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Abstract

This study explores the affordances and constraints of using the four core practices of ambitious science teaching (AST) as the main curriculum of science methods courses in preparing novice teachers for equitable instruction. Employing a longitudinal qualitative case study approach, this study follows three novice secondary science teachers' trajectories over three years, from their preparation to their second year of teaching. Participants were three white women who taught primarily Latinx, English language learners, exceptional learners, and/or those who live in poverty. The contemporary vision of science learning promoted by the NGSS and critical race theory guide our analysis of novice teachers' instruction. Findings suggest that using AST practices as the main curriculum of science methods courses can help prepare novice teachers for equity *if* the approximation of these practices facilitates novices in problematizing their normalized views, expectations and practices of disciplinary teaching and learning. The core practices are limited, however, in their ability to develop novice teachers' critical consciousness about racism and systemic inequity, which profoundly affects interactions with marginalized youth in classrooms.

Key words: teacher preparation, diversity and equity, critical race theory, longitudinal study

Introduction

Despite the efforts of equity-minded teacher educators, the struggle to produce well-prepared science teachers who support deep learning for students from historically marginalized communities continues. By 'students from historically marginalized communities,' we mean students of color, English learners (ELs), exceptional learners, and those living in poverty. Supporting these students' meaningful science learning is an urgent issue in the United States. The Next Generation Science Standards (NGSS) put forward a vision of science learning focused on sense-making and complex reasoning (NGSS Lead States, 2013; NRC, 2012). Science teachers are expected to facilitate "three-dimensional learning," which the majority of teachers have not experienced in their own science education. Moreover, many teachers in U.S. public schools are responsible for supporting the learning of students who have very different cultural, linguistic, and socioeconomic backgrounds than their own. Students of color are expected to comprise 54% of total enrollments in the U.S. elementary and secondary schools by 2024 (Kena et al., 2015). In contrast, the overwhelming majority of public school teachers remain white (about 80%) and female (about 77%; Taie & Goldring, 2017), and 74% of preservice teachers enrolled in teacher preparation institutions of higher education (IHE) are white (notably, IHE prepare 85% of new teachers in the United States; U.S. Department of Education, 2016). The ongoing mismatch between the backgrounds of diverse students and the individuals who teach them raises the question of how to prepare novice teachers in developing practices that support deep learning for students from historically marginalized communities.

Recently, there has been growing attention to the idea of using "core" or "high-leverage" practices of teaching as a main curriculum for teacher education to address this challenge (Ball & Forzani, 2009; Ball, Sleep, Boerst, & Bass, 2009; Grossman, Hammerness, & McDonald, 2009;

McDonald, Kazemi, & Kavanagh, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). By teaching a set of core practices to preservice teachers, advocates of core practices seek to prepare novice teachers to provide rigorous learning experiences for the wide range of students in their classrooms. In fact, the scholarship of these core practices reflects a major shift in the field of teacher education from primarily focusing on content knowledge to emphasizing *practices* of teaching as the central element of teacher education (Ball & Cohen, 1999; Forzani, 2014; Grossman & McDonald, 2008; McDonald et al., 2013). Identifying and teaching a few selected core or high-leverage practices that support students' equitable and rigorous engagement with disciplines may better prepare novice teachers to "counter longstanding inequities in the schooling experiences of youth from historically marginalized communities in the U.S." (Core Practice Consortium, 2016, para. 3).

There is a need for research addressing the preparation of preservice secondary science teachers for equitable teaching in the era of the NGSS. This study explores the affordances and constraints of using core practices as the main curriculum in preparing secondary science teachers to work with students from historically marginalized communities meaningfully and equitably. During a nine month preparation period, a cohort of preservice secondary science teachers approximated a set of core practices and tools for ambitious science teaching (AST) (Windschitl et al., 2012) both with their peers in methods courses and with students in their field placements. The core practices of AST are designed to promote students' sense-making and complex reasoning as outlined in the NGSS. Employing a longitudinal qualitative case study approach (Merriam, 2009; Yin, 2013), we followed three novice secondary science teachers for three years, from preparation to their second year of teaching. Participants were white women who taught science to students from historically marginalized communities during their first two

years of teaching. The following questions guide the analyses:

1. What role do AST practices play in developing preservice secondary science teachers' capacity to create equitable and meaningful learning contexts for students from historically marginalized communities?
2. Which participating teachers, if any, provided opportunities for students to engage in meaningful disciplinary practices, as outlined in the NGSS, during their first two years of teaching, and how? Who failed to do so, and why?

Theoretical Framework

Preparing Preservice Secondary Science Teacher for Equity in the Era of NGSS

Teacher preparation is situated between teachers' past experiences as students and their future experiences as teachers. Preservice teacher education presents unique opportunities to influence novice teachers' professional trajectories, and disrupt the traditional K-12 instruction that marginalizes students from historically underserved communities (Feiman-Nemser, 2012; Kennedy, 1999).

Numerous studies on preservice teacher learning show that novice teachers enter preparation programs with their own ideas, beliefs, and experiences about science teaching and learning (e.g., Kang, 2017; Horn, Nolen, Ward, & Campbell, 2008; Lortie, 1975). Novice teachers use those ideas, beliefs, and experiences to make sense of the new ideas and practices presented to them (Kang, 2017; Feiman-Nemser & Remillard, 1996; Hewson et al., 1999; Horn et al., 2008). Notably, researchers found that novice teachers from dominant communities tend to bring ideas to the classroom that could make the learning environment less accessible to students from historically marginalized communities (Bianchini & Solomon, 2003; Gay & Kirkland, 2003; Mensah & Jackson, 2018; Rodriguez, 1998; Southerland, Gallard, & Callihan, 2011;

Southerland & Gess-Newsome, 1999). These novice teachers tend to hold a Eurocentric, positivist view of science, and think that their own views and cultural repertoires—Western norms and ways of thinking, talking, or doing—are the only legitimate or appropriate approach to schooling and science instruction (Bang, Warren, Rosebery, & Medin, 2012; Mensah & Jackson, 2018; Southerland et al., 2011). Researchers note that this ethnocentrism (Southerland et al., 2011) and Eurocentric view of science (Bang et al., 2012; Rodriguez, 1998) have to do with novices' lack of recognition that many of their own expectations and beliefs are culturally laden and constructed in a society with historically persistent and systemic racism, classism, sexism, and heterosexism (Calabrese Barton, 2001; Hand, Penuel, & Gutierrez, 2012; Ladson-Billings, 1995, 1999, 2006; Rodriguez, 1998). Therefore, the actions and behaviors of students from families, backgrounds, or countries different from that of their teacher can be seen as different, and therefore *wrong*. This ethnocentrism or epistemological elitism often becomes the source of novices' deficit views toward historically marginalized students, their families, and their communities. Mensah and Jackson (2018) problematize this traditional Eurocentric view using the conception of 'science as white property,' highlighting its inherent exclusiveness and alienation of people of color. In addition, researchers find that novice teachers tend to describe a wide group of people in the same way while glossing over individual characteristics ("Students of color tend to suffer more because of a lack of support at home"). Conversely, researchers also find that novice teachers describe students as individuals in a vacuum, ignoring historical, racial, and cultural inequities ("I don't see the need to differentiate student groups according to culture; I do consider an individual student's need", "when I teach I am fairly colorblind and I honestly think the vast majority of my students are too"). Both essentialism and individualism hinder novices in creating inclusive learning environments, as they oversimplify marginalized students'

responses to schooling and science instruction. Furthermore, researchers find that novice teachers tend to embrace the idea of equality over equity (e.g., "In order to achieve equity in the classroom, one needs to be colorblind. Ethnicity, disabilities, economic status should all be left at the door"). Southerland and her colleagues (2011) suggest that the rejection of *equitable* science instruction in favor of *equal* science instruction is closely tied to characterization of schooling as a meritocratic and individualistic endeavor.

Novice teachers' ideas, ideological beliefs, and expectations profoundly affect their interactions with marginalized students in science classrooms by impacting how they interpret classroom situations, thus shaping their responses. Kennedy (1999) explains this using the notion of "a frame of reference." According to Kennedy, teachers are likely to teach in the way they themselves were taught because the apprenticeship of observation (Lortie, 1975) provides them with a frame of reference, i.e. a normalized view of what is supposed to happen in classrooms. Importantly, this frame of reference creates a standard expectation of what is appropriate or inappropriate, and what is counted as 'success' in teaching and learning. Teachers use this frame of reference to interpret and evaluate classroom situations. Novices are likely to create an exclusive learning environment, inaccessible to some students when that frame of reference is grounded in ethnocentrism, epistemic elitism, essentialism, individualism, or belief in educational meritocracy. They likely interpret different ways of thinking, talking, or doing by students of different racial, linguistic, cultural, and socioeconomic backgrounds as wrong or inappropriate, rather than scientifically meaningful and generative. Thus, they fail to take productive pedagogical action. Equity-minded science educators point to the settled hierarchies of seeing, thinking, acting, and knowing in classroom interactions as profound challenges for achieving equity in science education (Bang et al., 2012; Gutiérrez & Calabrese Barton, 2015).

