehicles and moving toward valuing multiple approaches to sensemaking. These examples are typical of the broader corpus of data, however, in that they emphasize the 'inviting' portion of

the code, and are less explicit about the 'hearing the science' portion. That is, the preservice teachers were not usually clear about what they would do to ensure that they were able to recognize what was scientific about children's expressed ideas or work.

Table 5: How focal preservice teachers used *inviting students' ideas and hearing the science in students' ideas* (approach #3)

Preservice teacher	Sample instance
Leo	Think about Indigenous ways of knowing and Indigenous practices in science when thinking about seeing science as part of justice movements * Two-eyed seeing and Indigenous STEAM resources
Shayna	Instead of just having "selected teams share their Explanatory Models", I would allow all teams to share their models because it is important to give each child a voice in science and give them chances to see themselves as scientists. This also provides the opportunity to make public the strengths of different children. However, if a team didn't want to share, I would still find a way to display all the models. I would do this by removing student names from the work and displaying them for all students to see. This is important because it helps show the different ways of thinking.
Skye	this is a good time to let students share ideas about matter that may be culturally specific to them and their identities

Finally, four of the focal participants (and seven participants total) incorporated *connecting science to justice issues*. Three of the examples in Table 6 had to do with the environment, with Leo specifically referencing environmental justice; the fourth, from Shayna, connected to the COVID-19 pandemic. These statements varied in their specificity; Shayna, for example, noted that she planned to "tie in to larger societal issues/challenges" with regard to COVID, but was not explicit about how she intended to do so. Leo was somewhat more specific, noting that they would support children in engaging in activism through advocating for a composting program for the school. (Elsewhere in Leo's plan, they noted that this was their goal for the unit, and was broader than just one lesson – a point that is often the case for *connecting science to justice issues.*) Among the connections to justice made across the data set as a whole, most were fairly abstract, but indicated an intention to try to make a connection – an important first step for a preservice teacher.

Table 6: How focal preservice teachers used *connecting science to justice issues* (approach #4)

Preservice teacher	Sample instance
Leo	Unit learning on the importance of composting, what can we do with what we learned to advocate for environmental justice in the community? Making posters and perhaps letter writing to the school district for a composting campaign.
Shayna	Lead a discussion about how the models they used might be impacted with COVID-19 changing the way that some people experience taste and/or smell. * -tie-in to larger societal issues/challenges
Skye	This is also a good point to work in the justice movements about water protection, community gardens, and how clean water access is important to communities
Teri	Seeing Science and Math as a Part of Justice Movements: Make explicit connections to our world's concerns with plastic. You can show a picture of plastic-filled oceans or landfills.

Summary of Results

In sum, in response to our first analytic question, *What justice moves are used most and least often?*, we found that preservice teachers used five justice moves very often. These moves included *varying participation structures, making real-world connections, attending to students' positioning, inviting students' ideas and hearing the science in students' ideas,* and *attending to families and communities*. At least 13 preservice teachers used each of these moves at least once, as shown above in Table 2. These moves span across the first three approaches to equity.

Several other justice moves were used infrequently or never. These less-prominent moves spanned across all four of the approaches to equity, but approach 4 (seeing science as a part of justice movements) was (perhaps not surprisingly) least represented in these preservice teachers' lesson plans.

In response to our second analytic question, *How do preservice elementary teachers vary in the ways they employ these justice moves?*, we focused on a set of four justice moves, and found both consistency and variability in how preservice teachers took up the moves. For example, in terms of *attending to students' positioning in science*, we saw consistency in concern for affirming children as people who do science. Only rarely did we see explicit connection to

science practices in this affirmation. In looking at how preservice teachers *encouraged children's decision-making*, we found that preservice teachers sometimes offered children choice in the design of an investigation, and that the teachers connected this to support children's science identity development. We saw two main forms of *inviting students' ideas and hearing the science in students' ideas*. First, most prominently, we saw examples of providing children with the opportunity to express their ideas in multiple ways (e.g., writing, drawing). Second, more rarely, we saw examples of genuinely attending to, and valuing, multiple ways of knowing in an epistemological sense. Finally, when preservice teachers opted to *connect science to justice issues*, their connections often had to do with environmental concerns. These connections were often fairly general or abstract—the preservice teachers said they would make a connection, but were less likely to specify what connection they would make or how they would make it.

