UNIVERSITY OF CALIFORNIA

Santa Barbara

Teacher Educator and Preservice Teachers' Efforts to Enact Justice-Centered Science Pedagogy During Covid-19

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Education

by

Valerie Elizabeth Valdez

Committee in charge:

Professor Julie A. Bianchini, Chair

Professor Jason Duque

Professor Rebeca Mireles-Rios

September 2022

The dissertation of Valerie Elizabeth Valdez is approved.

_____

Rebeca Mireles-Rios

_____

Jason Duque

_____

Julie A. Bianchini, Committee Chair

August 2022

Teacher Educator and Preservice Teachers' Efforts to Enact Justice-Centered Science Pedagogy During Covid-19

ACKNOWLEDGEMENTS

This study would not have been possible without the preservice teachers and teacher educator who spoke their truth so vulnerably and generously. Thank you!

This study could also not have been done without the unwavering support of my advisor and committee chair, Julie Bianchini. I feel so fortunate to have had Julie as an advisor. Her brilliance, kindness, and support in generating ideas were absolutely instrumental in my years in the doctoral program. Julie is an advisor who nurtures her student's ideas, and her support has meant the world to me. Thank you so much, Julie!

I'm so grateful for the collaborative efforts of the COASTAL research team. Thank you to Cameron Dexter-Torti, Matthew Bennett, Liliana Garcia, Donald McNish, Royce Olarte, Sarah Roberts, and Julie Bianchini.

A million thank yous to Karin Lohwasser – I am so grateful to have gotten to know you! I appreciate your guidance, sense of humor, and kindness. Thank you for everything!

I'd like to thank the Gevirtz Graduate School of Education at UC Santa Barbara. As a doctoral candidate, I was given the opportunity to teach an undergraduate course, as well as a course in the Teacher Education Program. I learned so, so much from teaching these courses, and I appreciate your confidence in me as an instructor. Thank you to Jen Scalzo – it was an honor to teach with and learn from you.

Thank you to the faculty at the Gevirtz Graduate School of Education – I learned so much in your courses, and in my interactions with you. Thank you to my brilliant committee members, Jason Duque and Rebeca Mireles-Rios. You illuminated aspects of teaching and research that I would not have thought of, and I am so grateful for your perspectives. Thank you for being so kind and supportive.

Thank you to my incredible colleagues at ATCPA - the “dream team”! I was very lucky to get to teach amongst and learn from such an incredible group of teachers. Thank you to Paris Williams! I am so grateful for your influence. A huge thank you to the incomparable Tawna Turner, my mentor during my preservice year. Your commitment to our 1st graders was like nothing I’d ever seen before, and every day I saw you work harder than anyone to ensure that our students were learning. I’m so inspired by your authenticity, dedication, and care for students. Thank you so much, Tawna.

Thank you to my friends and colleagues Valerie Sedillo, Katherine Osborne, and Jason Saenz. Your friendship and our laughs uplift me, no matter what. I love you, guys’d!

Thank you to Ben for all of your support – it has meant the world to me.

Thank you to my mother, Elizabeth. Mom, you have always gone way above and beyond for us, and I’m so grateful for you. A huge thank you to my siblings- Juan, Adriana, Alexandria, and Erika. My family has always hyped me up and made me feel like I could do anything, even when I didn’t. I’m so lucky to have such an incredible support system.

Finally, thank you to the students at ATCPA. When I first started working there as a campus monitor, I had no idea what I wanted to be when I “grew up”. But, being around all of you immediately lit up something within me. Teaching and interacting with all of you was the most transformative experience of my life. Now, I can’t imagine not being an educator – and it’s all because of being lucky enough to be in the orbit of your brilliant hearts and minds. Thank you!

VITA OF VALERIE ELIZABETH VALDEZ
August 2022

EDUCATION
Bachelor of Arts in Sociology, University of California, Berkeley, June 2011
Master of Arts in Education, University of the Pacific, June 2013
Doctor of Philosophy in Education, University of California, Santa Barbara,
August 2022 (expected)

PROFESSIONAL EMPLOYMENT
2013-2018: Elementary Teacher, Alexander Twilight College Preparatory Academy, Sacramento CA
2014-2015 Lead 2nd/3rd Grade Teacher, Alexander Twilight College Preparatory Academy
2014-2017: Mentor Teacher/Clinical Faculty, Alexander Twilight College Preparatory Academy
2018-2020 Adjunct Faculty in Literacy Instruction, Antioch University, Santa Barbara CA
2018-2021 Teaching Assistant, Department of Communication, University of California, Santa Barbara
2019-2021 Teaching Assistant, Department of Education, University of California, Santa Barbara
2019-2022 Graduate Research Assistant, Department of Education, University of California, Santa Barbara
2021-2022 Teaching Associate in Teaching Multilingual Learners/SDAIE, Teacher Education Program, University of California, Santa Barbara
2021-2022 Teaching Associate in Social Connectedness, Motivation, and Self-Regulation in Education, University of California, Santa Barbara
2022-present Assistant Professor of Education, Stevenson University, Owings Mills, MD

FIELDS OF STUDY
Justice-centered science pedagogy
Positive and trusting teacher-student relationships
Preservice teacher development
Teacher educator practices
Observation and debrief conversations

ABSTRACT

Teacher Educator and Preservice Teachers' Efforts to Enact Justice-Centered Science Pedagogy During Covid-19

by

Valerie Elizabeth Valdez

Scholars note that teacher preparation is a critical part of addressing equity and justice in K-12 school settings (Goodwin & Darity, 2019; Kretchmar & Zeichner, 2016; Zeichner et al., 2016). However, despite efforts to make teacher education programs more equitable and diverse, many continue to underprepare preservice teachers to center social justice and meet the academic needs of culturally and racially diverse students (Mensah, 2021) and inequity and racism persist in teacher education (Kohli, 2022). Therefore, it remains crucial to investigate how preservice teachers in teacher education programs can gain experience in learning how to enact teaching that decenters whiteness, fosters criticality, fosters rigorous scientific learning, provides a context which values the epistemologies of diverse cultures, and supports students in working to change social inequities (Ladson-Billings, 2000; Trigos-Carrillo & Rogers, 2017).

The need for social justice teacher education is perhaps even more critical for preservice teachers of STEM subjects, as justice-centered discourses are often absent from science and mathematics classrooms and teacher education contexts (Rodriguez, 2015).

Science preservice teachers who make socially just science instruction the foundation of their classrooms adopt curriculum that is academically rigorous and relevant to students (Ladson-Billings, 2020), teach students about the historically racist and inequitable aspects of science practices and products (Morales-Doyle, 2017), and also teach that science is a critical tool in alleviating equity and social justice issues.

In this study, I utilized a multiple case study design to examine a science teacher educator and a cohort of preservice secondary science teachers' understandings and enactments of justice-centered science pedagogy (Morales-Doyle, 2017). Justice-centered science pedagogy engages students in academically rigorous learning based on social and environmental justice issues. The three domains of this framework are antiracist and equitable science education, social justice science issues, and youth as transformative intellectuals. Using semi-structured interviews, observations, and content analysis of their course website, data were gathered over the course of the yearlong program to understand the teacher educator and preservice teachers' opportunities to learn about justice-centered science pedagogy, as well as the ways that they were actually taking this work up. Results from this study demonstrate that the pandemic created limitations to the enactment of justice-centered science pedagogy, and that while preservice teachers reported focusing on academics, eliciting student ideas, framing students as producers of knowledge and culture, and prioritized building positive relationships with students, few reported utilizing social justice science issues in their science lessons. Implications from this study offer that explicit instruction and professional learning communities in both reform-based and justice-centered science practices can prepare preservice teachers to more fully enact justice-centered science teaching.

TABLE OF CONTENTS

LIST OF TABLES

Chapter I: Introduction

Attending to social justice concerns is crucial to improving educational outcomes in diverse and changing schools. Scholars note that teacher preparation is a critical part of addressing equity and justice in K-12 school settings (Goodwin & Darity, 2019; Kretchmar & Zeichner, 2016; Zeichner, 2016). In the United States, almost half of students in schools are students of color, yet the "teaching force continues to be overwhelmingly White, middle class, and monolingual native English speaking" (Cochran-Smith & Villegas, 2016, p. 445; Sleeter, 2017). In order to enhance learning and reduce inequality in increasingly diverse schools, Banks et al. (2015) argued that "teachers must be prepared to take into account the differences and academic needs of a wide range of students as they plan and teach" (p. 233). Culturally relevant pedagogy, supported by curriculum, activism, and advocacy was identified as critical to socially just teacher education. Such pedagogy, Chubback and Zemblylas (2016) argued, fosters academic excellence while also focusing on cultivating cultural competence, critical analysis, and activism.

However, despite efforts to make teacher education programs more equitable, many continue to underprepare preservice teachers to center social justice and meet the academic needs of culturally and racially diverse students (Mensah, 2021). Many teacher education programs have focused on diversifying their programs, but inequity and racism remain pervasive in teacher education (Kohli, 2022). To combat this, teacher educators must address their blind spots in justice and equity teacher education (Kitchen & Brown, 2022), as neglecting issues of social justice and instruction contributes to a school system that perpetuates inequity and teachers who are inadequately prepared to teach diverse students (Milner, 2006). If left unaddressed, these systems continue to benefit White people while

oppressing Black and other minoritized people (Philip & Benin, 2014); therefore, it is important that preservice teachers in teacher education programs gain experience in learning how to enact teaching that decenters whiteness, fosters discourse and criticality, provides a context which values the epistemologies of diverse cultures, and supports students in critiquing and working to change existing social inequities (Ladson-Billings, 2000; Trigos-Carrillo & Rogers, 2017).

The need for social justice teacher education is perhaps even more critical for teachers of STEM subjects, as justice-centered discourses are often absent from science and mathematics classroom and teacher education contexts (Rodriguez, 2015). Social justice in science teacher education is concerned with teaching and learning "science as a civil right, a moral obligation, a social responsibility, and an ethical choice" (Mensah, 2013, p. 320). This requires that teachers work to construct a social justice science teacher identity (Kaur, 2012). Constructing a social justice science teacher identity involves believing that every child has the right to learn and have equitable access to science, working to provide quality science learning opportunities to all students, and the commitment to creating learning opportunities that involve phenomena based on real social and environmental justice issues (Boylan & Woolsey, 2015).

Educators who make socially just science instruction the foundation of their classrooms adopt curriculum that is academically rigorous and relevant to students (Ladson-Billings, 2020), teach empowering content and liberating, student-centered pedagogies (North, 2009), teach students about the historically racist and inequitable aspects of science (Morales-Doyle, 2017), and also teach that science is a critical tool in alleviating equity and social justice issues. Science educators can raise students' awareness about environmental

and sociopolitical issues in science through the use of critical, community-based pedagogies (Buxton, 2010) and by building connections to students' lives, cultures, interests, and experiences (Paris & Alim, 2014). Thus, social justice science instruction requires teachers to identify and make inequality visible, plan instruction around authentic and community-based problems, give students a critical lens through which they may analyze and critique inequitable and racist systems, and teach ways that students can generate change and contribute to the creation of a more equitable society (Goodwin & Darity, 2019).

Because preservice teachers may not have developed this knowledge and orientation to social justice, it is important that teacher education programs work towards filling in this gap (Chen & Mensah, 2018; Land, 2018). Moreover, in the U.S., science education in public schools has been driven by *A Framework for K-12 Science Education* (National Research Council, 2012) and the *Next Generation Science Standards* (NGSS; NRC, 2013). However, in *A Framework for K-12 Science Education*, issues of "justice" are only referred to twice (Forsythe & Chan, 2021) and justice-centered issues and topics are largely absent from these standards (Rodriguez, 2015). Justice is not explicitly referred to in the standards; thus, for preservice teachers to become competent in and develop in this area, it is critical that they have support from their teacher education program in learning justice-centered pedagogies in their teaching of science.

Conceptual Framework Guiding Discussion

Because teaching in an equitable and socially just way is essential, many scholars have created practices and frameworks to support teachers in this work. One such framework, which will be used to frame this study, is Morales-Doyle's (2017) framework for justice-centered science pedagogy. Based on the seminal tenets of culturally relevant

pedagogy (Ladson-Billings, 1995) and Paulo Freire's critical consciousness (1972), socially just science instruction presents a way of engaging students in academically rigorous learning which is based on social and environmental justice issues. The three tenets of the framework include basing instruction on antiracist and equitable academic expectations, social justice science issues, and framing youth as transformative intellectuals.

In his case study, Morales-Doyle (2017) applied his framework to a secondary science classroom in which he was the instructor. He found that, when engaged in a science unit based on measuring soil lead levels in the local community, students were able to demonstrate high achievement and competence in the NGSS, work on real environmental justice issues in the community, and were positioned as agents of change by presenting their findings in a community forum. Morales-Doyle's application of this framework demonstrates that this justice-oriented teaching and learning can coexist with, and enhance, rigorous teaching and learning. One of Morales-Doyle's directions for future research was to prepare science preservice teachers to engage in this work with their students, supporting them in creating lessons and learning opportunities in which all three domains of social justice science teaching are present.

Reading Morales-Doyle's study caused me to question how this social justice stance and ability could be fostered. I was interested in the pedagogical approaches that teacher educators adopt to teach and reinforce a more justice-oriented approach to teaching science. Enacting teacher education that supports preservice teachers in becoming justice-oriented practitioners who are skilled in creating lessons based on social and environmental justice phenomena, framing students as transformative intellectuals who are empowered to enact change, and maintaining antiracist and equitable academic expectations is complex work

(Ell et al., 2017). While teacher educators may be very experienced and highly skilled, teaching in a socially-just way may require a different set of skills and pedagogical knowledge that needs to be learned and cultivated (Goodwin et al., 2014; Loughran, 2014; Rowan et al., 2019). If teacher educators are to be effective at creating justice-oriented learning opportunities for preservice teachers, learning and support are necessary for teacher educators, and research must be conducted to understand their practices and what more they need to know to engage in this work. Studying how they learn and opportunities that they have to learn are necessary in order for teacher education programs to plan impactful professional development and other learning opportunities that most effectively support teacher educators and the preservice teachers who they work with (Kincheloe, 2011). By studying how teacher educators enact this work, how they are supported by their institutions, and how preservice teachers actually take up this work, teacher education programs may learn how to create professional learning that fosters teacher educators' justice-centered teaching, which can then be learned and integrated by their preservice teachers for the benefit their students.

Overview of Dissertation Study

In this qualitative study, I investigated how socially just science instruction was taught to a cohort of preservice secondary science teachers, and what they ultimately learned about justice-oriented science instruction. I examined how one teacher educator provided justice-centered instruction, learning resources, and support to a cohort of nine secondary science preservice teachers at a large public university in California. Using Morales-Doyle's framework, I focused on how the teacher educator taught the preservice teachers about social and environmental justice science issues, and in turn, how they might then teach that

material and provide justice-centered learning opportunities to their students. I also examined how preservice teachers were prepared for facilitating antiracist and equitable science education in their classrooms, and what they learned about positioning their students as transformative intellectuals.