These settled hierarchies privilege western norms and views of science and can shape who and what is seen and heard as scientifically meaningful in school science classrooms.

An important role for preservice teacher education is to alter the initial frame of reference that novices bring in, so that they are able to see things differently, and teach differently (Kennedy, 1999). To promote equity in science classrooms, it is essential to provide opportunities for novices to develop *multicultural* and *flexible* frames of references that enable them to recognize, honor, and build upon various ways of thinking, talking, and doing in a way that expands students' understanding of the world (Calabrese Barton, 2000; Mensah, 2009; Rosebery, Warren, & Tucker-Raymond, 2016). Broadening novices' frames of reference begins with the critical recognition that their (and their students') ideas, expectations, and experiences are constructed in a deeply racialized and unjust society which has historically privileged a particular group's experiences, knowledge, language, and culture (Calabrese Barton & Berchini, 2013; Gay & Kirkland, 2003; Ladson-Billings, 1999). This critical consciousness, coupled with deep appreciation and respect for the lived experiences of people from historically marginalized communities, enables novices to see the structural inequity—how history, power, culture, race, and languages shape unequal science learning opportunities for some students in classrooms—beyond participatory inequity among individuals. From an instructional point of view, expanding an initial frame of reference with the development of critical consciousness increases teachers' interpretive power (Ball & Cohen, 1999; Rosebery et al., 2016). The increased interpretive power enables teachers to disrupt the traditional instruction that marginalizes students in science classrooms.

Practice-Based Teacher Education and Core Practices: An Untested Hypothesis of Preparing Novice Teachers for Equity

Equity-minded teacher educators have explored various pedagogical activities to prepare novice teachers for equitable science teaching and learning in the context of their preservice education. Some examples of pedagogical activities are: discussing articles that provide feminist perspectives on the nature of science (Bianchini & Solomon, 2003), participating in service learning projects (Calabrese Barton, 2000), conducting critical ethnographies (Calabrese Barton, 2001), participating in critical book clubs that promote candidates' multicultural understanding (Mensah, 2009), and exploring historically marginalized students' ideas in practice (Roseberry et al., 2016). Overall, four patterns emerge from prior work. First, salient pedagogical approaches undertaken by teacher educators—called pedagogy of investigation and reflection—render novices' beliefs visible and enable them to directly confront and challenge their beliefs (Grossman & McDonald, 2008). Second, it is difficult, though not impossible, to alter novice teachers' views, assumptions, and ideological beliefs, in particular, those deeply held, taken-for-granted notions that come from experience (Bianchini & Solomon, 2003; Mensah, 2009). Third, the majority of research on this topic takes place in the context of elementary teacher education, which is substantially different from a secondary school context. Finally, prior studies were typically limited to examination of novices' responses to the innovative pedagogical activities *within* the preparation period. There are few science education researchers who follow novice science teachers beyond their preparation, to examine whether and how innovative pedagogical approaches affect novice science teachers' actual classroom *practices* when they become the teachers of marginalized students (see exception Bianchini & Cavazos, 2007; Bianchini, Johnston, Oram, & Cavazos, 2003).

The research on teaching and teacher education suggests that the relationship between what teachers see, think, or believe and what teachers actually do with students in a classroom is

neither simple nor straightforward (Cohen, 2011; Hiebert & Morris, 2012; Kennedy, 2010; Lampert, 1985). Researchers who followed novice teachers after the completion of the program found that many teachers claimed to embrace program ideas, such as culturally relevant teaching, but could not put these into practice (Artiles, Barreto, Pena, & McClafferty, 1988; Ensor, 2001). This 'problem of enactment' (Kennedy, 1999) has been noted as a persistent challenge facing the teacher preparation community.

The idea of refocusing teacher education from knowledge or belief to practice ("practice-based teacher education") is designed to addressing this persistent challenge of enactment. The proponents of core practices problematize those approaches to teacher education that mostly focus on theoretical topics with marginal relevance to the realities of the classroom. They argue for moving teacher education closer to the work of teaching (Ball & Cohen, 1999) by expanding teacher education to include enactment—approximating, rehearsing, and practicing with students in classrooms—in addition to analyzing or reflecting on experiences (Grossman & McDonald, 2008; McDonald et al., 2013). Grossman and McDonald (2008) state that:

> While myriad students in teacher education may have read about the value of investigating students' funds of knowledge, we suspect that many fewer have opportunities to practice both eliciting such knowledge from students and weaving such knowledge into classroom instruction in ways that bridge between the everyday and the academic. (p. 191)

Proponents suggest that the identification of a few high-leverage or core practices of teaching that support high-quality student learning, alongside a practice-based approach to teacher education, will "ensure that new teachers begin their careers significantly better equipped to

create intellectually and emotionally engaged disciplinary learning for all of their students" (Core Practice Consortium, 2016).

Yet, the argument that teaching core practices to preservice teachers will prepare them to create equitable and meaningful disciplinary learning environments for historically marginalized students is debatable. However, it is legitimate to ask if the chosen core practices fully address equity concerns, such as helping novice teachers to attend to the ways in which historicized injustice manifests in the system of power which plays out in classroom practices, beyond improving individual students' access and opportunity. Sheth (2019) argues that "current conceptions of good science teaching, such as ambitious science teaching, have much to offer in terms of promoting participatory equity goals. They, however, remain colorblind by not critically addressing racism embedded in science and science teaching" (p. 5).

Sociocultural and Critical Race Theory

The focal phenomena of this study are three white female science teachers' learning experiences facilitated by a secondary science methods course that uses the four core practices of AST as its main curriculum, and the participants' later science instruction with historically marginalized students during their first two years of teaching. We draw on sociocultural and critical race theory (CRT) to analyze whether and how the activity of approximating AST practices helps the novice teachers to develop their capacity of creating meaningful and equitable learning environments for historically marginalized students. Sociocultural and CRT perspectives offer invaluable insights to the examination of the focal phenomena. Unlike the traditional perspective of learning as the change of mental representations stored in an individual's head (Clancey, 1997), sociocultural and situative perspectives (Greeno, 2006; Greeno & Gresalfi, 2008; Lave & Wenger, 1991) view learning as "a trajectory of that person's

participation in the community—a path with a past, present, shaping possibilities for future participation" (Greeno & Gresalfi, 2008, p. 180). Grounded in the premise that learning, activity, and context are inherently inseparable, sociocultural theorists use *activity systems* as the unit of analysis to understand how and why activities in a setting, such as approximating core practices, result in changes in novice teachers' participation in the work of teaching as valued by the community. Understanding novice teachers' learning (i.e., increasing capacity to create equitable and meaningful learning contexts for historically marginalized youth) necessitates a careful examination of the characteristics of novice teachers (e.g., personal backgrounds and experiences), and their *interactions* with both people and informational resources across settings and over time. Sociocultural perspectives are particularly useful to study the role of core practices in novice teacher learning because of their attention to mediation. When approximating one AST practice—for example, 'eliciting student thinking'—novices' interactions with students in K-12 classrooms are mediated by intentionally designed *tasks, tools, and talk* to accomplish a particular pedagogical goal. By closely examining the type and nature of novices' interactions with students mediated by core practices, sociocultural perspectives enable us to explain how and why desirable change in novices' trajectories of participation occurs to increase their capacity for equitable teaching in relation to the use of AST practices.

This study also draws on critical race theory (CRT) (Ladson-Billings, 1999, 2004; Parsons, 2017) as the analytical lens to understand novice science teachers' developing capacities for promoting equity. Emerging out of critical legal studies in the 1970s, CRT centralizes race, racism, and power in the examination of phenomena (Bell, 1987, 1993; Crenshaw, Gotanda, & Peller, 1995; Delgado & Stefancic, 2001). Basile and Lopez (2015) analyzed science and mathematics education policy documents through a CRT lens and

identified four common themes that hold implications for novice teachers learning about equity (see pp. 521-522 of Basile & Lopez, 2015). These are as follows: 1) *interest convergence* as a motive for racism (i.e., racism confers "material" benefits for wealthy white people and psychological benefits for lower-SES white people; Bell, 1980, 2005 as cited in Basile & Lopez, 2015, p. 521); 2) race is a *social construct* rather than a biological fact (Delgado, 2001); 3) objectivity-minded views of race and equity—for example, *color blindness*—are artifacts of privilege and can perpetuate or conceal racist ideas (Solorzano & Yosso, 2001); and 4) *racial commodification*, which is the belief that whiteness itself can be possessed and confers with it the privilege of owning property (Leonardo, 2002). In the context of preparing novice teachers for equity, interest convergence draws our attention to novice teachers' motivations—what motivates the three women who chose to work with historically marginalized youth? A naïve salvation-oriented goal, such as "saving the poor student of color," is a manifestation of interest convergence. The second theme, that race is a social construct, draws our attention to the ways in which race is socially constructed through interactions mediated by both curricula and teachers in classrooms. Examining whether and to what extent novice teachers attend to race when designing and enacting their curriculum, and when interpreting classroom situations, allows us to recognize novices' increasing capacities for creating inclusive learning environments. The third theme, the need to challenge notions of color blindness and similar claims of objectivity, helps to problematize novice teachers' generic or color-blinded discourses about equity or equitable participation. The final theme, *racial commodification*, is applicable in that science is often considered "white property" (Mensah & Jackson, 2018). Traditional Eurocentric, positivist teachings of science promote exclusivity and reify white, male ownership of science. In considering this theme of CRT, we ask whether and to what extent novice science teachers

develop multicultural and flexible frames of reference, while moving away from ethnocentrism, epistemic elitism, and essentialism. Building upon Ladson-Billings' argument, Mensah and Jackson (2018) remind us that "educators continue to be educated and educate others in ways that ignore systemic racial inequities and their own role in perpetuating those inequities" (p.5). By drawing on CRT as the analytical lens, we hope to better understand and ultimately dismantle the practices of structural ideologies of systemic and endemic racism in secondary science classrooms.