Discussion and Implications

The practical justice framework presents a range of approaches to including justice moves in an elementary science lesson (NASEM, 2022; see also Davis, 2022). Preservice teachers understandably are at different places in their journey of working toward justice; these are new ideas for some, whereas for others, their lived experiences or their learning experiences or both have laid important groundwork. Thus, with this study, we were interested in exploring which justice moves seemed most accessible for these beginning teachers, and which ones, despite being challenging, might be taken up as well.

Our findings suggest that a few moves were frequently taken up by the preservice teachers. Some of these seem in the realm of "just good teaching" (Ladson-Billings, 1995)—moves like varying the participation structures students experience, making connections to children's real-world experiences, or providing shared experiences with phenomena. Others

seem particularly important for supporting children and youth who have historically been marginalized in science, and whose marginalization continues. Some of these include attending to how students are positioned as people who do science (e.g., Carlone et al., 2011; Esmonde, 2017; Louie, 2017), inviting children's science ideas and hearing the science in those ideas (e.g., Bang & Medin, 2010), encouraging children's decision-making around science practices to support their identity and epistemic agency (e.g., Carlone et al., 2021; Haverly et al., 2020; Krist et al., 2023), and connecting science to issues of justice (e.g., Davis & Schaeffer, 2019; Morales-Doyle, 2017). To see these moves in preservice teachers' lesson plans as often as we did was encouraging.

Of course, the level of sophistication of the incorporation of some of these justice moves was relatively low. For example, many preservice teachers invited children's science ideas with the stated intention of attending to multiple ways of knowing—but they did so only with a focus on incorporating opportunities for children to "write *or* draw their ideas", rather than intentionally drawing on the range of ideas and practices that children might bring from their family, linguistic, or cultural resources (e.g., Suárez, 2020) or explicitly describing how they would listen to and for those more expansive ideas. Furthermore, almost half of the preservice teachers in this sample made at least a nod to connecting science to issues of justice – but they did so by simply saying that they would "connect to issues of justice" without specifying how. Nonetheless, we see these findings as remarkably encouraging, as moves like these lay stepping stones for ongoing work that builds in sophistication as teachers gain experience and knowledge.

This work, while preliminary, has important implications for teacher education practice. Science teacher educators can use these findings to inform their work with preservice elementary teachers. In particular, this study helps to identify a few justice moves that are potentially fruitful, in that novice teachers may find them accessible – moves like attending to students' positioning and encouraging students' decision-making. Other moves may need more support, like helping teachers attend to a range of ways of knowing in science. The justice framework may have served as a cultural tool (Esmonde, 2017) to make certain moves more salient for preservice teachers – but they may need further opportunities to gain situated experiences that would allow them to more fully challenge normativity and engage multiple ways of knowing (Esmonde & Booker, 2017). Finally, preservice teachers may benefit from concrete examples of how they can connect science to local or global justice issues. These insights will also help to inform our refinement of the practical justice framework piloted in this study.

This study also makes important contributions to theory. In considering teacher learning, it is crucial to understand the building blocks new teachers have as starting places for their further development (Haverly & Davis, 2023). Thus, identifying the strengths, as well as the challenges, of these beginning teachers helps us to recognize those building blocks and begin to see how they may be interconnected for teachers. In particular, this study helps us begin to understand how preservice teachers understand specific teaching moves they could employ for more justice-oriented science teaching, and how sophisticated those understandings are, as used within the practice of lesson planning. This points to those strengths and challenges and hints at which building blocks may need further bolstering through initial teacher education or ongoing professional learning. In terms of interconnections, we saw that *attending to students' positioning* (an aspect of approach to equity 2) and *inviting students' ideas and hearing the*

science in students' ideas (an aspect of approach to equity 3) often co-occurred. This suggests a potential connection between approach to equity 2, increasing representation and identification in science – which preservice teachers tend to gravitate toward – and approach to equity 3, expanding what counts as science – which appears more challenging for them.

Conclusions

In future work, we intend to extend this study in three important ways. First, because identity is an important element of a sociocultural perspective on learning, we intend to delve into facets of the teachers' identities and commitments, including their critical consciousness (Watts, Diemer, & Voight, 2011). Second, we see looking at lesson planning as an important first step, but we are most interested in the teachers' enacted practice, to see how they use these moves in their science lessons with children (e.g., Davis & Palincsar, 2023; Kang & Zinger, 2019). And third, in the long run, we are interested in looking at how these novices' knowledge, beliefs, practice, and identities develop across time and across contexts (Thompson et al., 2013; Kang & Zinger, 2019).

Beginning elementary teachers face many challenges as they learn to teach science. These challenges are even compounded as they work toward *equitable and just* science teaching. This study shows that they bring many strengths, assets, and resources to this work, as well.