In their one-year teacher education program, the preservice teachers earned a master's degree in education in addition to a single-subject teaching credential. The preservice teachers took a series of university courses designed to support them in developing their pedagogical content knowledge and abilities to provide equitable and ambitious science instruction.

In order to examine some topics that they were learning about in their teacher education program, I decided to observe one of their courses. I observed their professional issues course because it followed a seminar-style format and covered a variety of professional topics that were important to developing skills that are essential to becoming an effective and equitable teacher. I also decided to observe this course because it was taught by the teacher educator that I also interviewed and observed for this study. During my four observations of these class sessions, I investigated how the three domains of justice-centered science teaching were taught and discussed during this course - how these topics were planned for by the instructor and how they came up naturally during class discussions.

I also observed feedback conversations in order to know how the teacher educator supported the preservice teachers in implementing justice-centered science teaching, what went well in that domain, and what opportunities for growth were present. Through the interviews, I was able to learn about both the preservice teachers and teacher educator experiences. These observations and interviews worked together to demonstrate justice-

centered science topics and instruction that the teacher educator implemented, topics that were discussed and grappled with, the teacher educator's perspectives on her work with the preservice teachers, and ultimately what the preservice teachers learned about justice-centered science teaching.

Altogether, I collected four types of data. First, I used interview data; I interviewed preservice teachers to understand what they learned and how they developed as justice-oriented teachers. I also conducted several interviews with Dr. Lake in order to understand her aims, and what she thought they could have improved on in their work and interactions with the preservice teachers. I also conducted a content analysis of the professional issues course website in order to understand resources and learning opportunities that were facilitated to support the preservice teachers. Dr. Lake taught this course and all nine secondary science preservice teachers were enrolled in this course, which was a requirement of their teacher education program curriculum. Finally, I observed feedback conversations between Dr. Lake and three of the preservice teachers; these conversations were part of a protocol in which the teacher educator would observe the preservice teacher teaching a lesson, and then facilitate a conversation with them afterwards to discuss strengths of their teaching, as well as opportunities for growth. These conversations were centered around targeting students' academic needs and making content accessible in order for students to succeed academically, while prioritizing an equity and justice lens through which they interpreted and reflected on their practices.

It is important to note the context in which this study took place. When this study was conducted, there had been increased public attention to pervasive police violence afflicted upon Black people in the United States. The death of George Floyd at the hands of

a police officer re-catalyzed the Black Lives Matter movement and motivated protests against racial injustice. As a result of the death of George Floyd and numerous racist acts of violence by law enforcement, there was an increased urgency in addressing racism; issues of racial justice were more publicly brought to the forefront (Nguyen et al., 2020). Many institutions of higher education, including the university in which this study took place, took action to provide antiracist and transformative justice education learning opportunities to students and faculty. This was done with the intention to illuminate systemic racism and teach ways to enact ongoing personal and communal work in order to contribute to creating a more just society.

Furthermore, this study took place in the midst of the Covid-19 pandemic. The data from this study were gathered during the 2020-2021 academic year, when many U.S. schools resorted to remote and/or hybrid instruction. Not only did this completely alter the way that teaching and learning were conducted, it highlighted racial and socioeconomic inequities, and emphasized the role schools and teachers need to take in helping to eradicate these inequities.

Due to the pandemic and subsequent social distancing guidelines, most teacher education program (TEP) coursework and field placement were conducted in a remote format, making critical parts of teaching and teacher education (i.e., relationship-building, engaging students, eliciting student participation, etc.) more complex and difficult to enact successfully. In fact, because the emergency shift to an online-instructional format was new to everyone, there were few robust examples of how to teach in this way. While this proved difficult for experienced teachers and teacher educators (Cutri et al., 2020), being completely new to the profession and learning how to teach in this context was particularly

challenging for preservice teachers. Interviews conducted with the preservice teachers identify difficulties that they faced in regards to engaging students and eliciting student participation (a prerequisite for the activities associated with justice-centered science teaching), and their strategies for adapting and learning how to work in this particular, difficult context.

This study was conducted with the intent of discovering not what a "perfect" justice-centered science education program could look like, but instead with the intent of discovering the successes and challenges of doing this work, from the perspectives of people who are taking ongoing steps to do it, learn, and reflect on their practices. Understanding the thought processes around justice and equity teaching, and the ways that they may have grappled with this is important for informing the ways that teacher education programs can better support both preservice teachers and teacher educators.

Rationale for Dissertation

This study is important because it addresses gaps in the knowledge base on justice-centered science teacher preparation. First, it reveals how a justice-centered science teacher education course could be structured. This study explores various resources, discussion topics, and performance tasks that may support preservice teachers in learning how to enact justice-centered science practices. This study shows what course material could be covered, how it could be organized, and how preservice teachers could discuss these topics.

Moreover, this study also addresses a gap in critical, justice-oriented feedback conversations (Land, 2018; Wetzel et al., 2017). The observation and feedback protocol is a critical part of becoming an effective teacher (Copland, 2010; Sheridan & Young, 2017). These conversations can be difficult to navigate, and it may be difficult to balance giving

directive feedback while facilitating a space for preservice teachers to reflect on their teaching in an agentic way. By analyzing feedback conversations between the teacher educator and three of the preservice teachers, I demonstrated which topics and themes emerged, and the ways that they were discussed between the teacher educator and preservice teachers. Better understanding of which topics were raised, how questions were posed to extend preservice teachers' thinking, and what areas the preservice teachers might be grappling with provide valuable information about issues to consider when planning for and facilitating feedback conversations.

This study also addresses gaps in understanding the ways that teacher educators make sense of their practice, especially in regards to teaching preservice teachers about social justice. Considering the complexity of the work of teacher education, teacher educators' practices are under researched (Kincheloe, 2012). Furthermore, there are often a lack of supports for teacher educators, and they often have to navigate the transition from teacher to teacher educator with little professional development or explicit guidance on their role (Goodwin & Kosnik, 2013). This study will provide an analysis of a teacher educator's practice, the issues that they grappled with, and their strategies for supporting preservice teachers.

Moreover, this study will address preservice teacher learning within the situated context of remote instruction. Preservice teachers typically engage in in-person classes; however, their courses were conducted entirely online due to the pandemic. This different context affected the interactions and discussions between preservice teachers and their teacher educator, the questions they had, and how they made sense of justice-centered science. Furthermore, the unique context impacted preservice teacher concerns, ideas, and

ways of putting their teacher education coursework knowledge into practice. Pressing issues regarding vaccines, health and safety, getting students to turn their cameras on, and other complex topics would have likely been nonexistent in years prior. However, these were topics that came up the year of this study and added to the complexity of learning how to teach. While this study identifies difficulties with preservice teachers' enactment of socially-just science instruction, it also reveals their strategies for overcoming these difficulties and making science accessible and comprehensible, even through a remote instruction format. Therefore, this study contributes to revealing the personal struggles and successes that preservice teachers encountered with learning how to teach during this time, and may add to literature on teacher resilience. Of course, teacher resilience and burnout are systemic issues that can not and should not be solved by simply having "grit" and pushing themselves to persevere in difficult situations (Gorski, 2016). However, understanding teachers' perspectives on the difficulties they experienced during online instruction may help teacher education programs and administrators to build support systems for them. By observing their professional issues course, I was able to understand these diverse problems of practice. I was also able to observe how preservice teachers worked together and used each other as resources to learn, thus enabling them to strategize solutions for very specific, unique problems of practice in a particularly difficult teacher education context.

Research Questions

The following three research questions guided this study:

RQ 1: What efforts did the teacher educator put forth to teach preservice teachers about the domains of justice-centered science pedagogy?

RQ 2: What were the teacher educator's understandings and experiences of justice-centered science pedagogy?

RQ 3: To what extent did the preservice teachers report enacting the domains of justice-centered science pedagogy? What were their understandings and experiences of teaching in justice-centered ways?

Organization of Dissertation

This study is organized into several parts. First, I present the literature review and conceptual framework that situate the study within existing research. I then present the methods section. This is followed by three distinct findings sets. The first findings set presents what was taught to the preservice teachers, and draws from data on observations of their professional issues course and content analysis of the course website. Data from the feedback conversations are presented here as well. The second findings set presents data from interviews with the Dr. Lake in which she describes her experiences, beliefs, and efforts to enact justice-oriented teacher education. The third findings set presents data from interviews with the preservice teachers; these interviews highlight their experiences of learning how to teach, as well as their enactment of aspects of justice-centered science pedagogy. This study contributes to the knowledge base on science teacher preparation, in particular, the learning experiences and opportunities that can be enacted to support preservice teachers in becoming justice-centered science educators.

Chapter II. Conceptual Framework and Literature Review

Conceptual Framework

In this section, I will introduce the justice-centered science pedagogy framework and explain the ways in which this framework acts as a lens for this data gathered in this study. I will also elaborate on the three domains of justice-centered science pedagogy: (a) antiracist and equitable science education (b) social justice science issues, and (c) positioning youth as transformative intellectuals.

Justice-Centered Science Pedagogy

This study draws from the work of Morales-Doyle (2017) on the processes of using pedagogical approaches to teaching science in equitable and reform-based ways. This framework highlights that science can be used to explore local environmental justice-related science issues, facilitate antiracist and equitable science education, and position students as competent agents of change whom are capable of disseminating their scientific findings, equipped with the knowledge that they can produce a positive effect on their community. Justice-centered science pedagogy aims to support social transformation through science education, and is built on the traditions of critical pedagogy and culturally relevant pedagogy. The justice-centered science pedagogy framework is rooted in two seminal educational frameworks; it is based on Paulo Freire's concept of *conscientization*, as well as Gloria Ladson-Billings' conceptualization of culturally responsive pedagogy.

Morales-Doyle's framework is informed by the work of education activist Paulo Freire. Freire (1970) argued that to create social change, people must have *conscientization*, or critical consciousness. Freire defined critical consciousness as a state in which people are aware of social inequality, understand their positionality within that inequality, and take

action against societal oppression. He theorized that, in schools, critical consciousness is developed through the facilitation of "problem-posing", where students come to their own understanding of issues of injustice through discussion, questioning, grappling with complex topics in community, and formulating solutions. Critical consciousness helps students understand that what they are learning is not only useful to them, but can also be used to create societal changes.

Morales-Doyle's framework is also based largely on Ladson-Billings' (1995) seminal work on culturally relevant pedagogy. Culturally relevant pedagogy empowers students intellectually, socially, emotionally, and politically by making students' cultures, experiences, and interests the foundation of classroom instruction and practices. Culturally relevant pedagogy rests on three components: academic success, cultural competence, and facilitating the development of a critical consciousness in students.

Culturally relevant pedagogy is centered on teachers' understanding of their own and students' cultures, and an ability to connect to their students through this understanding (Gay, 2002; Ladson-Billings, 1995; Villegas & Lucas, 2002). Strategies to foster this connection may include bringing in artifacts and texts that reflect students' interests, and using real world examples and problems during instruction that connect to students' identities (Bouillion & Gomez, 2001). Additionally, teachers can notice and respond to variability in how students demonstrate knowledge, allowing for student choice and alternative and varied formative assessments. Culturally responsive teachers can also position students as competent leaders and provide opportunities for students to coteach lessons and incorporate learning materials and mediums that are relevant to them (Emdin, 2020).

Another domain of culturally relevant pedagogy is academic achievement. While both Freire and Ladson-Billings' frameworks overlap, Morales-Doyle utilized both due to Ladson-Billings' explicit focus on academic achievement. While Freire's framework contained opportunities to facilitate higher-order thinking and sensemaking, it is not explicit about having an emphasis on rigor and high academic expectations. This emphasis on academics entails that teachers must plan for instruction around domain-specific competencies and facilitate opportunities for students to engage in collaborative sensemaking and engage in problem solving around those standards. By doing so, teachers can improve their students' abilities to apply, analyze, synthesize, and evaluate information in order to excel in school and life. Rigorous science instruction equips students with the knowledge, skills, and practices of a scientist, which then supports students in pursuing future academic and career interests in the sciences.

The development of cultural competence is also central to Ladson-Billings' framework; this is the ability to help students grow in the knowledge and understanding of their own culture while acquiring skills in other cultures, typically mainstream culture (which may help students become socially, politically, and economically competitive). Teachers who integrate cultural competence plan lessons around students' cultures in an intentional, asset-based, and meaningful way, often eliciting students' particular interests and input prior to planning. This lies in contrast to "multicultural" weeks or units on "heroes and holidays", in which teachers tend to keep academic content on diverse cultures distinct and separate from mainstream curriculum (Banks, 2013).

While building his framework on the concepts of critical consciousness, academic expectations, and cultural competence, Morales-Doyle's framework expands on the work of

Ladson-Billings and Freire by explicitly using social justice issues related to science as the phenomena, and the framework is designed for use by science teachers and the collaborators (i.e., community organizers, students' family members) who facilitate learning opportunities for students with them. The three components of this framework include antiracist and equitable science education, social justice science issues, and positioning youth as transformative intellectuals. I will describe each of these components in further detail below.

Antiracist and Equitable Science Education. One of the tenets of justice-centered science pedagogy is its explicit attention to the importance of providing students with an antiracist and equitable science education. This requires that teachers teach rigorous science content while also providing support to students in accessing the content and participating in classroom discourse (which is conducive to making sense of the content). Morales-Doyle (2017) acknowledged that academic standards can be problematic, which aligns with other researchers who have found that the NGSS have fallen short in regards to the lack of representation in their development (Rodrigues, 2015) and connection-building with local communities (Lee, 2014). While the NGSS has these limitations, Morales-Doyle designated alignment with the NGSS (along with AP standards, which align with the NGSS science and engineering practices) as the criteria for meeting equitable science education, as they represent the forms of knowledge that are valued by educational institutions and are thus prerequisites for advancing in further educational or career opportunities related to science. This is further substantiated by an account from high school student and co-author of a paper with Morales-Doyle (et al., 2022). In this paper, high schooler Elani Clay discussed what she believed were the two greatest challenges for students in science classrooms: (1) students' experiences of apathy about science and (2) access to rigorous science learning

opportunities for students who are very interested in science, or want to pursue science as a career and/or in higher education. She discussed the importance of teaching relevant, social justice-oriented science content in order to combat student apathy, while emphasizing that teachers still need to also teach content at a high standard, which will open educational and career pathways for students:

> But another challenge is also trying not to go away from the science. I'm going to be an aerospace engineer and so I wouldn't want to just talk about politics in my science class, I want to learn the science. So, for some students, like my friend, the challenge is apathy and for others, like me, the challenge is not straying too far from the science (Morales-Doyle et al., 2022, p. 232).

Clay's quote highlights, from a student's perspective, the need to teach canonical science content and adhere to state standards that students need to know, and is a major reason for Morales-Doyle's utilizing the NGSS performance expectations and practices as a primary indicator of academic expectations for justice-centered science pedagogy. While the NGSS has room for improvement in terms of addressing equity and diversity, the NGSS has made substantial advances over previous versions of science education standards. One major advance is that the NGSS provides student performance expectations that address what scientists know, what they do, and how they think (Devitt, 2022). An aim of the NGSS is to make school science education more aligned with the professional activities and ways of thinking of actual scientists and engineers, which can support students like Elani Clay in achieving their career aspirations in science.