Method

Preparation Program Context

The study's setting is a 14-month, post-baccalaureate certificate-plus-master's program housed in a research-oriented university in the Western United States. The program offers several social foundational courses, disciplinary-specific methods courses, and field-work seminars. Similar to other programs, candidates take a four-credit foundation course, "Foundations of Cultural Diversity & Equity," which explicitly addresses issues regarding culture, race, and equity. This course was designed to help candidates interrogate the issues of white privilege, racism, and subtle and persistent forms of individual and institutional bias inhibiting historically marginalized youth from achieving academic success. Candidates engage in readings, discussions, equity audits, and community asset mapping, ultimately writing a "leveraging funds of knowledge" report (see appendix A for the course goals, objectives, activities, and weekly readings). The candidates enrolled in this 10-week long course during the fall quarter while simultaneously taking a secondary science methods course. The methods course continued until the end of the program.

Student teaching placements were organized during the summer at the beginning of the program, and lasted the entire school year. In the first half of student teaching (August to January), candidates spent two days per week at field sites (about 12 hours total) and the other three days at the university taking courses. From the end of January to June, they spent the school day as student teachers and took courses at the university in the evening. They completed additional courses in the second summer before finishing the program. Candidates' field experiences were primarily guided by two courses: a fieldwork seminar and a subject matter methods course. The fieldwork seminar, offered to all candidates across disciplines, focused on common teaching issues, such as classroom management, disciplines, edTPA preparation, and job interviews. A subject-specific methods course, which included a number of teaching-related activities, was the primary university-based guide for candidates' field experiences relevant to disciplinary teaching and learning.

Approximation of Core Practices Guided by Science Methods Courses

The secondary science candidates attended a total of 20 methods course sessions at the university from September to June. A set of four core practices of AST (Windschitl et al., 2012) were used as the main curriculum of the methods course. These AST practices were developed by synthesizing of four bodies of literature: studies of 1) student learning, 2) expert teaching, 3) equity in instruction, and 4) disciplinary activities of contemporary science. The AST practices consist of one *planning* practice (i.e., constructing the big idea of the lesson) and three *discourse* practices (i.e., eliciting students' ideas, supporting ongoing changes in thinking, and pressing for evidence-based explanation). Overall, AST practices specify how to begin a unit, how to organize activities during the unit, and how to end the unit, with the aim of supporting students' scientific sense-making. For example, a unit may begin with the introduction of a puzzling real-

world phenomenon or a problem that functions as the 'anchor' to students' experiences throughout the unit (practice #1). The teacher first elicits students' initial ideas about the anchoring phenomena (practice #2), and then supports changes in their students' thinking by engaging them in various activities (practice #3). Toward the end of the unit, the teacher presses students to revise their explanations of the phenomena based on the evidence (practice #4) (for further detail, see Windschitl et al, 2012).

Throughout the methods course, candidates repeatedly engaged in sequenced activities: (a) planning a lesson or a unit and revising the plan based on feedback, (b) enacting the plan with peers and with their students, and (c) analyzing student responses and producing a written report that included the final (revised) version of the plan (see details of pedagogical activities in Table 1). The methods course instructor modeled each AST practice and provided opportunities for candidates to experience each practice as students of science. Following this demonstration, candidates worked in groups of four to five to plan and approximate the modeled practice with their peers via rehearsal (Davis et al., 2017). Thus, candidates had opportunities to practice and see the various forms of approximation conducted by their peers while playing the role of students, teachers, or observers. Candidates then wrote reflective reports.

Following rehearsal activity in the methods course, each candidate approximated AST practices in their own field placement classrooms. Candidates went through multiple revisions of *tasks, talk, and tools* of the targeted practice while receiving feedback from both the course instructor and their peers. During the approximation in classrooms, candidates videotaped their teaching and collected samples of student work. After the approximation, they brought samples of student work and videos to the methods courses, and analyzed the artifacts with their peers.

This approximation ended with a written report that included analysis of student work and the revised design of *tasks, talk, and tools* based on the analysis.

Throughout the fall quarter (September to December), candidates approximated the four AST practices while conducting two rounds of guided field teaching. During the winter quarter (January to March), candidates conducted two additional rounds of field teaching while approximating AST practices. In the spring quarter (April to June), candidates engaged in guided field teaching once again.

--Insert Table 1 about here--

Participants

This study was part of a larger project on novice teachers' learning trajectories from preparation to their second year of teaching. In this paper, we focused on three novice teachers, Leslie, Mary, and Brenda, who went on to teach in schools serving historically underserved students upon completion of their preparation program. Leslie, Mary, and Brenda were white females who entered the teacher preparation program in 2014 (see participants' details in Table 2). Leslie majored in chemistry and Mary and Brenda majored in biology. Each of them brought unique life histories and experiences to the program. Leslie grew up in a low-income, working-class family and had experienced some difficulties in her life. During high school, her family moved around a great deal, and she had to sleep on couches or on the floor at times. Before entering the program, Leslie worked as an SAT preparation tutor for an online company. Mary and Brenda both grew up in middle-class families in small suburban towns and had relatively smooth lives. They went to school in suburban, white, middle-class communities. After graduating from college, Mary became involved in conservatory research in South Africa and Morocco for about two years. This experience motivated her to become an educator because she

thought "the biggest impact you could make is educating people and teaching people empathy and how to relate that to knowledge." Similar to Mary, Brenda graduated from college and worked in the medical device industry as a quality control inspector. She said, "I had already climbed the corporate ladder pretty high making a lot of money. It was just like, 'You know? I didn't like it.' I wanted to make a difference." All three women wanted to help people and improve the world through education. They also wanted to help students to develop critical thinking through science education, instead of simply teaching science via rote memorization or lecture.

--Insert Table 2 about here—

During the preparation period, Leslie was placed in schools located in white, upper middle-class communities. Meanwhile, Brenda and Mary were both placed in schools serving two starkly different communities, an affluent white community and a working class, primarily Latinx community (see the details of field placement settings in Table 2). None of the participants reported seeing the forms of science teaching discussed in their methods courses in their field placements.

Data Generation

Data were generated via artifact collection, observation, and interviews. The primary source of data was what is called a *teaching episode (TE)*. During the preparation period, candidates generated a set of artifacts whenever they approximated the core practices with students in their field placements. A 'teaching episode' included the following artifacts: (a) initial and revised plans, the feedback that novice teachers received, and instructional materials used, (b) a teaching video, (c) samples of student work, and (d) written analyses of student work. A total of five TEs per teacher were produced during the preparation period. During the first two

years of teaching, we visited the teachers' classrooms three times per year with their invitation, producing 18 TEs. We also conducted a post-observation interviews lasting 30-50 minutes to understand each teacher's pedagogical reasoning and her experiences with historically marginalized students in the local context.

The other source of data was collected annually: *end-of-year interviews*. These were semi-structured, 60-minute interviews with each participant. The interview conducted at the end of preparation focused on understanding the field placement setting and novice teachers' experiences approximating core practices in their field placement classrooms. The exit interviews conducted at the end of the first and second years provided in-depth information about the instructional culture, norms, expectations, available resources, leadership, and support for new teachers.

Lastly, we collected a set of *candidates' vision statements* written at the very beginning of the program, and revised in the middle and at the end of the program. A set of statements were used as the complementary source of data.

Data Analysis

Analyzing the role of core practices in developing novices' capacity for equitable teaching (RQ1). We analyzed novice teachers' practice and discourse trajectories during the preparation period to understand the role of AST practices in developing their capacity for equitable teaching (RQ1). The underlying assumption was that if novices developed multicultural and flexible frames of reference, they would engage in the work of teaching in ways that honored and expanded students' ways of making sense of the world. Also, the increasing critical consciousness about race, racism, and structural inequity would be reflected in

novices' pedagogical choices when planning and enacting the curriculum, as well as their interpretations of marginalized students' behaviors and performances in classrooms.