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Appendix A: Coding Scheme

Code label	Description of code from justice framework
Approach 1:	**Increasing opportunity and access in science**
SHARED EXPERIENCE	● Provide a shared experience with a natural phenomenon to launch a science investigation. ● Does the lesson make sure that all students have equal footing with respect to the contexts?
MULTIPLE MODALITIES	● Use multiple modalities (e.g., audio, video, text) for children to engage with ideas.
LONG TERM	● Make science a long-term endeavor.
PARTICIPATION STRUCTURES	● Use participation structures that give students opportunities for scientific discourse and to build on one another's ideas. • Does the lesson attend to students' positioning in small and whole group contexts?
TALK MOVES	● Develop talk moves to support scientific discourse (consider using posters, table tents, back-pocket questions), while making sure to not make students' use of talk moves simply another way of enforcing the teacher's rules.
ACADEMIC LANGUAGE	● Introduce academic language *after* experience with the phenomenon. Don't pre-teach vocab about concepts. • Does the lesson use language in accessible and accurate ways, and help students to do so?
SCIENCE PRACTICES	● Scaffold the science practices as opportunities for thinking and knowledge generation, not just hands-on science.
EML & LD LANGUAGE SUPPORTS	● Use language supports and other scaffolding for emergent multilingual learners and children with learning differences.
Approach 2:	**Increasing achievement, representation, and identification in science**
SINGLE STORY	● Am I using a "single story" as I think about any of the children in my classroom? Am I assuming some children won't be good at or enjoy science?
NICENESS	● Is my orientation toward "niceness" leading me to having low expectations for any of my students?
REAL WORLD CONNECTIONS	● Am I connecting the lesson to children's lives?
POSITIONING & POSITIONING (SPs)	● Position students as knowledge builders, doers, thinkers, and critics of science in authentic and age-appropriate ways, and make sure every child has a voice.
SCIENCE PRACTICES ACROSS CULTURES	● Privilege investigation. Name and scaffold the science practices and draw parallels to the work of scientists across cultures.
REPRESENTATION	● Provide examples for identifying culturally relevant topics and contributions of beyond European, white, male individuals. • Am I making a broad range of images of "who does science" visible in my classroom?
DECISIONS	● When possible, allow children the opportunity to make decisions about questions to ask, investigation design, data collection, and data organization.
Approach 3:	**Expanding what counts as science**
ASSUMPTIONS	● Am I making any deficit-based assumptions about students' prior experiences?
INVITING IDEAS / HEAR THE SCIENCE	● Invite a broad range of ideas and prior experiences from students, particularly students of color. • Does the lesson attend to whose ideas and work in science are taken up, validated, valued, and made public? • What *do* the students already know about the concept or phenomenon (rather than what do they *not* know)? How can I "hear the science" in what my students are saying and recognize their ideas as reasonable? • Ask children to write, draw, demonstrate, or graph their ideas (to broaden the perspective on "science doer"). Recognize and value multiple ways of knowing.
FAMILIES & COMMUNITIES	● Make content meaningful to students' lives by using students' out of school knowledge and experience. Connect science to the practices and knowledges of the

	children's families and communities. • Am I incorporating the strengths and resources of families and community organizations into my science instruction? • How can I adapt this lesson plan to connect to our community's characteristics, phenomena, and goals? • Am I working to understand children's sensemaking in the context of the practices and experiences of their families and cultures?
MEANINGFUL ROLES	● Set up meaningful student roles for small group work for investigations (that shift away from typical science competencies).
INTEGRATION	● Integrate science with literacy, math, and/or social studies, as appropriate.
DOCUMENTATION	● Have students take pictures of or otherwise document how they see science in their lives.
Approach 4:	**Seeing science as a part of justice movements**
JUSTICE CONNECTIONS	● Consider connecting to real-life scientific justice issues in children's lives. This can work particularly well with units on the environment, health or human body systems, water quality, and engineering. • Am I providing opportunities for students to work toward justice in issues related to the sciences? • Start with issues that are relevant to the community, and look for ways that science could be one tool for working on that issue.
CHANGE AGENTS	● Help students become agents of change by writing letters or inviting community leaders to the classroom, after investigating issues related to scientific justice.
OWN COMMUNITY QUESTIONS	● When possible, allow children to explore their own questions, particularly questions about their community and its needs, rather than only providing them with questions.
ORGANIZATIONAL CONNECTIONS	● Use local museums, zoos, or aquaria to make community justice connections