Social Justice Science Issues. Justice-centered science pedagogy entails that real social justice science issues (SJSI) be the central themes in science curriculum (Morales-

Doyle, 2017). SJSI provides a starting point for students to explore the insights of critical social issues and science, while also providing opportunities to question and consider the aspects of culture, race, and diverse epistemologies.

In the beginning of a justice-centered science project, students and teachers work together to define the SJSI. In order for this to be productive and to activate students' schemas, teachers need to foreground students' knowledge of the issue and provide prompts and opportunities for students to consider the problem in various ways. Also, as pressing as students' and teachers' SJSI concerns may be, it is also important for students to not come to see their community from a deficit perspective, as there is a risk of participatory research focusing more on deficits and harm caused by oppressive systems (Tuck, 2009). Therefore, an important component of SJSI is to highlight the assets and agency of students and their communities, demonstrating that they can work toward change and *also* view their community from an asset perspective. Moreover, SJSI instruction highlights the systemic issues at the root of the problem, illuminating the larger factors that have created the problem. By foregrounding student knowledge of their community and then placing what they observed within the larger context of environmental racism and struggles for environmental justice, the SJSI is defined in a way that is ambitious, productive, and hopeful.

Youth as Transformative Intellectuals. In a justice-centered science curriculum, students should be given opportunities to engage in youth participatory science; this entails that students define the social justice science issue, apply a scientific lens, plan and conduct an investigation, analyze data and assess student learning, and reflect, disseminate findings, and take action. Moreover, criteria for assessment and demonstrating competence must have

a purpose beyond simply showing their teacher what they learned. Furthermore, with students' newly acquired knowledge and experience in sharing what they have learned about a justice-centered science phenomena, they also have the heightened ability, encouragement, and agency to act on disseminating their findings. Therefore, justice-oriented teachers should try to facilitate ways for students to share what they have learned about SJSI to the community, or even share what they learned with family, siblings, extended family, or other students. While this could entail presenting one's findings at a community organization's meeting, or in various public forums, Morales-Doyle and Frausto (2021) shared that this could look like asking students to write a blog post, post about their social justice science-related findings on social media, create a presentation for elementary-aged students, and more. By creating these opportunities and using them as a means of assessment, teachers can have a better understanding of what their students have learned in a way that extends beyond standardized, rote understandings, and students can more authentically consider the impact of science and the relevance of their findings to their lives and communities.

I want to make it clear that I am using the justice-centered science pedagogy framework as a lens for this study; it is utilized in order to understand how and to what extent the tenants of justice-centered science pedagogy show up in a justice-minded teacher educator's pedagogy, rather than evaluating a teacher educator that intentionally utilizes justice centered science pedagogy. Before beginning my research with the teacher educator, I had spoken with her and learned that she prioritized making science relevant to students, and emphasized the importance of anchoring science content in social justice and/or local phenomena. She also heavily focused on eliciting all students' ideas and maintaining high academic expectations, which are central to justice-centered science pedagogy; however, the

teacher educator was not explicitly teaching or utilizing justice-centered science pedagogy. Thus, rather than assuming an evaluative stance, my intention was to examine how the tenets of justice centered science pedagogy emerged given that the teacher educator emphasized several principles of justice-centered science pedagogy.

Moreover, while the teacher educator did not set out to teach justice-centered science pedagogy, she based much of her pedagogy on a framework for science teaching called ambitious science teaching, which has some overlap with justice-centered science teaching. Ambitious science teaching is a framework for equitable and rigorous science teaching, and aims to engage and elicit the ideas of students of all backgrounds. Teachers that utilize ambitious science teaching engage in the following practices: plan for engagement with big ideas; elicit student thinking; support changes in students' thinking; and draw together evidence-based explanations (Thompson et al., 2013). Ambitious science teaching practices focus on supporting students of diverse backgrounds, using all students' ideas as resources for learning, and encouraging student discourse. Like justice-centered science pedagogy, ambitious science teaching places emphasis on high academic expectations and actively engaging with relevant science content, rather than following a lab procedure, memorizing terms for a test, or listening passively to a lecture. Ambitious science teaching is also similar to justice-centered science pedagogy in its emphasis on framing students as knowledgeable and using student ideas as resources for class discussion and learning. In both frameworks, students are encouraged to share out and collaborate to make sense of science content. Although there are some similarities, ambitious science teaching is not explicitly focused on social and environmental justice, and does not call for students to necessarily to positioned as agents of change. Therefore, given that I knew that the teacher educator had a social

justice orientation that ambitious science teaching did not make explicit in their framework, I was interested in understanding how the domains of justice-centered science teaching emerged in her pedagogy, and what the preservice teachers ultimately learned.

Situated Learning

This study takes into account how preservice teachers learned amidst the unforeseen context of the Covid-19 pandemic, which shifted all teacher education program activity and interactions to a remote instruction format. Therefore, it is beneficial to also frame the teacher educator and preservice teachers' experiences, knowledge of, and practices related to justice-centered science pedagogy with situated learning theory. Teacher learning is mediated by social interaction with students, peers, cooperating teachers, and professors, and is situated in the contexts of their placement classroom, university courses, and community (Grossman et al., 2009). To develop as teachers, preservice teachers must have authentic interaction within the contexts of learning opportunities facilitated by their teacher education programs, which allows them to deepen their pedagogical understandings, knowledge, and skills.

In situated learning theory, learning is experienced and mediated through a community of practice. Within a community of practice, group members share and develop practices, learn from their interactions with other participants, and gain opportunities to develop in their practice (Lave & Wenger, 1991). Therefore, learning is situated within a specific context and occurs with other participants working toward a common goal. This study examines a particular context which contrasted greatly with the ways in which preservice teachers typically learn how to teach, and this impacted both how the teacher educator taught and the ways in which the preservice teachers learned.

Literature Review

Because this study investigates learning how to teach reform-based secondary science, I broadly focus first on the ways in which teachers learn how to teach equitably and provide rigorous sense making opportunities for students in science classrooms. Next, I focus specifically on teacher preparation to teach secondary science courses, utilizing literature centered on preservice teachers' field placement experiences as well as experiences in teacher education courses. I then examine literature on teaching justice-centered science, and how teachers are prepared to enact this work. I also examine literature on teacher educators' pedagogies, their learning goals for secondary science preservice teachers, and the learning opportunities and resources that they use to support the preservice teachers in working toward those goals. Furthermore, the data for this study were collected during the Covid-19 pandemic, when social distancing guidelines caused K-12 and university classes to be moved online for at least seven months. This unforeseen emergency shift contributed to the way PSTs learned and the way the teacher educator instructed them, so this section also includes literature on learning how to teach during a pandemic.

Learning to Teach Reform-Based Secondary Science Education

Learning to teach reform-based science using equitable instructional strategies is complex, challenging, and requires frequent practice and rich learning opportunities (Capps & Crawford, 2013). *A Framework for K-12 Science Education* [*Framework*] (National Research Council [NRC], 2012) and the *Next Generation Science Standards* [*NGSS*] (NGSS Lead States, 2013) have been developed with the goal of changing the way science is taught in the U.S. Reform-based science instruction is centered on supporting students' understanding of core ideas and engagement in scientific practices (Reiser, 2013). Students

are encouraged to collaborate with one another and their teacher to learn science by "doing science" (Furtak, 2017) rather than memorizing formulas or engaging in decontextualized lab activities that merely require students to follow a series of steps. To frame science learning as authentic, relevant, and meaningful, it is essential to foster science classrooms that look and act like communities in professional science settings and make students' deep and complex content knowledge an aim of science instruction (NRC, 2012).

This shift to facilitating meaningful and engaging sensemaking activities challenges more antiquated notions of science teaching as "the delivery of knowledge for students to absorb" (Loughran, 2014, p. 811). Aligning with the ideas of constructivism, reform-based science teaching calls for teachers to develop a more dialogic disposition that encourages discourse and sensemaking, assuming the role of facilitator rather than a transmitter of information. Reform-based science teaching also requires partnerships with students in order to generate and investigate questions rather than relying on the teacher's perspective (Furtak & Penuel, 2018). This may require a shift in teachers' beliefs and visions of effective science teaching, competence in pedagogical content knowledge, and ability to plan and enact relevant labs and discussion (Banilower et al., 2018).

These ways of teaching and learning guided the development of the Next Generation Science Standards for K-12 (NGSS Lead States, 2013), which included understanding of how students learn science, the integration of knowledge and practices, and provides a framework for teachers to ensure that all students have equitable opportunities to engage in science learning (NRC, 2012). However, teachers may have varying competencies in enacting reform-based science teaching; research demonstrates that teachers tend to overemphasize student questioning and participating in investigations, but underemphasize

students' reasoning and providing explanations based on evidence (Forbes et al., 2013). Beyer and Davis (2008) posited that science teachers may not view (or be aware of) providing explanations as an important part of science.

In reform-based science lessons, models are central to scientific practice. Students create initial models of a phenomenon and then identify questions (Windschitl et al., 2008). Modeling thus creates a way for students to leverage their prior experiences and understandings as they attempt to explain what they observe, and they can use additional observations and data to revise their models (Windschitl et al., 2008). Teachers encourage students to construct explanations using evidence they collected and interpreted. Ultimately, students will revise their models so that they accurately and fully explain the phenomenon (Berland et al., 2016).

Eliciting student reasoning and facilitating student discourse is central to reform-based science learning, as this enables students to engage in problem solving, hear others' ideas, and develop their conceptual understanding of the learning material (Michaels & O'Connor, 2012). For both issues of sensemaking and equity, the ability to orchestrate discourse is a defining characteristic of effective science teaching (Michaels et al., 2008) and structured opportunities to talk in classrooms supports student learning in a variety of ways (Resnick, 2017). Student talk has been used for sensemaking about science concepts, providing claims and evidence, and positioning young learners as competent (Brown & Ryoo, 2008). The role of who is empowered to talk and the type of communication that is accepted as a part of science sensemaking is also important for creating equitable learning opportunities. The ways in which teachers engage students, orienting students' to each other's thinking, encouraging students to explain their reasoning, and allowing them to

comment on their understanding, can lead to deeper engagement in the material (Duschl & Duncan, 2009). Effective classroom discourse promotes students' funds of knowledge as a means for making sense of material activity in the classroom, helping better shape learners' identities as someone who does science (Gonzalez et al., 2005).

Therefore, teacher facilitation of modeling and classroom discourse is central to reform-based science teaching, as high quality facilitation creates more productive discussions and improves the quality of student contributions and understanding. The openness of teacher questions is key (Lehesvuori, 2018; Martin & Hand, 2009; Oliveira 2010); teachers who ask students to explain their reasoning and give wait time to allow student thinking and elaboration (Lehesvuori et al., 2019; Rowe, 1974) elicit higher quality classroom discourse, which leads to more authentic understandings (Mortimer & Scott, 2003). Once students provide ideas and elaborated responses, the teacher can then facilitate discussion by asking clarifying questions, requesting evidence for claims and inviting students to connect their responses to others' responses. The utterances and actions teachers use to facilitate productive talk are referred to as talk moves (Michaels & O'Connor, 2012). Science teachers are therefore tasked with supporting students in developing discursive interaction that is necessary to rigorously engage in scientific sensemaking (Osborne et al., 2016). The idealized form of this instructional practice further addresses issues of equity within the classroom in multiple ways. Students' ideas are central to meaning making and thus, even incomplete understandings are treated as resources to build toward collective understanding. Furthermore, these sensemaking discussions can potentially allow students to express their ideas in ways that reflect their cultural values and ways of knowing (Windschitl et al., 2018).

However, facilitating sensemaking and asking open-ended, inquiry-based questions is often difficult for teachers because they need to be able to respond quickly and appropriately when they receive student responses (Aziza, 2018). Teachers also need to monitor the responses to their questions, orient students to each other's thinking, and orchestrate discussions to serve the instructional goals, understanding when to pivot and redirect students' thinking or extend their ideas (Smith & Hackling, 2016). Because facilitating high-quality discourse is central to student learning, teachers should be provided with professional development or other opportunities to develop these dialogic skills (Jacques et al., 2020).

Opportunities to learn how to teach reform-based science can include both formal and informal professional learning. The professional learning opportunities consist of formal programs that include specifically designed induction programs, professional development programs, and scheduled opportunities to work with other teachers or along with assigned mentor teachers (National Academies of Sciences, Engineering, and Medicine [NASEM], 2015). Informal learning opportunities are less constrained, have social interactions, connect to a larger community, and are often conceptually oriented (Rogoff et al., 2016). These opportunities can occur during planning sessions, discussions in the hallway, observations of instruction, or even with conversations among colleagues (Desimone et al., 2014; Hopkins & Spillane, 2014). They can also be in science spaces that are outside of schools, including zoos, museums, or natural areas (Harlow, 2012; National Research Council, 2009). With frequent opportunities to learn, science teachers can challenge their beliefs about science and build their content knowledge; this includes building an understanding of how students learn concepts, becoming aware of difficulties students have during instruction, and expanding

their understanding of quality instruction. They can also build their abilities to enact components of science instruction that allow students to engage in and experience aspects of science. The creates science instruction that involves students generating and pursuing scientifically oriented questions, collecting and analyzing data, developing and revising models, making explanations, and disseminating their findings (NGSS Lead States, 2013).

Preservice Teachers Learning to Teach Reform-Based Science

Frequent and rich opportunities to learn effective science teaching are also critical for secondary science teachers whom are in their preservice period. In addition to needing to develop the content knowledge and abilities to facilitate ambitious instruction, they often possess beliefs about science that have been formed based on their own experiences of observing and learning science as a student (Lortie, 1979), and some of these beliefs may contradict more explorative and reform-based ways of teaching science. For example, Kang (2008) found that the majority of preservice teachers in her study described science knowledge as students simply receiving knowledge, as opposed to describing science as inquiry. These beliefs about the learning and nature of science can limit preservice teachers' abilities to teach science as a collaborative, relevant, inquiry-based subject. Science preservice teachers enter teacher education programs with diverse abilities, experiences, and conceptions of teaching. Some preservice teachers may possess an emerging knowledge of teaching science as inquiry and then be able to enact effective, reform-based teaching (Crawford & Lunetta, 2002; Windschitl, 2003). However, other preservice teachers may find it difficult to enact teaching science as inquiry in their classrooms (McGinnis et al., 2004). Teaching reform-based science is challenging, especially for preservice teachers with emerging knowledge and skills (Anderson, 2002; Newman et al., 2004; Windschitl, 2003).

In a study on exploring preservice teachers' opportunities to learn, Cohen and Berlin (2020) found that preservice teachers had more opportunities to learn reform-based pedagogy by practicing how they will teach (i.e., microteaching) instead of reading about or discussing classroom instruction. Preservice teachers also benefit from a setting in which they can reflect on their teaching and identify next steps to improve some facet of their practice; this is often facilitated through conversations with their cooperating teacher and/or university supervisor (Karlstrom & Hamza, 2019).