Coding the trajectories of practices. Guided by sociocultural theory, each teaching episode (TE) was used as the unit of analysis. The analysis of novice teachers' practices focused on two observable dimensions that profoundly shape historically marginalized students' science learning experiences: the *framing* of learning goals and the *positioning* of learners. Informed by CRT, we explicitly attended to the power and privilege in a learning setting configured by novices' framing and positioning. Specifically, in each episode, we first examined ways in which learning goals were *framed* in the planning document and/or were communicated with students during lesson enactment. We identified segments where a candidate described learning goals, objectives, assessment tasks, or learning outcomes in the written documents of each teaching episode. Additionally, we examined segments of teaching videos, when available, where a novice teacher introduced the learning goals and tasks, typically at the beginning of instruction. Multiple sources of data collected through multiple methods allowed us to triangulate the interpretation of framing and positioning (Denzin & Lincoln, 2005). The coding scheme was developed iteratively while analyzing the data over nine months and reviewing the literature. In the final coding scheme, the framing of science learning in each teaching episode was coded dichotomously as either expansive or hierarchical. *Expansive framing* refers to the framing of science learning as expanding ways of making sense of the world without privileging western ways of doing or thinking. For example, in a lesson about Gas Laws, one participant drew upon the 2015 National Football League's football deflation scandal. The student learning goal was to "figure out how a football might be able to 'self-deflate' after moving from a warm to a cool environment." *Hierarchical* refers to the framing of science learning as the acquisition of

canonical content or skills (e.g., the learning goal is to understand Boyle's Gas Laws), and reflected that novices privilege their own or western views of sciences as right or better than others (see details in Table 3).

The second dimension was how students, and their ideas lived experiences, were *positioned* in relation to disciplinary knowledge and ways of knowing. In each TE, we first identified the main instructional tasks using written documents (e.g., lesson plans, handouts, curriculum materials) and teaching videos. We analyzed whether and how students' ideas, interests, and everyday experiences were used to design a task. Then, we analyzed how students' ideas and experiences were treated during the enactment. The spectrum of positioning was grouped into three categories in the final coding scheme (see again Table 3). *Central* refers to situations in which students' ideas, interests, and everyday experiences constituted the central aspect of a learning environment, as the subject of inquiry or meaning-making. In addition, student ideas and cultural experiences were persistently positioned as scientifically valid, generative, and valuable during the enactment of a task, which indicates novices' progress toward equitable teaching. *Developing* refers to situations in which students' ideas, interests, or everyday experiences appeared in the task design, but scientifically inaccurate ideas or non-western ways of thinking were treated as "inappropriate" or "wrong" instead of valuable resources during the enactment. Alternatively, students' ideas, interests, or everyday experiences might have appeared in the task design in a superficial way, such as "a motivational hook." *Marginal* refers to situations that, by the design of the task, provided little or no connection to students' ideas, interests, and everyday experiences. Scientifically inaccurate ideas were treated as "misconceptions" or "wrong" during classroom interactions. The data was coded using this coding scheme.

--Insert Table 3 about here—

Three selected teaching episodes (#2, #3, #4, see Table 1) produced at different stages of the preparation were coded using the above coding scheme.

Coding the trajectories of discourses—novice teachers' interpretations of marginalized students' performances and behaviors in the science classroom. We identified the segments of data where candidates described their pedagogical reasoning or interpreted historically marginalized students' performances and behaviors. Guided by the four themes of critical race theory, candidates' discourses were analyzed focusing on the following questions: whether and how did the candidates attend to race and racism when they designed learning activities and interpreted students' responses? How were historically marginalized students characterized in candidates' discourses? To what extent did the candidates move away from generic discourses, such as color-blindness, individualism, and ethnocentrism, when interpreting classroom situations?

Cross-case analyses. The coding results revealed different trajectories toward equitable teaching for each participant during the preparation period. Cross-case analyses were conducted employing a constant comparative approach (Strauss & Corbin, 1998). Multiple forms of data (e.g., teaching episodes, interviews, vision statements) were examined qualitatively. Special attention was paid to any desirable shift in novices' trajectories (e.g., hierarchical → horizontal framing) in relation to the approximation of AST practices. The cross-case analyses helped us to formulate an initial theory about the roles of approximating AST practices in developing novices' capacity for equitable teaching. Later, this initial theory was revised following the examination of novices' trajectories during the first two years, as described below.

Tracing the trajectories of practices during the first two years (RQ2). We were first interested in figuring out who was more or less successful in providing high quality science learning opportunities, as outlined in the NGSS, for students from historically marginalized communities (RQ2). In assessing the quality of novices' science instruction, we drew upon an existing framework (Kang & Windschitl, 2018). Next, we examined novices' discourses about historically marginalized students' performances and behaviors to further understand their increasing capacities for creating inclusive learning environments.

Assessing the quality of science instruction and opportunities to learn. The aforementioned framework uses four metrics to determine the quality of students' science learning opportunities as mediated by a teacher's instructional practices: (a) framing of learning goals, (b) practice demand of tasks, (c) conceptual demand of tasks, and (d) responsiveness of classroom discourses (see the details of the coding scheme in Kang & Windschitl, 2018). *Framing of learning goals* refers to the ways in which learning goals are communicated to students in a lesson. This was coded on a scale from simply knowing a goal or the other facts, topic, or procedure (code="Low") to solving a complex problem or figuring things out (code="High"). *Practice demand of tasks* refers to the task's affordances for students to experience disciplinary practices ("doing science"). A high practice-demand task enables students to exercise conceptual agency, meaning the outcome is determined by their choices and actions. In contrast, a low practice-demand task limits students' disciplinary agency and opportunities for meaning-making. Those tasks typically prompt action taken by a student in which the outcome is determined by properties of an established procedure or methods (e.g., a cookbook lab). *Conceptual demand of tasks* refers to affordances for students' engagement in and advancement of disciplinary thinking. A high conceptual-demand task facilitates students in

generating multiple coherent connections between observable and unobservable aspects of natural phenomena in the process of constructing explanations or evaluating arguments. In contrast, a low conceptual-demand task affords only a minimal level of thinking or sense-making (e.g., describing what happens or what they saw during the lab). Lastly, *responsiveness of classroom discourses* refers to the degree to which the teacher systematizes cognitive, social, and linguistic resources discursively to assist students' deeper engagement in disciplinary practices in a supportive classroom learning community. In a highly responsive classroom, students' ideas are elicited, validated, and built upon in a way that collectively deepens understanding about the world. Meanwhile, the discourses in a low-responsive classroom are typically focused on monitoring on-task behaviors or reteaching (e.g., IRE). Each of the four components was coded as "High", "Medium" or "Low" reflecting its level of sophistication (see the full description of the coding scheme in Table 4).

--Insert Table 4 about here—

The lessons observed during the first two years were coded using this coding scheme (e.g., "H-M-M-L", "M-M-M-L"). The coding results enabled us to characterize each lesson as one of the four conceptual categories: Type I-focusing on doing without expanding thinking; Type II-engaging in disjointed practices focusing on a topic or procedure; Type III-engaging in disciplinary practices for sense-making with less sophisticated practices; and Type IV-engaging in disciplinary practices for sense-making as a community of learners. Type III and IV lessons reflected novice teachers' efforts to facilitate student learning as outlined in the NGSS. The results of coding revealed who among our participants was more or less successful in creating meaningful science-learning contexts for historically marginalized students during the first two years of instruction.

Coding the trajectories of discourses and cross-case analyses. Similar to the preparation data, analyses of novice teachers' pedagogical reasoning and interpretation about historically marginalized students' performance and behavior were guided by the four themes of CRT. In addition to our three guiding questions (see 'Coding the trajectories of discourses' above), we attended to the stated reason that each of the three white women gave for working with historically marginalized students. Finally, cross-case analyses were conducted using multiple sources of qualitative data. The purpose was to further understand how and why each participant—who crafted particular trajectories during the preparation period—engaged in the work of teaching during the first two years in a particular way. We paid special attention to the role of AST practices, local contexts, and school culture in shaping novices' interactions with historically marginalized students.

Findings

Part I: The Roles of Core Practices in Developing Preservice Teachers' Capacity to Create Meaningful and Equitable Learning Environments

The analyses reveal four notable patterns of candidates' trajectories during the preparation period (see Table 5). First, each candidate showed substantially different trajectories during the preparation period despite seemingly similar personal backgrounds (i.e., white, female) and their common exposure to the AST practices. Whereas Leslie immediately shifted her framing and positioning in a desirable way (i.e., hierarchical → expansive, marginal → central), Mary's changes came after deep struggles during the first four months of the preparation program. Brenda maintained a trajectory of hierarchical framing of learning goals and marginal positioning of student experiences throughout preparation period. These differences suggest a complex interplay of multiple elements of activity systems in shaping

novice teachers' trajectories, including their prior life experiences, experience approximating AST practices in their course, and experiences with students in classrooms.