Preservice teachers gain experience and practice in learning to implement reform-based instruction prior to teaching in their own classroom through their practicum experience, as well as their university coursework. In addition to practicing, the opportunity to apply what they learned in their courses with actual students is facilitated by the field placement experience, which is integral to teacher education programs (Vick, 2006). In teacher education programs, the practicum serves as a practical, immersive experience which attempts to connect teacher education coursework with the realities of classroom teaching (Allen & Wright, 2014). Preservice teachers need experiences that engage them in active learning that builds their knowledge, understanding, and ability to teach science, and the practicum provides this opportunity (Sahin-Taskin, 2018). Additionally, a study by Cofré et al. (2014) found that preservice teachers need instruction and practice in the science content that they will be expected to teach. Learning to teach also involves the development of instructional strategies or practices that promote student learning. For preservice teachers, this involves establishing a beginning repertoire (Feiman-Nemser, 2001; Hammerness et al., 2005). Feiman-Nemser (2001) described a beginning repertoire as a limited range of approaches to curriculum, instruction, and assessment. Similarly, Hammerness et al. (2005)

described a beginning repertoire as various instructional strategies to promote learning that range from day-to-day strategies like explaining concepts or leading class discussions to broader strategies like designing and carrying out lesson plans that build understanding or developing and implementing assessments. Feiman-Nemser (2008) referred to this as learning to act like a teacher with a repertoire of skills, strategies, and routines as well as professional judgement. Competence in teaching science is best attained by direct experience with teaching and interacting with learners, combined with opportunities to reflect on their teaching and problems of practice; therefore, field placement experiences are viewed as an essential context for preservice teachers to learn about the teaching of science and develop practical teaching skills that support student learning (Koc, 2012; Tobin, 1993).

Although field placement experiences can vary in terms of activities and duration, ultimately, these experiences consist of a period of observation, modeling, teaching, reflection, and feedback conversations with the supervision of a cooperating teacher (Fazio & Volante, 2011). Because they work so closely and provide various forms of support to preservice teachers, cooperating teachers have often been cited as the greatest influence on preservice teacher learning (Murray & Male, 2005; Roberts, 2000; Weiss & Weiss, 2001). Cooperating teachers provide preservice teachers with feedback (Broad & Tessaro, 2010; Clarke, 2006), ask pedagogical questions and provide an environment in which preservice teachers can reflect on their practice (Stegman, 2007; Zeichner & Liston, 1987), and mediate the multitude of teaching activities and help preservice teachers navigate their various responsibilities (Fairbanks et al., 2000; Wang, 2001). Working in a classroom setting and

learning from a cooperating teacher greatly shapes preservice teachers' abilities to effectively enact reform-based science instruction.

The school culture at preservice teachers' field placements also influences preservice teachers' development of reform-based science instruction skills. A study of five preservice science and mathematics teachers revealed that an important influence on their abilities to enact reformed-based instruction relates to their perceptions of a supportive or a non-supportive school culture that is facilitated by the principal, students, parents, and other personnel (McGinnis et al., 2004).

Working in conjunction with practicum experiences, coursework in teacher education is critical to building one's teaching skills. Creating carefully constructed practicum experiences with university teacher education coursework has been highlighted as one of the most powerful and effective ways of supporting preservice teacher learning (Darling-Hammond, 2006). Teacher education coursework offers preservice teachers the opportunity to learn about teaching and learning theories as related to science, and also gives them the opportunity to learn about best practices in designing meaningful learning opportunities for students. In addition to providing opportunities to learn theory and practice, teacher education coursework is essential in transforming preservice teachers' conceptions of science; if preservice teachers enter their teacher education program with conceptions of science learning as a rote activity, teacher education coursework may help change their views of science instruction as involving a more relevant, inquiry-based, constructivist approach (Tsai, 2006). Furthermore, preservice teachers who are able to demonstrate more sophisticated, reform-based science instruction often enact practices which they learned about in their teacher education methods coursework (Kang,

2008). Teacher education courses provide a theoretical base, a setting to discuss pedagogy, and some opportunities to practice for novice teachers, while practicum experiences provide them with frequent opportunities to practice and apply what they have learned. Both experiences work together to greatly support PSTs in being able to effectively teach science.

Learning How to Teach Science in Justice-Centered Ways

A justice-centered approach to teaching science addresses inequity in science education as one component of oppression by challenging systemic issues such as white supremacy and capitalism. Justice-centered science pedagogy encompasses the development of critical academic skills that prepare students to make change (Pulido et al., 2013). Conceptualized by Morales-Doyle (2017), the criteria that culminate to justice-centered science pedagogy include (a) equitable academic expectations, (b) social justice science issues, and (c) students as producers of knowledge and culture. To work toward a more justice-oriented classroom, it is essential that science teachers deeply understand their students' cultures, local communities, and possess the ability to plan problem-posing instruction and facilitate classroom discourse that is equitable and encourages all students to share their ideas around scientific concepts, which sets the foundation for them to then share their scientific ideas with others (Finkel, 2018).

Students become more able to share their scientific ideas when teachers adopt an equity stance and put forth effort to elicit diverse ideas from a wide range of students. Bianchini et al. (2015) investigated how teachers could be supported in developing an equity stance, and explored the effect of professional development that was focused on models of facilitating science and mathematics teachers' talking about equity in meaningful ways.

Bianchini et al. found that various factors limited teachers' development toward an equity focus, including the teachers' beliefs that they were deeply knowledgeable in equitable instructional practices, their prior knowledge about professional development, and their hesitation to examine their own or peers' teaching practices. The authors advocated for challenging teachers in distinguishing between the instruction being modeled and the ways that they plan and deliver instruction in practice.

Situating science education in the community has been discussed by several scholars. In a study on community-centered maker programs for secondary science students, Calabrese-Barton and Tan (2018) found that supporting youth in co-making in a community context situated knowledge production within local contexts in decolonizing ways, disrupting power dynamics among youth, adults, and the community. Gray et al. (2020) examined associations between the communal learning opportunities afforded to Black and Latinx middle school STEM students, and their engagement patterns during STEM activities. Students were provided with opportunities to rate their engagement during scholastic activities. Gray and colleagues found that students reported higher levels of engagement on the weeks when students rated the activities as higher in communal science activities. Archer et al. (2020) found that situating science instruction in informal community settings (i.e., zoos, STEM clubs for girls) supported equitable learning outcomes and disrupted power dynamics, positioning students as competent and agentic.

Integrating STEM instruction within the community requires not only a knowledge of the community, but also a knowledge of students' cultures and interests (Harrington et al., 2019). Mensah (2022) substantiated the need for science teacher education to address preservice teachers' cultural competence and abilities to plan instruction that is equitable

and centered on students' cultures. Some studies have highlighted instructional approaches addressing cultural and linguistic needs of students of color (Calabrese-Barton & Tan, 2008; Lee & Buxton, 2010; Moje et al., 2004). Scholars argue that teachers must foreground epistemologies which reflect students' communities (Dominguez, 2017), and one way to accomplish this is through the enactment of liberating, asset-based, culturally responsive teaching practices.

There are various, complex factors that go into learning how to teach science in culturally responsive ways. Chen and Mensah (2018) found that preservice teachers were more able to teach science in culturally responsive ways when the teacher education program facilitated a space in which preservice teachers were able to explore and discuss their personal identities and histories. Chen and Mensah also found that university coursework, more agentic, less restrictive positioning in their student teaching classrooms, and opportunities to authentically teach were identified as significant influences on the development of their ability to teach science in culturally responsive ways. When a preservice teacher in the study was positioned as an observer in her placement classroom, she identified how the dominant racial narrative and deficit views of students of color were reinforced and perpetuated through teacher-student interaction. Seeing her cooperating teacher continue to perpetuate this caused her to consider how she would work to maintain an asset-based perspective and disrupt this narrative in her future classroom.

Rivera Maulucci (2013) addressed this self-examination aspect of becoming a justice-oriented teacher by focusing on the role of emotions in science preservice teachers' development of a social justice orientation, stating, "Emotions and emotional labor are implicated in all phases of teaching for social justice" (p. 473). Rivera Maulucci suggested

that teacher education programs provide support in fostering preservice teachers' autobiographical sensemaking and justifications for their beliefs. Furthermore, Rivera Maulucci suggested that preservice teachers be provided with resources that can help them make sense of and critique their schooling experiences, which supports the development of their visions of social justice teaching. Moreover, Rivera Maulucci highlighted that social justice work can feel challenging at times, as working to identify and respond to social justice issues can entail significant emotional labor. Therefore, she advocated for building support networks with fellow preservice teachers and sharing resources for coping strategies in order to continue in this work.

Tolbert (2015) posited that developing a justice-centered orientation can also be mediated through conversations with a culturally responsible mentor. In a study with secondary science Maori preservice teachers, Tolbert (2015) identified four practices of culturally responsible mentors: (a) support preservice teachers in deconstructing racism; they recognize that "issues of inequity and injustice in science and science education have been both perpetuated and silenced, and they are not timid about naming racial microaggressions or other instances of racism in the curriculum, school, or science classroom" (p.1352). Mentors also facilitate opportunities for preservice teachers to encourage students to share their experiences and use topics that are relevant to students as phenomena. Culturally responsible mentors also help teachers reflect on how to enact high academic expectations for minoritized students through the facilitation of discourse, and support them in communicating an "ethic of caring" (p.1353) to their students. Tolbert noted that secondary science can often be centered wholly on academics, and being able to communicate warmth,

accessibility, and care to students, especially in an academically-rigorous context, is essential.

According to McCullough and Ramirez (2012), teacher education programs should provide opportunities for preservice teachers to build connections between school, families, and the community, specifically with community science events or family science nights. Building home-school connections increases preservice teachers' enthusiasm for teaching, increases students' engagement and excitement for learning science, and helps preservice teachers feel more confident in using culturally responsive activities and interacting with their students' family members. In addition, connecting with families and creating culturally responsive science activities deepened and diversified preservice teachers' content knowledge and gave them the opportunity to use culturally responsive activities with students and their families, increasing feelings of self-efficacy in science teaching to students of diverse backgrounds.

In one action research study, methods course educators Mark and Id-Dean (2020) explored evidence of culturally responsive pedagogy in instructional planning for secondary mathematics and science preservice teachers. By examining preservice teachers' lesson plans and identifying indicators of culturally responsive pedagogy, Mark and Id-Dean were able to systematically identify evidence of successful culturally responsive pedagogy-aligned instructional planning, as well as areas that needed improvement. Their aim was to identify strengths and areas for growth in preservice teachers' lesson planning, and then work to integrate and explicitly model culturally responsive pedagogy in their teacher education coursework.

Teacher Educator Pedagogies

There are a number of practices that teacher educators enact in order to support preservice teachers in becoming effective teachers. Teacher educators model best teaching practices, deliver teacher education instruction, facilitate discourse related to pedagogy, and create learning opportunities for preservice teachers to practice, reflect on, modify, and integrate their learnings into their teaching practices (Cao et al., 2019).

In addition to supporting preservice teachers in learning pedagogical content knowledge, it is imperative that teacher educators create targeted opportunities to support teachers in creating equitable, culturally sustaining spaces for learning (Russ, 2017). Nieto (2000) highlighted the complexity of teaching these practices to preservice teachers; in order for teachers to enact these practices, teacher educators must be themselves working toward competency in these practices, be reflective and willing to grapple with this ongoing work, and be engaged in explicit modeling for preservice teachers. If preservice teachers learn ways to plan for culturally responsive teaching in their teacher education programs, then they are more likely to include these practices in their teaching careers (Mensah, 2011).

Doucet (2017) discussed that teacher education programs are uniquely positioned to equip preservice teachers with the tools to build culturally sustaining classrooms, and outlined what this looks like in practice. Doucet proposed six commitments that teacher educators can model in their programs and nurture in their preservice teachers so that they are prepared for the work of educating all students in asset-based and culturally-sustaining ways. Doucet asserted that teacher educators should support preservice teachers in 1) engaging in ongoing learning about race and diversity, 2) building a trusting class community, 3) building partnerships with students' families, 4) combating racism, and 5) addressing diversity.

However, numerous studies point to the challenges that justice-oriented teacher educators face when facilitating justice-centered teacher education. These challenges include preservice teacher resistance (Crowley & Smith 2015) and difficulty navigating the reactions and dispositions of preservice teachers of privileged backgrounds (Matias et al., 2016; Owen 2010). Teacher educators who hold a social justice orientation have reported that these difficulties increase as more critical lenses are introduced (Chung & Miller, 2011), such as when course content contrasts with dominant narratives of schooling (Clark, 2010; DiAngelo & Sensoy, 2010).

Teacher educators may also face resistance from their institutions. Many feel as though they are one of few in their departments or universities advocating for educational equity and that this negatively impacts their position within their profession and may result in microaggressions (Gorski, 2016). Concerns about course evaluations also impact teacher educators' abilities to carry out teacher education instruction with a critical lens (Atwater et al., 2013). Moreover, an added complexity for teacher educators who want to root instruction in the community is navigating equitable ways to deal with power dynamics, resources, and constraints between schools, community organizations, universities, and the people who learn or work within them (Tolbert et al., 2018). Despite these challenges, the ability for teacher educators to apply a critical perspective to their courses and other contexts is essential if the intention is to prepare preservice teachers to create equitable education systems. This must be done very thoroughly, intentionally, and continuously, as offering limited, surface-level opportunities to learn about equity and diversity can actually cause preservice teachers to have a false sense of preparedness, which can be detrimental in their work with students of diverse backgrounds (Nieto, 2017).

While there can be challenges for justice-oriented teacher educators to cultivate that disposition for the preservice teachers they work with, teacher educators can navigate this with intentional planning for their courses. Mensah (2022) accomplished this in her science methods course, aiming to broaden participation in science preservice teachers and their students. The science methods course incorporated several multicultural themes that supported the preservice teachers to rethink their perspectives of science and expand their approach to science teaching in order to meet the needs of their students as science learners. This is in alignment with Leonard et al. (2011), who asserted that teacher educators should advocate for integrated methods and field-based science courses to help preservice teachers to facilitate authentic science learning, especially in urban settings. Mensah's course serves as a model for multicultural science education and teacher education curriculum.

Learning to Teach During the Pandemic

Beginning in March of 2020, school districts were ordered to suspend in-person instruction due to the Covid-19 pandemic. With little time to prepare for this transition, this abrupt shift to distance learning heavily disrupted students' and families' lives, completely altered how teachers were expected to teach, and changed teacher preparation for preservice teachers. To mitigate the spread of the COVID-19 virus, teaching faculty had to quickly convert their typically in-person instruction to an online learning format in order for instruction to continue (Long et al., 2020).

Teacher education programs situated in university contexts traditionally incorporate school-based practicums (Zeichner, 2010). Placements in classrooms are required to earn most teaching credentials (Bahr & Mellor, 2016); however, as a result of the Covid-19 pandemic, and the social distancing requirements to prevent its spread, this requirement had

to be heavily modified (Sasaki, 2020). Instead of teaching alongside a cooperating teaching and interacting with students in-person, PSTs were forced to enact their new theories and practices of teaching on an online format.