Second, close analyses of both Mary's and Leslie's cases suggest that approximating AST practices created opportunities for them to see what 'normally struggling' students can do in a well-designed instructional condition. Over time Mary and Leslie shifted their discourses about good science teaching, indicating some changes from their initial frames of reference.

Third, although both Mary and Leslie both showed desirable changes in their practices, only Mary demonstrated increasing awareness of racism and structural inequity in interpreting classroom situations. Leslie demonstrated her deep care and empathy for her struggling students, but in a colorblind way. It appeared that Mary's increasing awareness had something to do with her experiences at the field placement school that utilized an informal tracking system. Neither Mary nor Leslie attended to issue of race in designing and enacting curriculum.

Fourth, Brenda maintained her initial views, teaching practices, and simplistic discourses regarding historically marginalized students despite her approximation of the AST practices. Brenda was excited about the new practices because she thought she could avoid becoming "a boring teacher lecturing all day." Close analyses suggest that her ethnocentric and essentialist frame of reference was unchanged at the end of the program.

--Insert Table 5 about here--

For the sake of the space, this section presents the case of Mary in detail. The other cases are briefly discussed to illustrate the affordances and constraints of approximating AST practices in developing novices' capacities for creating inclusive learning environments.

The case of Mary: "It's not about the right answer. It's about making connections."

Early on in the program, approximating AST practices was very challenging for Mary, in part

because the idea of expanding students' sense-making—one key feature of AST practices—was completely foreign to her. Mary always experienced science as a lecture or a lab that follows a prescribed procedure. Mary recalled her high school experience as the following: "I'd always been taught [science], 'here's a lecture, and then go.' We didn't really do labs." In college, she continued, "'[you] go to your lab, and then just do the lab. There were directions, and we just didn't ask questions." Mary's initial frame of reference, rooted in her own science learning experiences, was largely contradictory to the views of teaching promoted in the methods course. In fact, Mary continuously failed to meet the instructor's expectations in her initial plans because her lessons were designed to deliver abstract science ideas. She went through multiple revisions while receiving feedback from the instructor and her peers before she began her field placement teaching. Mary said, "It was very, very challenging in the beginning of the year. There were tears. I was like, 'I'm awful at this!' Then I really started to see progress, especially when you see it with the students… and I was like 'this is working!'"

Mary's field placement during student teaching was a low-track seventh grade life science classroom at a middle school collocated with a high school (7-12 grades) where approximately a quarter of students were ELs. The approximation of AST practices enabled Mary to create a qualitatively different learning environment for her Latinx and EL students from the typical instructional conditions that the students experienced. For example, in her second field teaching lesson in the fall quarter (Preparation TE#2 in Table 5), Mary approximated an AST practice, "supporting on-going changes in student thinking." She designed and enacted one activity to support changes in students' thinking about an observable phenomenon. Mary stated, "Normally, labs are done after information has been introduced in a lecture, but this time, the students completed a lab in order for them to develop their own explanations about why the

eggplant was drying up based on their observations" (TE #2 report). Mary noticed that students who typically did not participate in class activities engaged more actively with this change. In her genetics unit (Preparation TE#3 in Table 5) she approximated all four AST practices. Mary designed the unit around a puzzling question, "why do you look like your siblings?" She invited students to talk about their families or share personal experiences and connected the "Punnett square" activity back to her question about sibling appearances. In her teaching report, Mary stated, "[my students] were able to make connections which I didn't experience before" and "They were using this great academic language, I'm like, "Yeah!" Mary was excited about students' enhanced participation and use of academic language, which were her frames of reference to assess the success of science teaching and learning.

As Mary put effort into leveraging students' everyday experiences, she saw her "shy girls," ELs, raising their hands and sharing their ideas. She interpreted this changing pattern of participation as related to the re-framing of science learning from "getting the right answer" to "making connections." Per Mary:

> Before no one was raising their hand. When everyone was so focused on the right answer, I don't know science, whatever. Then end of the year everyone was raising their hand. Even all of my girls were raising their hand which before I had very shy girls. I'm like, come on, girls. People then started realizing *it's not about the right answer. It's about making connections*. I think instilling that… took a while, but I was like, no one's here to make fun or judge people, we're going to try to construct this together, we're all learning. I'm probably way more than they are… *that's how I felt about 'the eliciting students' lived experiences*.'

Approximating the core practices helped Mary to bring a well-designed *task, talk, and tools* into her classroom to set up meaningful learning contexts, which subsequently presented opportunities for Mary to learn about students and their lived experiences. This also provided opportunities for Mary to see how the participation and engagement of Latinx and ELs in her lower-track 7th grade science classroom changed alongside the change of instructional conditions. Analyses across the teaching episodes show notable changes in Mary's initial frame of reference, such as viewing meaningful science learning as "making a connection," instead of getting the right answer. Similar to Mary, Leslie noticed that a student who "didn't do any homework" and "normally got Ds or zero credit," actively and excitedly participated in activities in the unit designed using the AST practices. Leslie said, "Once I realized that my kids that normally struggle were the kids that were doing the absolute best with this, I was like, 'Okay, in. I'm totally in."

In addition to the shift in her approach toward designing science learning environments, the analyses of Mary's discourses showed her increasing awareness about how historically marginalized students' science learning opportunities are constrained by structural racial inequity. Her critical awareness appeared in her interpretations about classroom situations, but it was not reflected in her pedagogical decisions, such as planning or enacting curriculum. Notably, this increasing awareness seemed to be related to her field placement condition. Mary's field placement school had about 64% of Latinx and about one quarter of students were ELs (see Table 2). While working in a 7th grade lower-track classroom, Mary noticed that "there were significantly more white students in the honors classes than the classes that I was teaching. I know my fifth period was a hundred percent Latino and my first period I think there was one white student." As Mary were witnessing what her EL students could do in a well-designed

instructional condition, she came to see the tracking system based on a standardized reading test as deeply troublesome. Mary said,

> "The way that they're differentiating putting kids into honors is based on a standardized reading test, which I think is ridiculous because, then all those students that are learning English as a second language, that's just throwing them under the bus. Because my school is a seven through 12 school, once they're placed in those honors classes, they're likely to stay on that track until they graduate. I think how they do on that stupid test, standardized reading test, is going to dictate basically how they do and where they go to college."

In contrast, Leslie, who worked with "white, middle class kids" in her field placement school and took up the AST practices early on, did not provide evidence of increasing her consciousness about race and racism throughout the preparation period. Leslie constantly expressed her deep care and empathy about individual students in a colorblind way, reminiscent of the rhetoric of 'science-for-all.' She "want[s] every student to have the opportunity to succeed." She thought that the reason students struggled was because of the "traditional science teaching method." Similarly, Brenda, whose background resembled Mary's, worked in an eighth-grade physical science classroom. The students in Brenda's classroom showed a wide spectrum of racial, linguistic, and economic backgrounds. Brenda said she had "[an] extremely low-SES Hispanic population", "the really, really high economic rich kids from Harvard", "one student who came from Argentina at the start of the year, [and] didn't speak any English." Brenda was excited about the AST practices as an alternative for giving lectures. Brenda said, "I am so happy to have learned these amazing new techniques for teaching students and to have come into this profession at a time where I can be innovative as I adapt curriculum to meet NGSS." Despite

Brenda's excitement and use of program languages, science learning was continuously framed as knowing or understanding some abstract science ideas (code=hierarchical framing), and students' experiences played a marginal role in the design of learning activities, with the exception of one teaching episode (Preparation TE#4 in Table 5). Furthermore, Brenda continuously described multi-lingual students who had yet to master English as a problem, instead of recognizing their language as assets. During the exit interview, Brenda said, "Most of them were born here and they're still English language learners in eighth grade. Something's wrong." She described one particular student's struggles: "I do distinctly remember one of my EL students. She was having a really hard time and she just didn't understand why we were doing this. I don't really know why it would've been such as barrier with the language because there wasn't really a language component to it. I thought it was interesting." Brenda thought that she could better supporting ELs by using the techniques and strategies that she learned. Brenda said, "just provide [ELs] a little more support. Asking probing questions. Trying to get them to voice their thoughts and their thought process, so that I can understand what's going wrong if something is going wrong and help them through that thought process." Despite her excitement for AST practices and tools, neither Brenda's practices nor her discourses were substantially altered during the preparation period.

Part II: Becoming a New Science Teacher and Working with Historically Marginalized Students

Overall three themes emerged from our analyses of the first two years of teaching. First, high-quality science learning opportunities that facilitated students' sense-making (i.e., type III or IV lessons) were rarely observed during the first two years (see Table 5). Such lessons were observed once a year in both Mary's and Leslie's classrooms, but not in Brenda's. Second, in

those lessons coded as high-quality science learning opportunities, Mary and Leslie leveraged the curriculum that they developed during student teaching instead of using the curriculum provided by the schools. Finally, novice teachers' under-developed critical consciousness constrained their creation of inclusive learning environments. Despite their deep care for their students, both Mary and Leslie were unprepared to attend to and leverage race and culture when designing and enacting curriculum with historically marginalized students. Brenda, who encountered severe classroom management issues in her first year, abandoned most of the AST tools and practices that "didn't work with my kids." Brenda regressed to a delivery mode of teaching while increasingly using deficit language to describe historically marginalized students, and eventually left the school in her second year.