However, some studies highlight the positive outcomes of the sudden shift to remote instruction. Kidd and Murray (2020) suggested that this innovation had positive outcomes, specifically that educators had to innovate their previous practices and values to navigate the transition from initial pedagogic discomfort to pedagogic agility within these new contexts.

That said, a number of studies discuss the difficulties of the sudden shift to an entirely online format following school closures due to the COVID-19 pandemic (Flores Gago, 2020; Marshall et al., 2020; Pressley & Ha, 2021; Whalen, 2020). The early stages of lockdown forced students, preservice teachers, teachers, and teacher educators to have to quickly organize their living spaces and routines to accommodate working from home; this was made even more difficult if they lived with multiple people, including having to care for children and overseeing their schooling. Furthermore, matters of equity were central, as many people did not have sufficient access to high-speed internet, a comfortable at-home working environment, or the supplies necessary to effectively teach and learn. The sudden need to having to quickly navigate working from home added stress for many people, and compounded the already complex matters involved with teaching and learning how to teach.

This study contributes to the literature by examining ways that the tenets of justice-centered science pedagogy emerge in a teacher educator's and preservice teachers' practices. Understanding how justice-centered learning materials, resources, and pedagogies are utilized could act as a reference for teacher educators and teacher education programs who

want to enact similar justice-oriented pedagogies. This study serves as a contribution to the body of literature of what justice-centered science education can look like in practice; in order to have greater proliferation of justice-centered teacher education programs, it is beneficial to have more research on what teacher educators' actual practices in regards to justice, and what preservice teachers are ultimately learning. Moreover, this study captures how justice-centered science pedagogy emerges in a remote instruction format, and presents findings about how the remote instruction context limits this instruction, as well as some ways that the remote instruction context can be navigated to effectively enact tenets of justice-centered science pedagogy.

Chapter III: Methods

Because I focused on understanding participants' beliefs and experiences, the questions for this study were most thoroughly and comprehensively answered by using a qualitative approach. Qualitative research provides an interpretive, naturalistic scope through which researchers can study particular people and contexts to make sense of phenomena (Denzin & Lincoln, 2011, Smith, 2006). I utilized a case study methodology, as it is particularly suitable for investigating the relationship between teacher's actions and beliefs (Olafson et al., 2015). Specifically, this study adopted a multiple case study approach (Yin, 2013) as the experiences and beliefs of several preservice teachers and a teacher educator were examined.

I planned the study design in order to gain an in-depth understanding of how teacher candidates and a teacher educator were situated together and experienced the complex process of teacher education; thus, a research design consisting of semi-structured interviews, observations of their professional issues course, observations of selected feedback conversations, and content analysis of the professional issues course materials was appropriate for this study. Qualitative data allowed me to gain contextual information, insight into the meaning and purpose of the behavior and beliefs of the participants, and an emic view of the people and contexts that I studied (Guba & Lincoln, 1994).

Study Context

The context for this study was a post-baccalaureate teacher education program at a public university in California during the 2020-2021 school year. Preservice teacher participants were enrolled in a secondary single-subject teaching credential program and preparing to earn teaching credentials in science education in junior high or high school

classrooms. The small, one-year program also granted master's degrees in education to the preservice teachers in addition to teaching credentials, and consisted of a combination of university coursework and fieldwork in several placement classrooms.

Due to the pandemic, preservice teachers completed all coursework related to their own teacher preparation remotely, engaging in discussions, meetings, classes, and other activities through Zoom and other online tools. Moreover, the preservice teachers' field placements were also online, as K-12 schools also had to shift to remote instruction due to social distancing guidelines caused by the pandemic. After several months of teaching and learning remotely, teachers and students then had to quickly adjust to a hybrid instructional setting when social distancing guidelines allowed for it in March of 2021.

Fieldwork Placement Component

Part of participating in the university teacher education program was the field placement component, in which preservice teachers learned how to teach in an experienced teacher's classroom. The preservice teachers participated in three different field placements during the academic year, which gave many of them the opportunity to teach different grade levels and subjects. The field placement experiences were concurrent with coursework in order to give the preservice teachers the opportunity to immediately apply theories and knowledge they learned in their courses. While I did not observe the preservice teachers in their placement classrooms, I asked several questions on the interview protocol about their work and activities in their field placements.

Field placement experiences for preservice teachers primarily occurred in remote classroom settings throughout the school year; the local school district began allowing students to participate in hybrid learning environments in March 2021. Small cohorts of

students attended in-person classes while other students joined classes simultaneously, though remotely. Thus, these preservice teachers were responsible for engaging students first in a solely remote format. Once the social distancing guidelines changed in late March, they then followed a hybrid format, teaching a group of students in-person and some students online (depending on parent and student preferences).

In addition to getting the opportunity to participate in field placements with the guidance of a cooperating teacher, the preservice teachers also received guidance from a university teacher educator about their teaching in the field placement context. Periodically, the teacher educator read the preservice teachers' lesson, observed the lesson, and afterwards gave feedback on the preservice teachers' lesson plans and instruction. I observed three of these feedback conversations with three different preservice teachers, in order to understand the nature of these conversations and how the teacher educator navigated them to extend preservice teacher learning.

Coursework Component, Including a Professional Issues Course

The preservice teachers in this study engaged in various courses in the Teacher Education Program. The science methods courses were a series of three courses which supported the preservice teachers in developing pedagogical content knowledge related to reform-based science, designing learning experiences for diverse learners, curriculum design, becoming a reflective and professional educator, and learning about theories and research related the teaching of secondary science. While some principles of justice-centered science teaching were presented in the course (i.e., equitable academic expectations), the course was not aligned with justice-centered science pedagogy, nor was the teacher educator intentionally implementing justice-centered science pedagogy.

I chose to conduct observations of the secondary science professional issues course. Unlike traditional courses that may only last one quarter or semester, the professional issues course was a year-long course taught by the same instructor. This course met every week or bi-weekly. I observed a total of four classes throughout the academic year; I conducted my first observation in January 2021, and then spaced the following three observations out over the rest of the school year.

I chose to observe the professional issues course for two reasons. First, I wanted to select a course which focused on several different aspects of becoming a teacher. The professional issues course not only covered ambitious science teaching methods, but also focused on justice-centered and antiracist science subject matter and instruction, and building positive relationships with students. Furthermore, I wanted to observe a teacher educator who worked with this cohort of preservice teachers throughout the academic year, and the teacher educator who taught the professional issues course also conducted observation and feedback conversations with the teachers throughout their time in the teacher education program.

In addition to observing four of the class sessions, the teacher educator also gave me access to the professional issues course website. I conducted a content analysis of the resources that were available to preservice teachers in relation to the domains of justice-centered science pedagogy.

Feedback Conversations

The observation and feedback conversation cycle is critical to developing student teachers' abilities to reflect on their instruction, lesson planning, interactions with students, and professional knowledge (Timperley, 2001). Edwards (1995) proposed that opportunities

to discuss their practice with a knowledgeable other allows student teachers to "… translate their experiences into frames provided by public knowledge and to acquire the more powerful language frameworks so that they become insiders in the professional discourse and are able to articulate it" (p. 598).

Participants

Preservice Teachers

Data were collected for nine secondary science preservice teachers. All nine preservice teachers participated in the interviews and professional issues course that I observed for this study. I selected five of these preservice teachers as my focal participants; the focal participants included Rachel, Sawyer, Liam, Mobius, and Turtle Dad. Participants were offered the opportunity to select their own pseudonym.

While I coded all participants' interviews for indicators of justice-centered science pedagogy, I chose to focus my analysis on five preservice teachers because this allowed me to more deeply examine each of these five preservice teacher's beliefs and orientations related to justice-centered science teaching and learning. All of the participants were interviewed at four separate points throughout the school year, and this was a significant amount of data to draw from. Thus, I opted to code all interviews, but selected five to focus on more intently, as this allowed me to more thoroughly understand their experiences. I selected those particular participants because they represented a diverse range in the preservice teachers. I selected Mobius and Liam because both of their first languages were not English. I selected Sawyer because he self-identified as Latinx and a first gen college student. Rachel self-identified as a White female and spoke about social justice considerably more than any of the other preservice teachers. I had a similar justification for selecting

Turtle Dad; he spoke about facilitating equitable discourse, framing students as agentic, and building relationships frequently, and also provided several interesting examples from his own experience of working with students. I thought his examples culminated to a rich case that should be examined more deeply.

I also observed three feedback conversations between Dr. Lake and three preservice teachers; the preservice teachers who participated in this were Mobius, Gil, and Kim. Observation and feedback conversations occur with each candidate periodically, and I selected them for this part of data collection because they were scheduled to have these conversations with Dr. Lake.

Table 1

Preservice Teacher Demographic Information

Preservice Teacher	Ethnicity	First Language	Gender	First Generation Student
Rachel	White	English	Female	No
Mobius	European	French	Male	No
Stella	Caucasian	English	Female	No
Gil	White	English	Male	No
Sawyer	Latinx	English	Male	Yes
Kat	White	English	Female	No
Turtle Dad	White	English	Male	No
Liam	Japanese	Japanese	Male	Yes
Kim	Caucasian	English	Female	No

Note. All information was self-reported by preservice teachers in an initial survey.

Teacher Educator

I selected a teacher educator whom I will refer to as Dr. Lake. One reason I selected her was because she worked closely with the secondary science preservice teachers throughout the entire academic year. This gave her the opportunity to get to know the preservice teacher participants, and for them to get to know her. Dr. Lake also taught the course that I wanted to observe. Because I observed the course that she taught, I became familiar with the teacher educator's pedagogy and the learning opportunities she facilitated with the preservice teachers. Having this familiarity allowed me to ask the preservice teachers questions about learning activities and her course. Another criteria for selecting Dr. Lake was due to her focus on ambitious science teaching, as well as environmental and social justice.

Author Positionality

Scharp and Thomas (2019) state that researchers should examine their own positionality, and illuminate the ways in which their own life experiences might influence their interpretations of participants' experiences. Therefore, I will discuss my own positionality. I identify as a Mexican woman and am proud to come from a small and culturally rich agricultural town in California's Central Valley. My reasons for conducting this study are very much rooted in my upbringing and proximity to a multitude of races, religions, and diverse ways of knowing; my local environment influenced my interest in exploring ways to honor the diverse epistemologies and assets of people of all backgrounds, both in and out of the classroom.

I am also a teacher educator and have worked closely with preservice teachers, and my idea for this study was the result of my longstanding fascination with the pursuit of

effective teaching that engages both students' minds and hearts. I have been fortunate to have held numerous roles in education, from my first position as a yard duty/campus monitor to my current position as an assistant professor of teacher education; my various roles have all given me valuable insight into what it means to co-create knowledge with students. Moreover, I taught in the teacher education program in which this study was conducted (I did not teach this study's participants) and thus have the experience of teaching coursework to preservice teachers. Being a teacher educator myself, I took steps to avoid bias by asking the teacher educator clarifying questions, and following up with her if I was unsure about the accuracy of my interpretation of the information that she shared with me.

Data Collection

Yin (2014) argued that data sources collected as part of case study analysis should illuminate important aspects of the research questions. In this study, I included multiple data sources to allow for investigation of multiple dimensions of justice-centered science pedagogy. Specifically, my data sources included interviews, course observations, feedback conversation observations, and content analysis of materials and resources used in a teacher education professional issues course.

Interviews

Interviews were included as a data source since one goal of this study was to understand the prospective teachers' own ideas about science teaching and their perspectives on their field experiences. The ethnographic interview allows researchers to obtain thick description of participants' experiences (Spradley, 1979).

Interviews with Preservice Teachers. I developed semi-structured interview protocols, in collaboration with the research group I was a part of. Semi-structured

interviews were conducted in order to allow for a more natural conversation between the interviewer and participant (Austin & Sutton, 2014). This interview format allowed the interviewers to ask consistent questions throughout all of the interviews, but allowed the freedom to alter or rephrase a question or probe the participant's thinking in order to gain a deeper understanding of the participant's experiences and beliefs. Moreover, these interviews gave participants the opportunity to clarify their responses and provide detailed, rich accounts of their experiences (McIntosh & Morse, 2015). The semi-structured interviews were designed to create opportunities for preservice teachers to reflect on their experiences both as students in the teacher education program as well as their experiences as teachers in their fieldwork placements. The interview protocols are included in Appendix A.

The first interview occurred during June/July 2020, during their summer teacher education coursework but prior to their fieldwork experiences. The remaining three interviews occurred while preservice teachers were in their teaching placements, with the second interview occurring after fall quarter in December of 2020, the third interview occurring at the end of winter quarter in March 2021, and the final interview occurring at the end of the year, in May/June 2021. Eight out of nine teachers participated in all four interviews (Kim did not participate in the third and fourth interviews). Each participant was interviewed individually, and all of the interviews took place on Zoom.

Before conducting the interviews, the research team met to go over the protocol and discuss if we wanted to change any questions (or the order of questions) in order to yield more or more targeted data on our research questions. While there were a few changes to the interview protocol throughout the course of the interviews, the interviews were consistent throughout the school year and maintained the same themes. The interviews all contained a

section on the preservice teachers' knowledge of and efforts to teach the NGSS. All interviews included a section with questions about knowledge of and efforts to enact equitable instruction for emergent multilingual learners. The protocols also asked questions about how they believed they were progressing in learning the knowledge, skills, and responsibilities of teachers, and how they envisioned themselves continuing to develop in their teaching practice. There was also a section on their preferences and experiences with feedback conversations; this section asked about their views on what constitutes effective feedback and specific ways of delivering feedback that they felt were most supportive of their development as a teacher.

The initial interview was conducted within weeks of starting their teacher education coursework, and prior to beginning their first field placement classroom experience; therefore, much of the interview consisted of discussion about their very recent and brief experience in their education courses, prior experience that they may have had in professional education roles, prior experiences with remote instruction, or asked them to think about hypothetical teaching situations (as they had not started their field placement yet). Because the first interviews were conducted immediately upon their start of the teacher education program, they served as a baseline for the preservice teachers' beliefs and experiences with teaching, without having yet learned much through the teacher education program. Subsequent interviews that occurred quarterly served as markers of the preservice teachers' development, beliefs, and conceptions of teaching throughout the school year.

Interviews with the Teacher Educator. Three semi-structured interviews were conducted with Dr. Lake, the teacher educator; the first interview took place in December 2020, the second took place in February 2021, and the third interview took place in April

2021. The interview questions were predominantly centered on four themes: (a) her methods of teaching and supporting the preservice teachers in learning how to teach the NGSS and ambitious science teaching, (b) Dr. Lake's views on social and environmental justice and how she integrated that into her work with the preservice teachers, (c) ways that she supported preservice teachers in framing their students as agentic and creating the safe environment that is necessary to do so, and (d) her vision and enactment of effective feedback for preservice teachers. While I referred to an interview protocol (included in Appendix B), these interviews were more organic and conversational than the interviews with the preservice teachers. While the interviews with the preservice teachers were also semi-structured and conversational, several of my colleagues contributed questions to the interview protocol, and it was necessary to ask most of the questions so everyone could obtain data that they were most interested in. However, I wrote all of the questions for the teacher educator's interview protocol and had the ability to add, probe, or omit questions altogether. This allowed me to focus on her experiences, perceptions, and feelings, and to allow that to guide the conversation.

I began these interviews by asking Dr. Lake about how she felt her work was going with the preservice teachers, and subsequent questions followed a semi-structured, conversational style driven primarily by her initial answers. After an open-ended conversation, I asked specific questions about her social and environmental justice teaching; feedback conversations with the preservice teachers; and her own strengths, opportunities for growth, and visions of effective teacher education. In addition to these conversations, at times, I contacted her for clarification or returned to something that was stated in previous

interviews, asking for more explanation in order to check the accuracy of my notes and interpretations (Merriam, 1988).

Observations

During the professional issues classes and feedback conversations, I observed and took detailed notes. While I took notes on everything that was shared during the class, I made particular effort to capture topics that were centered around issues of justice-centered science pedagogy.

Professional Issues Course Observations. This professional issues course covered a wide array of topics conducive to preservice teacher development. This course was tailored to the interests and pedagogical needs of the preservice teachers and was structured more as a seminar than a typical college course. During each class session, the teacher educator began by asking all of the preservice teachers how they were doing, then would either present on a topic pertaining to science education or have a guest speaker present, and then engage in collaboration and/or individual practices on something that they had learned. This was also a space for the preservice teachers to bring up any questions, concerns, or suggestions that they had, and the teacher educator frequently invited preservice teachers to share freely. Because the environment was conducive to discussion and bringing up concerns, I was able to hear about the preservice teachers' experiences and learnings as they worked with students and learned more about becoming an effective science teacher. Because of the potential for sensitive subjects to be brought up, I did not record these classes. Instead, I took highly-detailed notes, and after the class was over, I wrote memos to help me recall the most significant moments and learnings during the class.

Feedback Conversation Observations. Because opportunities to discuss their practice with a teacher educator is so important to teacher development, I chose to observe three conversations between a preservice teacher and a teacher educator. Two of the feedback conversations were debriefing conversations; the teacher educator watched a lesson and they discussed it afterwards. One of the three conversations was one in which a teacher candidate asked for help on their lesson planning; the teacher educator read through a lesson prior to the conversation and then discussed it with the preservice teacher. While the content of the conversations varied greatly, the teacher educator asked a series of questions and provided feedback to support the preservice teacher in identifying professional strengths and opportunities for growth.

Professional Issues Course: Instructional Materials and Resources

In order to gain greater insight into the knowledge the teacher educator hoped to foster in the preservice teachers, and to understand the material that they were learning, I examined the professional issues course website. The website was divided into many topics, all of which were centered around information that is important to know in the professional development process of becoming a teacher. While some topics included self-care, obtaining employment, and various other topics, for this study, I focused my analysis on topics that helped the preservice teachers learn about and enact justice-centered science pedagogy.

Data Analysis

The interviews were initially transcribed using Zoom's transcription software. I then transcribed all of the interviews with Otter.ai, which provided a more accurate transcript than the one generated from Zoom. Members of the research team checked several of the interviews for errors and corrected the transcripts in order to accurately reflect the audio

recordings. I checked interview transcripts that had not been checked by other members of the research team.

The interviews yielded information on a wide range of topics in relation to their experience of learning how to teach in their preservice year. One common theme in the interviews was their experience of learning how to teach reform-based science. The preservice teachers discussed their developing knowledge of the Next Generation Science Standards (NGSS), and their opportunities to plan lessons and units based on the NGSS. Their teacher education program also emphasized the practices of Ambitious Science Teaching, which is centered on eliciting student ideas, engaging students in sensemaking and discourse about science topics, and basing lessons on complex and relevant phenomena. Further, the interviews yielded information on their facilitating equitable classroom discourse, encouraging students to share ideas and instilling a belief that there are "no wrong ideas", and essentially framing students as agentic co-constructors of knowledge.

Interviews with Dr. Lake elicited her ideas about social and environmental justice issues, and how she prepared the preservice teachers to integrate that into her work. She also spoke about her own development in this area, and the complexities of learning about and teaching this to preservice teachers.

Observations of the Professional Issues Course and Content Analysis

The data in this study were rich, descriptive, and covered a variety of facets about what it means to be an equitable, justice-oriented, and effective teacher of science. My initial plan for this data was to focus more on the data from interview questions on feedback conversations, and how those conversations supported the preservice teachers in developing as equitable and culturally responsive secondary science teachers. However, when I saw the

extent of materials and resources that the teacher educator provided as learning material and references about social and environmental justice, as well as her own orientations to using relevant and justice-oriented phenomena in science teaching, I also became interested in documenting her efforts to effectively support preservice teachers during the professional issues class sessions, and how they took up this work.

Moreover, I had recently read "Justice-Centered Science Pedagogy: A Catalyst for Academic Achievement and Social Transformation" by Daniel Morales-Doyle (2017). This was a case study which examined how a justice-centered chemistry teacher in an urban high school supported students to succeed academically, while taking up issues of social and environmental justice that were pressing and relevant to their communities. This study fascinated me, and my immediate question while reading it was, "How might teacher educators teach science preservice teachers to do this?" I thought about the teacher educator in my study, and her evident efforts to support preservice teachers in supporting students academically, orienting science topics around social and environmental justice issues, and her emphasis on cultivating a classroom environment in which students felt cared for and known. Because I felt that these efforts aligned with justice-centered science pedagogy, I opted to use that framework to guide my study, which includes the following domains and lenses through which I conducted my analysis: antiracist and equitable science education, social justice science issues, and youth as transformative intellectuals. Therefore, I focused my analysis on examining interview, observational, and content analysis data on identifying indicators of these domains.

The codebook went through several iterations in order to most accurately document evidence of efforts to teach, learn about, and integrate justice-centered science pedagogy. I

coded each interview excerpt or section. For the content analysis, I coded each class resource as it aligned with a domain of justice-centered pedagogy. It is important to note that I expanded the dimension of youth as transformative intellectuals beyond how it was originally defined by Morales-Doyle (2017). This expansion made explicit the centrality of relationships to academic achievement and student participation; to encourage student participation and a willingness to share their ideas, teachers should foster relationships and trust with students (Bishop et al., 2014).

In the first cycle of coding, I used three a priori codes (Saldaña, 2016) constructed from the tenets of justice-centered science pedagogy to code preservice teachers' responses to the 22 interview questions. In the second cycle, I assigned subcodes to all responses coded in cycle 1; these subcodes emerged during the process of data analysis. In the third cycle, I looked for patterns in responses among focal participants and across time using another set of emergent codes. I then determined the overall number of each code and subcode, and differences in codes and subcodes assigned by focal participant and over time.

Table 2

Justice-Centered Science Pedagogy Codes and Subcodes

Tier 1 Code	Tier 2 Subcode	Tier 3 Subcode
Antiracist and equitable science education	· Ambitious science teaching · Equity and/or equitable practices · NGSS core ideas, practices, or crosscutting concepts · Scaffolds and strategies to make content comprehensible for students (e.g., sentence starters, technology tools, group structures) · Strategies, materials, or tools used to engage and support students in attending to and participating in productive discussions	· NGSS-aligned instruction specific to their grade and discipline · Rigorous, reform-based instruction in a remote or hybrid context
Social justice science issues	· Antiracism and/or culturally relevant practices · Place-based practices · Social and environmental justice science issues	· None
Youth as transformative intellectuals	· A safe and inclusive classroom environment conducive to speaking up and sharing all ideas · Equitable discussions that elicit ideas from a wide range of students · Relationships and rapport with students for students to feel safe to share ideas and take academic risks · Student agency through class jobs, leadership roles, etc. · Students' ideas as important · Framing students as producers of knowledge and culture · Students sharing their ideas or work in a public forum · Teacher as facilitator	· Confidence in interactions with students · Power dynamics between teacher and students · Students as knowledgeable contributors

Chapter IV: Findings Set 1

Teacher Educator's Efforts to Teach Preservice Teachers Justice-Centered Science Pedagogy

The purpose of this chapter is to illuminate the learning opportunities that were available for the preservice teachers to engage with justice-centered science pedagogy. First, I analyzed the resources that Dr. Lake used in her professional issues course for indicators of justice-centered science pedagogy. This section also presents findings about what the teacher educator taught to the preservice teachers during four of their professional issues courses and three feedback conversations, and how these connect to justice-centered science pedagogy.

I first present a content analysis of course readings, videos and other materials that were posted on the professional issues course website. These resources were analyzed to determine which resources aligned with the three domains of justice-centered science pedagogy. Secondly, I present observational data on the content of the professional issues course which the teacher educator taught. Lastly, I present observations of feedback conversations between the teacher educator and three preservice teachers, in order to determine if topics that emerged aligned with justice-centered science pedagogy.

Professional Issues Website: Course Resources

One important aspect of teacher education programs is the required coursework that supports preservice teachers in becoming competent in educational theories and practices. While teacher education courses vary from program to program, one course that was offered at the university in which this study took place was the professional issues course. The secondary science preservice teachers whom were the participants for this study all

participated in this course, and the instructor was the teacher educator that was also a participant of this study.

The purpose of the professional issues course was to provide a space for the preservice teachers to learn about various topics that are pertinent to becoming a teacher, as well as to learn skills and knowledge that will help them to become equitable and effective science teachers. The course that I observed included a wide array of topics; navigating placements at school sites, enacting antiracist pedagogy and environmental justice, and planning NGSS-aligned lessons were all topics that were discussed, amongst many more. At the university where my research was conducted, the professional issues course was not a quarter-long or semester-long course, but instead took place throughout the academic year. For this professional issues course, class was held from September 2020 through May 2021. While the class did not meet every week, they met almost every other week throughout the school year. Due to the social distancing requirement as a result of the Covid-19 pandemic, the class was conducted online over Zoom through the entirety of the school year.
Due to the online nature of the course, course readings, resources, and other learning materials were posted online on a course website in order to enable the cohort of preservice teachers to access the resources. In order to understand the content of the course and topics that the teacher educator planned to teach the preservice teachers, I conducted a content analysis of the course website. There were many resources covering a wide range of topics, and many of them were focused on the three domains of socially-just science teaching: antiracist and equitable science education, teaching about social justice science issues, and framing students as transformative intellectuals. Social justice science issues are not social justice issues broadly, but specifically examine scientific phenomena that is rooted in social,

racial, and/or environmental injustice. In the following sections, I outline the course website resources that were used to teach preservice teachers about these topics, and the extent to which they aligned with the justice-centered science pedagogy framework.

There were a total of 89 resources listed on the professional issues course website. Nine resources were intended for the preservice teacher to learn about their new school placement environment; these resources provided tips on getting acclimated to the school culture, getting to know colleagues, and navigating the logistical aspects of working in an unfamiliar environment. While these resources were not explicitly focused on justice-centered science, they provided information on getting to know their colleagues and creating the foundation on which a teacher could feel supported at their school, thus better enabling them to know which colleagues to talk to for certain matters and how to find teaching resources; all of this can help them to provide quality instruction. The professional issues course website also contained 10 resources on academic expectations and effective teaching of the NGSS, three resources on framing students/building relationships, and 62 resources on social justice science teaching.

While the course website contained several resources on maintaining equitable science education and teaching to the NGSS, as well as resources on building relationships and a classroom culture that positions students as agentic, the majority of the resources were centered on teaching preservice teachers about social and environmental justice issues related to science. Some of the resources were informative in nature (intended to teach the preservice teachers about social justice science issues), while others were teaching resources, or actual lessons, units, or concrete ideas that the preservice teachers could use in their classrooms to teach social justice science issues. An example of an informative

resource was an article titled, “The Toll About White Privilege”, an article written by physicist Apriel Hodari, detailing her efforts to improve training and reduce inequity in the scientific workforce in the White, male-dominated field of physics. An example of a teaching resource was a website from the American Institute of Physics, which has numerous lessons which teachers can use in their classroom that intersect science with issues of social justice. One example is a lesson titled, "The Black Scientific Renaissance of the 1970s-90s: African American Scientists at Bell Laboratories”.

The professional issues course website was organized as follows. The website was divided into 15 topics (not counting the “introduction to the course” section). The topics and total resources available (including those that did not align with justice-centered science pedagogy) are outlined in Table 3. As stated above, there were a total of 89 resources, with 62 resources that aligned with a domain of justice-centered science pedagogy. There were two topics that did not include any online resources as shown in the table; this is because teaching about these topics was discussed wholly through meetings and inviting guest speakers in the online format.

Table 3
Professional Issues Course Topics and Number of Resources

Course Topic	Number of Resources
Getting to Know Your School Ecosystem	5
Teaching Materials	12
Taking Care of Yourself and Others	7
Bending the Curve (using science to address climate change/environmental injustice)	8
Environmental Justice	9
Talking About Race and Gender in STEM	17
Diversity and Inclusion in the Sciences	10
Art, Science and Technology	4
The Role of Ethics in Teaching STEM	2
Indigenous Ways of Knowing	4
Place-Based Teaching	1
Science: The Good, the Bad, and the Ugly (problematic issues in science)	4
Integrating Sciences and Social Sciences	0
Alternative Education	0
Job Interviews	6

The remainder of this section is organized by the three domains of justice-centered science pedagogy: (a) antiracist and equitable science education, (b) teaching social justice science issues, and (c) youth as transformative intellectuals.

Antiracist and Equitable Science Education

Dr. Lake provided many resources to support the preservice teachers in providing equitable and academically rigorous learning opportunities for all students. This entails effectively teaching the NGSS, and part of being able to teach the NGSS effectively is creating lessons and units that align with the standards. The NGSS are comprehensive, and each standard contains many smaller domains of knowledge and skills; for students to be able to meet the standards, teachers must be able to teach the standards in comprehensible ways that make sense to students (Haas et al., 2021). While this may be feasible for veteran teachers who have more familiarity with the standards and how to teach them, this can be more complex and may take a lot of practice for preservice teachers (Murray et al., 2009).

Therefore, it is beneficial for preservice teachers to have examples of high-quality, NGSS-aligned lessons and units; this allows preservice teachers to gain familiarity with the rigor of the standards, the academic content, effective teaching and scaffolding strategies, and activities and discussions that reinforce the science content. By seeing examples, preservice teachers may gain competence in teaching these lessons and feel more confident and able to create their own lessons that meet this same level of rigor and provide access to the standards for students of all levels.

Some examples of NGSS-aligned lesson plans and units included resources on the website *CK-12. CK-12* is a free website that includes resources to help teachers plan science units, as well as readings to help reinforce the standards. The CK-12 website has a feature titled, "Next Generation Science Standards Browser", which teachers can use to locate resources to teach the NGSS, based on their grade level and content area. Students can create an account, complete the assignments and assessments, and save their highlighted sections and notes that they took on their lessons.