In the following, we present the cases of Leslie and Brenda to illustrate *how* novice teachers crafted particular forms of science learning experiences while working with historically marginalized students during the first two years. The case of Mary is briefly addressed.

The case of Leslie. Leslie accepted a position at a large urban high school that served predominantly Latinx and low-income families. Leslie liked this position because of the reputation of the school district, the welcoming and open climate of the school's professional community, and the working-class community that the majority of students came from. Although instructional norms and culture were mostly focused on covering curriculum, the school functioned well and had strong leadership.

The student population was starkly different from Leslie's student teaching field placement (see Table 2). The majority of students who attended the school had to manage various outside responsibilities and constraints, such as having siblings to take care of, having to work, and/or not having a dedicated space to complete homework. In the middle of Leslie's first

year, she heard that one student was killed as the result of gang violence. During the interview, Leslie said, "My students from last year are so different from my students this year…I realized that I had a really easy class last year. It is different."

First year: "My students had very different experiences from me." Leslie was assigned to teach three Chemistry and two Life Science classes in her first year. The three chemistry teachers met regularly to co-plan their lessons and used the same curricular materials. As a new member of the team, Leslie was expected to use the co-planned curriculum along with the other two chemistry teachers. In contrast to Chemistry, Leslie was the only teacher who taught Life Sciences. It was a lower track course for students who failed in prior science courses and therefore could not move on to Biology. Leslie said, "Many of them are used to failing school, many of them are planning to go to a continuation high school later in the year, and because they expect to fail, they are not motivated by grades." There was no given curriculum for the Life Sciences course.

At the beginning of the year, Leslie followed the existing curriculum for Chemistry. After the mid-point of the year, when it was time for the Gas Laws unit, Leslie brought the 'football deflation scandal' curriculum from her student teaching to the department meeting and convinced the two experienced chemistry teachers to use her curriculum. The fact that the curriculum was designed using the NGSS standards, incorporating several science and engineering practices, facilitated its acceptance by the teachers who were aware of the upcoming transition to the new standards. Leslie implemented this curriculum with her students (coded as Type III lesson, see First Year #2 in Table 5). The unit was contextualized in the 2015 NFL football deflation scandal and centered on the question "Is Tom Brady a cheater?" Students were guided to test the scientific veracity of the New England Patriots' claim that their footballs

deflated on their own because of cold weather after moving from a warm locker room. Throughout this unit, students engaged in several activities to collect evidence to support or revise their initial models. In one lesson observed in March 2016, students as a group analyzed the behaviors of hot air balloon using the idea of gas law. Leslie witnessed her students excitedly engaging in the activities, debating the "deflategate" scandal even class had ended, and producing far more sophisticated written responses than with prior units. She saw students excitedly building and testing their *own* hot air balloons—to explore the relationship between gas molecules and temperature—which were decorated leveraging their artistic talent. Leslie said,

> I really, really, really am proud of the gas laws unit because we did it. It was my style of unit, and it wasn't perfect...but it was a way for me to show them *what the kids could do when given something*, and it got all the teachers onboard. My BTSA mentor was like, 'Oh, we need to do this for every unit,' and I was like, 'Exactly! Exactly!'

Leslie later presented this unit to the administration, showcasing how the unit intersected with the NGSS. Similar to Leslie's situation, Mary had to work against the traditional instructional culture of her school during her first year. Mary "had to" use department-developed PowerPoint slides and give multiple-choice tests. Whenever possible, Mary brought in curricula that framed science learning as expanding students' understanding of the world, rather than simply using the given curriculum that were designed to deliver abstract science ideas.

Analysis of three sets of teaching episodes produced during the first year of teaching shows that both Leslie and Mary attempted AST practices, tools, and strategies whenever possible. However, attending to and leveraging students' cultural experiences had yet to be a consideration in their curricula. In one unit on cellular respiration near Thanksgiving, for example, Leslie framed the unit as solving the problem of how to make bread fluffier. She began

the unit by asking, "I need to make rolls for Thanksgiving. What do you know about making bread, and how can we make the bread fluffier?" As Leslie shared a recipe for bread that she found online, students excitedly talked about their home recipes for making bread. This opened up a conversation that revealed students' rich cultural knowledge and practices at home. This conversation led Leslie to recognize that she was "completely unaware" of her students' home practices:

> I was showing them my recipe, and they're like, "Oh, where'd you get that recipe?" I told them. I was like, "I found this one online. It's for such and such. People love it." I was like, "I've tried this before. It's really good, but it's not super-fluffy." They're like, "Oh, well, my dad does blah-blah-blah, and when we do that, blah-blah-blah." Then this morphed into this whole conversation of what you do for Thanksgiving and Christmas that I was completely unaware [of] because I didn't grow up around a lot of Mexican kids, ever. They're like, 'No-no-no, that's not what we do for Thanksgiving. We don't do turkey and stuffing.' I was like, 'Really? Okay, what do you do?'

It appeared that recognizing different cultural practices was rather a 'surprise' than an anticipated part of teaching for Leslie in her first year of teaching. Upon the completion of her first year, Leslie reflected on the key changes that she made. She began "integrating the individual kids' and the groups of kids'" interests and ideas into her unit design. Leslie said, "[My students] had very different experiences from me, but they're also a totally different mentality. They have totally different attitudes and interests. It's fantastic, and it's not comfortable."

Second year. Leslie taught Chemistry only in her second year. Three salient norms and routines were observed in her classroom. The first was the introduction of each unit with some puzzling phenomena or questions that interested the students. Leslie had to negotiate with other

chemistry teachers to frame the unit using a phenomenon or problem—one key aspect of AST practices. The second routine was constantly 'going around the table' during small group work, therefore she had "more time to talk to each kid", to "see where their thinking is, what they need to get." Because she knew some of her students lived challenging lives, she had to figure out how to check on each and every single student. This 'go around to each table' routine was her strategy for addressing this challenge. The last routine was one suggested by the administration to "make the classroom structured enough for things to be productive." Leslie decided to post a "Do Now" list on the screen for when students entered her classroom and while she took attendance. Leslie used this "Do Now" routine to connect prior learning activities to the day's lesson.

Leslie continued to collaborate with the other chemistry teachers to plan and teach her chemistry lessons. Similar to the Gas Law unit, she found ways to share and integrate curriculum from preparation when she thought it would fit with departmental instructional goals. For example, in one lesson of the Stoichiometry unit observed in December 2016, students, positioned as workers at an airbag company, were tasked with figuring out the best and safest airbag system. This was one of the curricular units that she developed during student teaching while approximating the core practices. Students were guided to investigate the design of a small airbag system using baking soda and vinegar. Students had to figure out how to fill up the airbag without having any left-over reactants (Type II lesson, second year TE#1 in Table 5). In another teaching episode in February 2017, students explored if it was "worth [it] to spend the extra money to put synthetic oil in your car instead of regular oil." Despite some less sophisticated practices observed at times, Leslie persistently tried to frame science learning as solving a

relevant problem or making sense of everyday experiences while positioning students as capable sense-makers (Type III lesson, second year TE#2 in Table 5).

The case of Brenda. Brenda accepted a position at a small, new, STEM-focused urban charter middle school after she earned her credential. The school had only seven teachers and Brenda was the only full time science teacher. Brenda was excited about working at this school because of the students it served and the newness of the school. She said, "This school is very special. It's a brand-new school, just opening, that's a really cool experience. They have Chromebooks…I like using those." Brenda liked that the school offered a unique program where every single student had a personal learning plan focusing on their growth. She said, "We don't have any teachers that are here who've been teachers for 30 years and are just collecting a paycheck. Everyone's energized, wants to be there."

Similar to Leslie, Brenda's school served mostly students from low-income, working class, Latinx families (see again Table 2). Many students lived in poverty and experienced homelessness, gang violence, drug abuse, suicide, and/or had family members in jail. Many students had transferred between multiple schools before arriving at this one.