Another beneficial resource was the *Understanding Science* site, created by the UC Museum of Paleontology of the University of California at Berkeley. This website supports teachers in teaching students about the nature of science. It includes a teaching database and presents a nature of science flowchart, which displays four interdependent components of science teaching: testing ideas, exploration and discovery, benefits and outcomes, and community analysis and feedback. The site states:

> Science is a way of learning about what is in the natural world, how the natural world works, and how the natural world got to be the way it is. It is not simply a collection of facts; rather it is a path to understanding. Scientists work in many

> different ways, but all science relies on testing ideas by figuring out what expectations are generated by an idea and making observations to find out whether those expectations hold true. Accepted scientific ideas are reliable because they have been subjected to rigorous testing, but as new evidence is acquired and new perspectives emerge these ideas can be revised. Science is a community endeavor.

By presenting science as a path of understanding and not simply a set of facts to memorize and isolated labs to conduct, students may view science as relevant and something that can be used as a tool to solve problems. Furthermore, the teaching resources included within Understanding Science's Teaching Resource Database had all been vetted and aligned with the NGSS. These resources were intended to foster student understanding of and engagement with the nature and process of science as required by the NGSS.

Another resource that the teacher educator made available was the *STEP UP* website, developed by a national community of physics teachers and researchers who design high school physics lessons to empower teachers, create cultural change, and inspire women to pursue physics in college. Although this website primarily benefited preservice teachers who taught physics, the website contains complete units which align with the NGSS, providing a starting point for physics teachers to gain familiarity with the standards or to simply get new ideas on implementing NGSS from experienced physics teachers.

Teaching About Social Justice Science Issues

There were a total of 62 resources on social justice science issues on the professional issues course website. Of these resources, 46 were websites and 16 were articles. The most prevalent set of resources were connected to social justice and teaching science in ways that are equitable for all students. Having an understanding of and being able to teach about

environmental and social justice in science is critical for teachers of science; without acknowledging societal inequities, science teaching is perpetuating the status quo instead of disrupting dominant narratives of who scientists are and the nature of their work (Sheth, 2018; Titu et al., 2018). Therefore, it is crucial that preservice teachers learn not only to enact rigorous science teaching practices, but those practices must be foregrounded in historical and social contexts, and they must also be taught how to engage students in this work as well. While there were numerous resources under each topic, I discuss in detail the resources that seemed to be the most impactful for teaching and learning about justice-centered science.

Focus Topic One: Environmental Justice. This section opened with a resource on the basics of environmental justice, which preservice teachers could view as needed. The video explained why living in a more affluent area can lead people to have better health outcomes, whereas people living in under resourced areas have less access to resources, leading to negative health outcomes. The video explained that even when White and Black/Latinx people live in the same vicinity, Black and Latinx people are often relegated to areas that have high pollution and less resources, while White and wealthier areas tend to have access to more organic grocery stores and trees, and tend to not be near hazardous pollution sites. The video then explained that, oftentimes, resources in these parts of town, or in small towns and even countries, are depleted and then nothing is given back to the community in which they came from, leaving the community exploited and unhealthier as a result. While short in length, the video provided the preservice teachers with an overview of what environmental justice is and why it matters, and understanding this is foundational to teaching science that works to highlight and alleviate environmental justice disparities.

The course website also highlighted two organizations that work to fight environmental injustice. One group, Greenpoint, works to garner community support to change government and industry policies and practices to protect health and promote environmental, social, economic, racial, and climate justice. Greenpoint works to ameliorate many environmental injustices, including working toward implementing zero waste policies in vulnerable communities, to close incinerators and landfills, and to stop proposed incinerators. They have also completed numerous projects that resulted in cleaner water and cleanup of contaminated sites in vulnerable communities. The second organization was NiCHE, a Canadian-based group of researchers and educators who explore the historical context of environmental issues.

The preservice teachers were also provided with examples of some ways that teachers can integrate environmental justice science topics with the humanities. The course website had an example of two teachers who worked together to teach a seven-week seventh grade environmental justice and humanities unit. For two weeks, the teachers who created the unit combined their seventh grade science and humanities classes, creating an extended "project block", where they co-taught a large combined class of two seventh grade sections. During this unit, students went to their project block class for 2.5 hours a day for a series of learning tasks that the two teachers co-designed and co-taught. In the two weeks, students in seventh grade learned about large themes in the study of environmental justice and became experts in one of four case studies in environmental racism. Students had the opportunity to discover and unpack the complex implications of environmental racism. The students' culminating task was to create both a feature article that highlighted their case study as an example of environmental racism and an original watercolor protest piece. Together, these

two work products demonstrated their understanding of environmental justice, empowered them to create artwork to express their reactions, and shared their voice on this issue.

In order to prepare students to do this work, the teachers began the unit with a gallery walk, which helped students to build background knowledge. Students were asked to walk around looking at pictures of waste sites and environmental protests, and took notes on what they observed. Afterwards, students were asked to use what they saw in the pictures and make inferences to define environmental racism. While this was just an introductory activity, it helped students to immediately see the effects of environmental racism. Students continued to build background knowledge by watching a film titled, *Rise*, and reading related texts as a whole class. Then, students were given data about industrial and chemical spills, and were asked to make graphs correlating the spills with the races of populations in the area of the spills.

Once students had engaged in these schema-building and explorative activities, they were asked to create their own case study. The teachers had selected four different case studies and curated materials for students to use to learn about the case studies. Materials were available at different reading levels and teachers provided frontloading, scaffolds, and small group support in order to make the material accessible to all students. In their case study projects, students were asked questions designed to guide them to the understanding that the environmental injustices described in each of these case studies was the result of urbanization, development, and preoccupation with profit, without businesses being ethical and having concern for people who live in the community.

Focus Topic Two: Talking About Race and Gender in STEM. As Morales-Doyle (2017) asserted, "Inequity across race, class, and gender remains the most prevalent and

persistent problem in science education" (p. 1035). Given that this is an important issue in STEM, this section was extensive; it contained fifteen resources related to race and gender in STEM fields. This topic contained readings on three major categories: 1) The historical roots of racism in science, 2) The need to diversify STEM, and 3) Antiracist resources. Of all the resources, there were 13 online articles, 2 videos, and 2 teaching resources to support teachers' planning and instruction on this topic. I will discuss the resources that I found most relevant and potentially impactful for preservice teachers within each category.

The Historical Roots of Racism in Science. These resources were all presented as a way to increase preservice teachers' awareness of the racist underpinnings of many historical scientific studies. This section also discussed why minoritized people have encountered barriers to entering science professions.

One resource the teacher educator discussed with preservice teachers was the book, The Immortal Life of Henrietta Lacks (2010). The website she shared contained a summary of the book, as well as a teacher's guide. The teacher's guide contained activities to use in language arts, social studies, and science, in order to teach students about the way that Henrietta Lacks' cells became one of the most important tools in medicine, and led to many discoveries and advances, but that this was done unethically and without her consent. By providing not only the information, but an extensive teacher's guide which connected to several different academic subjects, this was a resource that the preservice teachers could easily integrate into a lesson with their own students. This section also discussed the USPHS Syphilis Study at Tuskeegee, the un-scientific concept of eugenics, and the bell curve and ideas about IQ, which are all rooted in white supremacy.

The Need to Diversify STEM. Several articles and resources on the course website also discussed the importance of diversifying the people who study and work in STEM. One notable article was titled, "Silence is Never Neutral – Neither is Science" (500 Women Scientists, 2020). The article raised the issue that scientific institutions must immediately work on rooting out anti-Black racism and all forms of racism and discrimination. The article states that, when science institutions stay silent on racism, a culture is created where talking about racism is actively discouraged and where Black, Latinx and Indigenous scientists cannot bring their authentic selves to work. The authors state that science institutions must train, hire and retain Black, Latinx, and Indigenous scholars. While they commend DEI efforts, they argue that DEI efforts and mission statements need to be backed up by a commitment to hiring people from minoritized populations, and policies need to be in place that prevent workplace hostility.

Antiracist Resources. The course website also contained information about working toward being antiracist and making antiracist education the foundation of one's classrooms. Although not a comprehensive or exhaustive list, the teacher educator posted several resources from an antiracist grassroots group on unlearning racist practices and integrating antiracist practices into teaching practices.

Indigenous Ways of Knowing. The course website also provided information about indigenous science epistemologies. One resource provided units on Indigenous STEAM. These units emphasize storytelling and relationships between elements of the physical world with each other, as well as their relationships with humans and animals. An important component of Indigenous science is the understanding that all things are related. Therefore, while completing these units, students (a) engage in telling stories and listening to stories

about the scientific phenomena, (b) interact directly with the scientific phenomena, and (c) think about the ways that humans' relationships with the scientific phenomena (i.e., pollution) have had a negative impact, and what that means for the environment. A second resource was an article titled, "Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action" (Kimmerer, 2002). The article discussed the importance of integrating traditional ecological knowledge into biology courses.

Youth as Transformative Intellectuals

There were a total of three resources that were coded as youth as transformative intellectuals. These resources were centered on getting to know students and eliciting their perspectives in the classroom.

Enactment of Professional Issues Course

Although the professional issues classes were conducted throughout the academic year, I began observing the course in early February through May; I conducted a total of four observations. I took notes on the material that Dr. Lake presented, the learning activities that she facilitated, and the resources (i.e., readings, online articles, videos, teaching resources) that were made available on the course website to support preservice teachers in developing as justice-centered science educators.

The content of the course was undoubtedly important to capture; however, preservice teachers learn pedagogies more effectively when content is modeled and integrated by their teacher educator, cooperating teachers, or other people they work with (Dinkelman, 2011). To not incorporate practices one teaches about could be considered contradictory and not conducive to authentic preservice teacher learning. For example, if a teacher educator demonstrates how to facilitate a discussion to preservice teachers, but teaches the preservice

teachers using strictly lecture-style methods, their teachings may not feel as authentic, meaningful, or even feasible for the preservice teacher to adopt (if they are not incorporating the practices themselves). Therefore, while it was important to capture the content of the classes, I was also interested in how the teacher educator modeled and integrated the principles of justice-centered science pedagogy in her interactions and ways of working with preservice teachers. Therefore, in the following sections I will outline not only how she taught the preservice teachers to enact aspects of justice-centered science pedagogy with their students, but also how she actually modeled that and implemented those practices herself.

Antiracist and Equitable Science Education

In all of the class sessions that I observed, maintaining equitable academic expectations and supporting all students' access to the NGSS came up. This was a very common occurrence in all of the class sessions, with Dr. Lake facilitating discussion on supporting the preservice teachers in presenting and discussing scientific ideas, facilitating student discourse, selecting anchoring phenomena, and scaffolding in order to help students make sense of learning material.

During the third class session, a panel from a local alternative school came to speak about their school and their philosophy on teaching students. One teacher brought up that the alternative program was unique due to its emphasis on maintaining high academic expectations, while also providing targeted scaffolding in order to help students comprehend the learning material. The teacher stated, "We meet them where they're at, but we don't remediate. I still use challenging texts, but I help them understand it". Other teachers on the panel elaborated that they view students from an asset-based perspective and try to foster

what students know, elicit their ideas, and work with that, rather than focusing on what they do not know.

Teaching About Social Justice Science Issues

The first class I observed was centered on restorative justice practices and building relationships with students. Dr. Lake invited two guest speakers, both of whom were teachers in the local school district. The guest speakers were teachers who had experience with creating a classroom environment built on restorative practices, and Dr. Lake asked them to speak about their strategies for enacting restorative justice, ways to enact it most effectively, and potential challenges to its implementation.

There are many definitions of restorative justice in practice and in literature; however, the definition provided by Song & Swearer (2016) was based on reviewing the literature and practical experiences with restorative justice practices in schools, specifically; they describe restorative justice as a philosophical perspective about the potential of humanity in community derived from various indigenous communities (Johnstone, 2011; Zehr, 2015). According to Song and Swearer, restorative justice consists of three principles: (a) relationships and their harms, (b) empowerment of all people, and (c) collaboration. An example of a restorative intervention is when an incident (i.e., a student is teasing other students in the class) is treated as a relational harm within a community rather than only focusing on the student who teased, allowed all relevant stakeholders (i.e., students who were teased) to share their experiences openly, and allowed for shared decision-making regarding how to address the harm and make it right not just for the students harmed, but for the community.

Dr. Lake opened the class by asking the preservice teachers to complete a quick write about their own knowledge of restorative practices before the guest speakers began discussing their own experiences with fostering a class community based on the foundation of restorative justice. Dr. Lake asked all teacher candidates to look at what they had written and share one word about what they wrote on the Zoom whiteboard. Some words that were shared were “equity”, “collaboration”, “mending”, “repairing relationships”, “justice”, and “intervention”.

The first guest speaker began by stating that being proactive is central to enacting restorative justice; she elaborated that a common misconception is that restorative measures occur after a harm has been done in the classroom; however, she emphasized that restorative justice first begins with building community, and making accountability to the class community the foundation of one’s classroom. Without the aspect of accountability and responsibility to the class community, she noted that restorative justice could not be fostered effectively. The guest speaker also noted the importance of taking care of oneself; they elaborated by stating that restorative justice requires that the teacher is present and ready to positively interact with students each day, and trying to be in a positive state of mind before entering the classroom helps one to also interact positively with students throughout the school day, when potential issues and tensions may arise.

The guest speaker then discussed the importance of taking time every day to build class community. They again emphasized that accountability to the community is critical for restorative justice to work. One speaker noted that they “do a community circle each Friday and at the beginning of each unit, do getting to know you activities, and it's become sort of a ritual". The second teacher echoed this, stating that building relationships takes time, but

that it is an investment in your classroom culture, and that it only helps students learn more easily. They continued to reinforce the idea that relationships are the foundation upon which learning happens, stating that not only is it generally beneficial to have good rapport, trust, and relationships with students, but it is also something that can be leveraged in order to effectively teach academic content.

The second guest speaker then discussed how restorative justice conferences can be facilitated when a harm has been done. She explained that conferencing is a key restorative justice strategy and a method for addressing discipline incidents. Through a face-to-face meeting or class circle, the person who has created harm has the opportunity to be directly accountable to those harmed, while the person harmed has the opportunity to share their viewpoint and have input about what the appropriate repair should be.

The guest speaker then detailed the steps of a restorative conference. First, the person who caused harm describes the incident and accepts responsibility for his/her actions. Then, the person who was harmed describes the incident and what he/ she experienced during and as a result of the incident, including physical, emotional and psychological harm. Other members of the community then have an opportunity to speak and describe their observations, and this opens the conference up for further discussion and questions.

The guest speaker discussed that participants in a restorative conference then collaboratively determine how the harm should be repaired with action that is meaningful and related to the specific situation. Participants then ensure that the person responsible for the harm is supported and has the capability to actually complete the repair and integrate back into the class community, without feeling shamed. The guest speaker then discussed the criteria for an effective repair, first emphasizing that the repair must be related to the

offense; they stated, "The repair should be genuine and resolve the root of the problem, not something like picking up trash for being mean to someone". Picking up trash does not at all address the issue of saying harmful things and hurting someone's feelings; thus, they emphasized that that would be an illogical consequence and would not actually help to repair the real issue. The guest speaker then discussed that a repair must also be reasonable, respectful, and responsible.