First year: "Kids generally don't have the best home life. It's not always the positive thing to bring up their home." Brenda was assigned to teach three different courses in her first year: 7th grade life science, physical science, and a robotics elective. The first lesson observed at the early stage of her first year showed that Brenda was experimenting with various program-recommended tools and strategies in her instruction. In the lesson observed in December 2015 (first year TE#1 in Table 5), her 7th grade students were engaging in a semester-long engineering project where they made a submarine sink or float. Brenda was teaching "how to use the chemical reaction between baking soda and vinegar to make a submarine sink or float by

changing its buoyancy." The lesson began with a discussion about what made a submarine float or sink and reminding students about the terminology of buoyancy. Students in small groups were tasked with mixing baking soda with vinegar at their table in small cups and describing their observations (e.g., seeing "bubbles"). Next, students drew their predictions of what might happen if the baking soda inside a balloon attached to the lip of a glass water bottle was poured into the vinegar inside the bottle. Students then poured the baking soda, made observations, and were pressed to explain what caused the balloon at the top of the bottle to get bigger. During these activities, Brenda constantly asked, "Why do you think the balloon was expanding?" of students individually working on their worksheets and during a whole group discussion at the end. Students raised their hands and shared ideas, demonstrating their intellectual engagement. For example, students said, "It is expanded", "It got bigger and bigger", "When you put baking soda inside vinegar, like we did in bubble labs right here, all the bunch of baking soda falls, made a lot of pressure, and went up and [made] the air inside the balloon. So the baking soda that went into the balloon makes it expand." The lesson included several program-recommended tools and strategies to support students' sense-making, such as sentence stems, before-during-after drawings (modeling), and the Predict-Observe-Explain (POE) strategy (type II lesson).

As time went by, Brenda encountered serious classroom management challenges while experiencing various incidents inside and outside of the school, including students waiting for the school bus in the morning witnessing a boy getting shot in the head. During our second visit in March 2016, we heard that three teachers had left the school in the prior three weeks because "it was too much stress working [there]." Brenda was in survival mode, planning her lessons at the last minute, mostly searching for activities on the Internet. Her instruction focused on the delivery of abstract science ideas (e.g., cellular respiration, photosynthesis, macromolecules)

using some hand-on activities. In the observed lesson (First year TE#2 in Table 5), Brenda was wrapping up a photosynthesis and cellular respiration unit. She stated that the goal of the observed lesson was "showing how the three big ideas are connected to one another, showing that it is just re-arrangement of molecules." During this 7th grade life science lesson, students received a bag of colored chips representing atoms. They were tasked to simulate the movement of atoms and molecules during the processes of photosynthesis and cellular respiration while following directions and filling out a worksheet (Type I lesson). The classroom was chaotic, and Brenda's instruction was constantly interrupted by her students. We saw several students throwing things at each other and kicking their backpacks back and forth while Brenda was helping a group in another corner of the classroom. Several students had their heads down on their tables the entire time. There was little conversation suggesting intellectual engagement, even with the handful of students who worked to complete the task. Brenda ignored students' misbehaviors and tried to get through the activity. When she noticed two boys were playing soccer using a backpack, Brenda finally addressed them, saying "This is ridiculous!" During the post-instruction interview, Brenda expressed her deep frustration about students' behaviors over the prior two weeks. She said,

> Kids' behaviors are a nightmare. Last week, my room was just a sea of popsicles sticks because they threw them at each other, tried to carve them down… Taking a bottle of glue and just pouring them on their hands like kindergarteners. Doing this and peeling them whole…. So I am hesitant to do any hands-on stuffs now. They just killed my spirit entirely.

Brenda attempted to contact parents to get some help with students' behaviors, but it was challenging because she did not speak Spanish and had to rely on a translator. She said, "There is

a language barrier….I don't really get everything. Stuff gets lost in translation." Her principal was out for conferences and meetings much of the time. She could talk to her teacher colleagues, but their schedule allowed very limited time to do so. Brenda suffered emotionally from what was happening in her classroom. She said, "I can't…I lose my mind. I am angry all the time. When I go home, I am just like I am just gonna sleep and go away. It's not good." Brenda thought that students' behaviors had a lot to do with their emotional struggles associated with their difficult lives outside the school, such as the recent shooting incident. She said, "We have like the crazy things jump out. I know that is the root of so many of their behaviors. They don't just act out for no reason." The ideas that she learned from her preparation, such as forming relationships or giving extra attention did not help Brenda. She said, "I feel like I need a psychology degree.… Every behavioral book says like, 'We just need to give extra attention. They need some support.' I am like, that's fine except there are 27 of them. All of them need extra attention. Otherwise I'd love to have this great one-on-one relationship. There are too many there, damaged and struggling."

In our last visit at the end of the first year (June 2016; First year TE#3), we observed some notable changes in Brenda's discourses and practices of teaching. Brenda used more deficit language to describe her students, such as "so many gaps in their prior knowledge", "kids that have no respect for themselves or anyone else", and "so many homeless kids." Brenda also tended to generalize problems to a group or population, while distancing herself from that group. For example, she said, "That's a population type issue that I have to overcome, especially because it's such a polar opposite from what I've experienced in life." Interestingly, Brenda decided to avoid bringing anything related to students' home or outside experiences into her lessons, which was contradictory to the vision of teaching advocated by the program. She

thought that students wanted to escape from their "not so pretty" home lives. In the observed lesson, for example, she showed a five-minute-long video about endangered animals in Africa due to poaching and had students create a short presentation or video as a group to educate their classmates about poaching. Brenda thought drawing on something that was unrelated to students' everyday life, such as animals in Africa, would work better for her students. Brenda explained,

> I am starting to realize that…because basically thinking about animals in Africa, it is an escapist [move. Students] can pretend to be somewhere else watching the animals. Versus if I am asking them to think about solids, liquids, and gases in their [lives], then they have to think about their home life. And that is not always a pretty thing for a lot of these kids. [W]e have a huge homeless population. Kids generally do not have the best home life.

As Brenda grew to know her students and their outside lives, she formed the idea that "relating to their home life in some ways is not always good for these kids." For example, she attempted to bring up everyday experiences in her lesson, such as "taking a shower." And then she recognized that there were students who were unable to take a shower for three days because the water was turned off. For Brenda, who grew up a white, middle class family and was previously well-employed in an industry, not taking a shower for three days was undoubtedly a surprise. With her continuous failure to engage students and connect to them, she began to reject program-recommended practices, tools, and strategies. Over time, Brenda's instruction came to be more and more distant from students' everyday experiences, focusing on the delivery of abstract science ideas and terminologies.

Second year: "I don't know whether I want to keep dealing with this nonsense."

Brenda set up firm classroom routines in her second year, such as always doing a warm-up using Google classroom at the beginning of each lesson. We saw Brenda beginning to reproduce

prevalent problematic discourses about students at under-resourced urban schools. For example, Brenda said, "Just more routines. Warm up is 100% non-negotiable. I do not deviate. This particular population, they want routine. They need structure." Brenda abandoned most tools and strategies from the program that "didn't work with this population." For example, she decided not to use sentence stems saying, "I actually didn't have a whole a lot of success with sentence stems. I found that [the sentence stems] confused my students more than anything. I haven't figured out why." Brenda still wanted to do some labs, because she did not like lecturing. However, labs made her "nervous" and were "scary" because "no matter how hard I try to get them to follow the directions, they just…I try to figure out how the lab works for this group."

Brenda increasingly used deficit language about her students over time, such as "[these kids] just don't care", "they got really lazy." Her framing of instruction in the three observed lessons in her second year was designed to teach abstract science ideas using unrelated, generic phenomena, where students were positioned to follow directions and receive knowledge (Type I lesson). For example, in one lesson observed in November 2016, students did a 'yeast lab' to determine "what food source creates the most carbon dioxide." Students simply followed the procedure to complete the task and answer the given question. The issue of classroom management did not get any better, as reflected in Brenda's comment: "I don't know whether I want to keep dealing with this nonsense." Brenda went on maternity leave at the beginning of the spring semester and decided not to return to the school.

Discussion: What Do the Core Practices Offer in Preparing Novice Teachers for Equity?

This investigation begins with the premise that one central task of teacher preparation to promote equity is supporting teachers from dominant communities to develop multicultural and flexible frames of references in conjunction with critical consciousness about structural inequity.

The findings suggest that using the core practices of AST as the main curriculum of science methods courses can contribute to achieving this goal by presenting opportunities for novice teachers to alter their normalized views and expectations about disciplinary teaching and learning. The core practices in and of themselves are limited, however, to increase novice teachers' critical consciousness about racism and systemic inequity, and disrupt a frame of reference grounded in ethnocentrism, essentialism, or epistemic and linguistic elitism. In the following, we unpack these ideas while discussing the trajectories of these three white teachers from preparation to their second year of teaching.

Affordances: Presenting Opportunities to Alter Novice Teachers' Normalized Views and Expectations about Disciplinary Teaching and Learning

The analyses suggest that one affordance of the core practices is facilitating novices in seeing what historically marginalized students can do in a well-designed instructional environment. This subsequently presents opportunities for novice teachers to alter their normalized views, expectations, and assumptions about science teaching and learning at schools. Both Mary's and Leslie's cases illustrate this point. The approximation of core practices helped Mary and Leslie begin their instruction with well-designed task, talk, and tools. In this activity system, mediated by program-recommended tools, practices, and strategies, Mary and Leslie were able to explore students' responses to changes in instruction. The enhanced participation and engagement of students, in particular those who "normally struggle" in science classrooms, helped Mary and Leslie to raise questions about the conventional views and practices of science teaching and learning that they experienced. Over time, these experiences facilitated Mary and Leslie in altering their initial frames of reference about disciplinary teaching and learning. Recall Mary, who changed her frame of science teaching and learning from finding the "right answer"

to "making connections." Leslie problematized the traditional instructional approaches that provide opportunity to succeed for "[only] those who are good at school." The limited space of this article prevents us from presenting all three teachers' trajectories over three years in detail. Nonetheless, it is important to note that Leslie and Mary persistently made efforts to engage students in sense-making activities using real-world phenomena while working against the school culture during the first year (e.g., Leslie convinced her chemistry department to use the curriculum that she developed). We conjecture that the experiences of seeing what students can do in a well-designed instructional setting helped these novice teachers to persistently enact the vision of science teaching that they formulated during preparation.

Proponents of core practices argue that teaching core practices to preservice teachers will better prepare them to create meaningful and equitable learning environments for a wide range of students (Core Practice Consortium, 2016). The findings of this study suggest that what matters is more the type and nature of experiences *mediated by the core practices* rather than the core practices themselves. In fact, this analysis shows that merely learning core practices is insufficient to prepare preservice teachers for equity, especially when novice teachers experience the practices as a set of strategies or techniques. This is particularly evident from the cases of Mary and Brenda. These two cases had many shared characteristics, including the teachers' personal backgrounds (e.g., white, middle class), and opportunities to interact with historically marginalized students during student teaching. Both Mary and Brenda were excited about the core practices, but for different reasons. For Mary, approximating core practices presented opportunities learn with and about students. In contrast, Brenda saw the core practices as "new techniques" to help her avoid lectures. Brenda thought she could use the new techniques when

she began teaching in her own classroom. As illustrated, she abandoned most of the tools and strategies that did not work with her students during the first year of teaching.

One notable finding emerging from these analyses is the importance of inscribed forms of artifacts (e.g., curriculum materials, tools, samples of student work) recommended by or produced from novices' student teaching. In this study, novice teachers produced curricular materials while approximating the core practices. All three teachers leveraged these artifacts, or 'practical tools' (Grossman et al., 2000), to create science learning experiences during the first year despite uneven levels of success. At times, the artifacts functioned as 'boundary objects' (Bowker & Star, 1999; Nolen, Horn, Ward, & Childers, 2011; Star & Griesemer, 1989; Wenger, 1999) when novice teachers entered into their school communities as newcomers (see the case of Leslie). The important role of inscribed forms of artifacts that link preservice teacher education to later instruction has been reported by other researchers (Grossman et al, 2000; Hiebert & Morris, 2012). Nolan and her colleagues (2011), for example, showed how novice teachers appropriated, negotiated, and recontextualized assessment tools and practices as they transitioned from preparation to their first two years of teaching. The artifacts, that reify or represent values, goals, and meanings advocated by the program (Nolen et al, 2011), can become useful resources for novice teachers to negotiate for and create meaningful and equitable learning environments for historically marginalized students.

Constraints: Lacking the Ability to Increase Novices' Critical Awareness about Systemic Racial Inequities

Analyses show that approximating the practices is limited in its ability to increase novice teachers' cultural competencies and critical consciousness of race, racism, and power. The novice teachers' under-developed critical consciousness and failure in developing multi-cultural

frames of reference profoundly affected their interpretations about classroom situations and pedagogical actions with historically marginalized students.

Out of the three teachers, only Mary, who saw the impact of the tracking system on learning opportunities for her Latinx and EL students, seemed to develop increased awareness of structural racial inequity during her preparation period. However, her critical awareness was limited to her interpretations. Leslie, who took up the core practices early on, continuously engaged in colorblind 'science-for-all' discourses during the preparation period. Her failure to develop a multicultural 'frame of reference' became a source of discomfort and stress as she began working with students from different cultures. Leslie, who came from a white, working-class family, repeatedly demonstrated her deep care and empathy for "struggling students" over the three years. This dedicated and deeply caring white woman was unprepared to anticipate Mexican students' different cultural experiences when designing lessons during her first year. The nuanced mismatch between Leslie's own cultural repertoires and the Mexican students' cultural repertoires was a source of surprise and discomfort to Leslie, instead of an inherent and anticipated part of teaching. Leslie's colorblind pedagogy did not prepare her to purposefully elicit and build upon Mexican students' different ways of thinking, talking, and doing as she began her career.

The case of Brenda further showed the complexity of preparing novice teachers for equity. Analyses show that the preparation experiences failed to disrupt Brenda's frames of reference grounded in ethnocentrism, essentialism, and linguistic elitism during preparation. A white woman—who quit a well-paid job and decided to become a teacher to make a difference through education—could not keep her sanity day-to-day while experiencing shocking events inside and outside her classroom. Brenda tried unsuccessfully to enact "participatory equity"

(Sheth, 2019) by providing more one-on-one attention or individual scaffolding. On one hand, the various circumstances that Brenda encountered at her school were deeply troublesome. Why do so many students of color have to witness the death of friends and family members by gun violence on their way to school? Why does this violence occur in particular schools, like Brenda's? Undoubtedly, it was an extremely challenging situation for any new teacher. On the other hand, Brenda's trajectories toward reproducing deficit language to discuss historically marginalized students and her regression to a traditional "delivery mode" of teaching is also deeply troublesome. Her undisrupted salvation-oriented goals, which signify interest convergence (Bell, 1980, 2005), might fundamentally limit her ability to work with historically marginalized students. With a lack of critical consciousness about structural and systemic inequity and failure to problematize her own whiteness, Brenda gradually adopted deficit language, positioning her students as the major source of problems. Despite the new pedagogical tools that she learned during the preparation period, Brenda was unable to create meaningful and inclusive learning environments for her students in this situation.

Admittedly, all three teachers' lack of attention to systemic racial inequity was partly a reflection of the colorblind curriculum and pedagogy of their methods courses, which failed to explicitly address systematic racial equity. As with the majority of teacher preparation programs in the U.S., discussion of race, racism, and structural inequity were limited to the social foundational course in this program. The analyses demonstrate the limitations of approaching race, racism, and structural inequity as separate from the methods of disciplinary teaching and learning. In this compartmentalized approach, novice teachers failed to see how race, power, culture, and language play out together *in the context of disciplinary teaching and learning* and how these forces resulted in unequal learning opportunities for historically marginalized

students. While discussing the movement of core practices and practice-oriented teacher education, Zeichner (2012) notes that the ability to successfully enact high-leverage teaching practices is necessary but not sufficient to improve the quality of teaching in the United States. He indicates that,

> "Efforts historically to establish teacher education curriculum based on specific competencies or performances have been plagued by a narrow technical focus ignoring the need to ground teachers' technical competence in an understanding of the historical, cultural, political, economic, and social contexts in which their work is embedded (Greene, 1978). It is important for those engaged in making the teaching of core teaching practices a central focus in teacher preparation programs to situate their work in relation to a vision of the teacher's role so that they do not imply that all that is necessary in teacher education is the mastery of a set of teaching practices. (p. 380)

Conclusion and Implications

This study explores the affordances and constraints of using the core practices of ambitious science teaching (AST) as the main curriculum of secondary science methods courses in preparing secondary science teachers for equity. The analyses suggest that the core practices can contribute to preparing novice teachers for equity by presenting opportunities for novice teachers to alter their frames of reference about science teaching and schooling. Approximating the core practices alone neither facilitates novices' development of multicultural, flexible frames of reference nor critical consciousness about systemic racial inequity, which profoundly limits novices' capacities to create inclusive learning environments.

The findings of this study have three primary implications for teacher education across practice, research, and policy to promote equity with beginning teachers. First, we recommend

that teacher educators who are interested in using core practices as the curriculum of methods courses articulate what they want to accomplish with novice teachers, explicitly connecting these core practices to the goal of equity. These core practices can be presented as *the* practices of science teaching that novice teachers need to master in order to address equity. Alternatively, core practices can be used as *a* tool for creating spaces in which novice teachers problematize their naïve and Eurocentric views about science teaching and learning, and learn with and about students in their classrooms. This study shows that the way in which core practices are presented to and experienced by novice teachers mediates whether and how they develop the capacity for equitable teaching.

Furthermore, teacher educators and policymakers need to think critically about the type and nature of interactions that novice teachers from dominant backgrounds have with students during their clinical experiences—with whom, when, where, and how. The findings of this study suggest that novice teachers from dominant communities need substantial and recurring interaction with diverse students, including those students who belong to groups historically underserved in schools, in order to develop the capacity to create meaningful and equitable learning environments for these students.

Lastly, the curriculum and pedagogy of science teacher preparation, particularly methods courses, must be designed to help novice teachers from dominant communities in developing multi-cultural and flexible frames of reference along with critical consciousness about structural inequity. The first step will be developing science teacher educators' critical perspectives on equity beyond a participatory equity goal. We call for collective action among science teacher educators to critically reflect on our own and candidates' whiteness, normalized views and expectations, and roles in promoting equity in classrooms. With this critical reflection, we will

be able to re-imagine the structure, curriculum, and pedagogy of teacher education to promote equity and social justice through public education.

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