The guest speakers then opened the discussion up for questions from the preservice teachers. One preservice teacher asked if relationship-building should be done separately from lessons and other academic activities. The guest speakers responded that relationship-building can and should be done during lessons, and that relationship-building does not need to be a standalone activity; while they stated earlier that it takes a lot of time, they clarified that it is mainly that way at the beginning of the school year, when teachers do not know students yet. However, they stated that relationship-building can be as easy as talking to students and connecting with them in some spontaneous way. The guest speakers utilized the majority of the class time with their presentation on restorative justice, and the teacher educator mainly facilitated discussion afterwards. Interactions and discussion with the preservice teachers were all positive, and the teacher educator sought the preservice teachers' input in how the class should be run for the rest of the session.

When the guest speakers ended their presentation, Dr. Lake asked the preservice teachers if they wanted to process what they learned about restorative justice independently, or enter into breakout rooms and discuss what they heard in small groups; they opted to process it independently. After giving some time to do this, she then asked the preservice teachers how they would like to spend the rest of their time together. After it was silent for

several seconds, a preservice teacher brought up a concern about students who were not turning in any work. The teacher educator advised the teacher to contact parents/counselor before the student falls too behind in class to pass. Two other preservice teachers then volunteered their input after the teacher educator asked if anyone had a similar situation. As a group, the teacher educator helped the preservice teacher come up with solutions, and asked the rest of the preservice teachers what they, or their cooperating teacher, did to address the issue of students not turning in any work due to remote instruction. Several preservice teachers shared their experiences, and along with the teacher educator, were able to offer suggestions for the teacher with the initial question.

During the third class session, the panel members from the alternative school discussed that they felt their school was transforming dominant ideologies of the roles of students and teachers. The panel explicitly opposed stereotypes often associated with alternative secondary schools, with the principal stating, ". . . our school is an interrogation of oppressive schooling, we are here to decolonize and center counter-stories. We have asset-thinking here, not deficit-thinking".

During the fourth class session, an experienced secondary science teacher from Northern California had led a presentation on antiracist science teaching. This was conducted on Zoom, and was open to preservice teachers in this teacher education department. While not all of them attended, several of them did; the teacher educator asked those that were able to attend if they could share what they learned with the group. The preservice shared that, through the presentation, they learned the importance of viewing some of the history of science and its products as problematic, and to facilitate dialogue to

discuss this with students. The presenter also discussed the importance of selecting science content that centers antiracism and social and environmental justice issues.

Youth as Transformative Intellectuals

During the first class session that I observed, the panel members who discussed restorative justice also emphasized the need for preservice teachers to build positive relationships with students. Dr. Lake herself demonstrated rapport-building behaviors with the preservice teachers, as she ended class by checking in with each preservice teacher. While she often opened up her check in by asking, “How are you doing?”, she followed it up each time with a much more specific question, demonstrating that she had familiarity with each preservice teachers' teaching placements, any current challenges, hobbies, and other interests.

Dr. Lake also demonstrated rapport-building behaviors during the second class session. When I joined the meeting at the beginning of class, she had started telling a humorous story, which led to a preservice teacher, Mobius, telling a humorous story of his own that was related to hers. The preservice teachers were smiling and laughing, and these anecdotes allowed the class session to open up in a positive way.

For the third class that I observed, the teacher educator brought in a panel of teachers who worked at a local alternative education school and were there to share their experiences working with at-promise students in an alternative school. The alternative program is an alternative education placement option that is available for students who have gone through the district expulsion process, have been recently released from incarceration, or were referred through the attendance review board process.

The panel from the alternative program was brought to speak to the preservice teachers about how the school runs day-to-day, how they support students emotionally and academically, and to potentially recruit preservice teachers to work at their school. Each member of the panel emphasized the importance of building relationships with students. They stated that one unique feature of their school is their student-centered focus and attention to lessening the power dynamic between teachers and students. One teacher stated that the school is formatted very differently from traditional secondary schools, with student choice being essential at their school. They stated:

> "They [teacher and students] go on Zoom and "shoot the shit" for thirty minutes, and then the teachers ask, "Do you want to do math (or whatever subject)?", and if the students say no, the teacher does a different subject. They do math eventually, but students have the choice of when".

All teachers on the panel emphasized the importance of student choice and supporting students in feeling that they have agency over their school day, and how it is extremely beneficial to student learning at their school. One teacher elaborated that their practices are not just for students at an alternative school, but would benefit students at any school.

In the second part of the third class session, a topic emerged as a result of the Covid-19 pandemic; the preservice teachers voiced concerns about going back to in-person instruction without knowing how and if they would receive the vaccine. One of the preservice teachers expressed concerns about access to the Covid-19 vaccine, as the local school district that they worked in announced that they would be shifting to in-person instruction in approximately a month. She perceived that the university and teacher

education program were not ensuring that students would be able to get the vaccine, despite having to be in-person again. This concern was echoed by several of the preservice teachers. Dr. Lake was responsive to their concerns. She shared what she knew about the status of vaccine administration to students at the university, and shared that she empathized and understood their concerns. She then asked for their opinions on what they would like her to do, and one of the preservice teachers asked her to advocate for them. The teacher educator then opened up her email and composed an email to the teacher education department administration in order to voice the preservice teachers' concerns about not knowing about a plan for getting vaccinated, while also being expected to teach students in-person. Several times, the teacher educator asked the preservice teachers what they would like her to write in in the email, and the preservice teachers voiced their concerns; when they wanted something to be added or edited, she changed it. Once the email was completed, she stated that she emailed it to the teacher education program administration. Although this was a worrisome time for the preservice teachers, Dr. Lake listened to their concerns, did what she could to address them in the moment, and acted as a mediator between the preservice teachers and the teacher education program administration.

During the fourth class session, Dr. Lake began this class by asking the preservice teachers how they were doing, what was going well for them, and what had been challenging within the last week. Similar to when she asked them this before, instead of asking how they were doing, she asked, then allowed them time to respond, and then followed with a more specific question. There were several times when her initial question to a preservice teacher was related to a current situation in their lives. For example, to a preservice teacher with the pseudonym Turtle Dad, she asked, “Turtle Dad, how are

you….besides the car trouble?". She did this with several students and had lengthy conversations with all of them, demonstrating familiarity with not only their interests and lives in general, but with the current problems or experiences they were having that week. Dr. Lake demonstrated substantive rapport-building and community-building behaviors when interacting with the preservice teachers during the professional issues class sessions. In turn, this seemed to be an environment in which preservice teachers felt comfortable with engaging in discourse, as well as with voicing concerns that they had.

Feedback Conversations with Preservice Teachers

I also conducted observations of feedback conversations between Dr. Lake and three preservice teachers. My analysis of the conversations is centered around identifying the extent to which the three components of the justice-centered science pedagogy framework came up: antiracist and equitable science education, teaching about social justice science issues, and framing youth as transformative intellectuals.

Furthermore, this study is centered on not only what the preservice teachers have learned or communicated that they have learned or thought about, but also the advice, teachings, and learning opportunities that the teacher educator has provided. This study aims to understand not only what the preservice teachers have learned, but how the domains of justice-centered science pedagogy are taught to them. Therefore, the parts of the conversation that I highlight may be from utterances from either the preservice teacher or the teacher educator.

I conducted observations of three feedback conversations between the teacher educator and preservice teachers, Gil, Mobius, and Kim. I took detailed notes and categorized the notes into the three domains of justice-centered science pedagogy.

Antiracist and Equitable Science Education

The justice-centered science pedagogy domain that came up most often in all three of the feedback conversations was antiracist and equitable science education. Morales-Doyle (2017) noted that this refers to both addressing the NGSS and providing equitable opportunities for students to participate and access the standards.

Dr. Lake's conversation with Gil was centered largely around how Gil could elicit ideas from a wide range of students. They also discussed the importance of providing examples, supports, and learning opportunities that would lead to deep learning. A specific topic that came up was the importance of increasing the rigor of students' written work. Gil showed Dr. Lake examples of a student model that was correct, but lacked detail and could have benefitted from a more thorough written explanation. He stated, "One of the things we really encouraged with the models is that they should stand alone. . . . She drew a lot of pictures and numbers in this model. I would next time ask her to write more". This demonstrates that Gil was thinking about ways to foster high academic expectations and support students in meeting the NGSS standards and Crosscutting Concepts.

Mobius' conversation with Dr. Lake was heavily centered on fostering his abilities to teach lessons and facilitate activities that would help students engage with and comprehend the NGSS and meet rigorous academic expectations. In order to do this, the teacher educator identified ways for Mobius to shift his instruction, activities, and practices to create richer learning opportunities for students.

A majority of the conversation was centered on academic expectations and making delivery of material clear enough for students to access the NGSS. This involved discussion around two themes: First, they discussed Mobius' expectations of students and practices.

Second, as having mastery of and practice with academic content is important in being able to teach it effectively, they discussed his knowledge of the content. This feedback conversation involved many technical terms which were, for me as the observer, difficult to capture while taking notes. It was also a great amount of information for Mobius to take note of. Because this conversation involved so much information and content-specific language, the teacher educator sent Mobius and I an email in which she summarized her main points. Because this summarizes her main points very clearly, I have incorporated it into these findings; therefore, this section will have both notes from the observation, as well as the teacher educator's email to Mobius.

In the following excerpt from her email, the teacher educator posed a question to help Mobius think about ways to increase students' abilities to build on and use patterns in chemistry. Being able to accurately use patterns to determine causality of phenomena is a crosscutting concept in the NGSS; therefore this feedback addressed a practice that connected back to helping Mobius effectively teach the standards. The teacher educator stated:

> Students started to see the patterns (CCC!) of acids dissolving into anions and protons and bases dissolving into cations and OH-. This is so important, as you've pointed out! How can you build on these patterns and make sure that students become proficient in using these patterns to recognize acids and bases on the molecular level? We also discussed how you want them to understand that the underlying molecular structure (which they can't see = unobservable) is causing what they can see (what they've already experienced about acids and bases = observable

> level). This connection between unobservable and observable level is hard for students to make, you started it well, keep going!

It is also important to note that the teacher educator not only provided feedback here, but also acknowledged that Mobius was on the right track and provided words of encouragement: “You started well, keep going!”.

To support students in accessing the standards, the teacher educator also suggested that Mobius try to think through the material as his students would, in order to help him think about possible student misconceptions beforehand, and to really identify exactly what students should know at the end of the lesson.

> [During the feedback conversation], I tried to model how you can take a student's perspective and think/explain the main ideas as a student would do. It helps to distill the main ideas you want students to take away and also to recognize "sticky" points.

The teacher educator further provided guidance to Mobius for supporting students in accessing content-specific, rigorous texts. She stated:

> It has been shown that vocabulary, definitions and reading texts are better provided after students have built some conceptual understanding of the materials. So they can link their understanding of the reading and what they have experienced already (simulations, experiments, activities) to make better sense of both.

Dr. Lake’s conversation with Kim was conducted in order to provide support for her in lesson planning; thus, Kim brought a lesson plan and corresponding PowerPoint for the teacher educator to look over. In her feedback conversation with Kim, the main justice-centered science pedagogy topic was maintaining high academic standards, and they

primarily discussed ways that Kasey's lesson planning could be improved in order to make content more accessible to all students.

Kim was teaching a lesson on energy and respiration; before starting the lesson, she was planning to have students predict what energy and respiration were and have students type predictions in the chat. The teacher educator suggested that students get up and do jumping jacks as a more interactive way to engage them and authentically introduce the concept. To connect the jumping jacks to the academic content, the teacher educator suggested to then ask students, "Why do you think I'm breathing harder?" and take student responses. Then she suggested asking, "What is transporting the oxygen? Here, the teacher educator suggested to address the concept with something fun, and then bring in the standards.

The teacher educator made an additional suggestion about best practices in introducing a new topic: to make it more specific and something that is relevant to their lives. She suggested the question, "How do athletes get the energy to do their sport?", as an example. Dr. Lake then brought up ways that Kim could get more of her students engaged and involved during lessons. She asked, "Can you cold call your students?". Kim expressed that she was hesitant to do so (primarily because she did not like the experience of being called on when she was in school), the teacher educator suggested first practicing cold calling about something related to the academic content, but not academic (i.e., "Do you need to eat before you play a sport?"). Or, for an even more low-pressure way of cold calling, she suggested telling students, "Choose A or B and then we'll all enter it at the same time ". Kim then stated:

Kim: I still feel like that won't work.

Dr. Lake: Then do it again. Say, "Oh man, we only got two students! Let's do it again!" Do it three times if you need to.

Kim: It just feels like pulling teeth.

Dr. Lake: It doesn't *feel* like pulling teeth – it *is* pulling teeth. [both Dr. Lake and Kim laugh]

Kim: I just don't like cold calling because I hated that [as a student]

Dr. Lake: Ask nicely. Tell them that you're going to call on someone. If they can't answer, ask them to call on someone else.

Kim: Ok, I'll try that.

In this excerpt, Dr. Lake empathized with Kim by acknowledging that cold calling may feel difficult, but is important in order to get as many student voices in the discussion as possible.

Teaching About Social Justice Science Issues

During the feedback conversation, social justice science issues were not explicitly mentioned. However, when discussing Greg's lesson, the teacher educator asked how the academic content could be connected to other areas of science or to students' lives in general (he had only connected the standard to a unit on the Serengeti). Greg responded by stating that he talked about this with his cooperating teacher and wanted to figure out more ways to connect the standard to students' lives.

While this is not considered teaching about social justice science issues, questions such as, "What is relevant to my students' lives? How can I connect the content to something my students have seen or experienced?" are a stepping stone to identifying social justice science phenomena that will resonate with students. Therefore, while there was no

direct mention of social justice, this seemed to be a question that was important when thinking about planning for social justice science instruction.

Youth as Transformative Intellectuals

As stated previously, this domain of socially-just science instruction includes the relationship-building skills that are necessary in order to have a trustworthy, inclusive class community that supports each other in their learning, and can also debate respectfully and express varying viewpoints (Emdin, 2020). Another preliminary skill that is necessary to frame students as producers of knowledge is the ability to engage students in discussion and orient students to each other's thinking. Both are necessary in order for students to feel comfortable and empowered enough to not just simply learn academic content and share their cultures, but to engage authentically with ideas that mean something to them.

In the feedback conversation, Gil discussed that he had tried a new strategy to facilitate discussion and accountability between students, called a peer review. In a peer review, students examine each other's work and provide feedback about the aspects of the assignment that students did well on, as well as provide suggestions, questions, or things to consider to improve their assignment. In the following excerpt, Dr. Lake asks about how the peer review went.

> Dr. Lake: How did it work with the peer review?
>
> Gil: It was kinda awkward, and I had to tell them how to do it.
>
> Dr. Lake: I think peer review is a really great strategy. But they haven't done it before, so they're afraid of criticizing each other. So they have to learn it.

The teacher educator validated Gil's belief that peer reviews are awkward, and provided an explanation as to why peer reviews may be hard to facilitate initially; students have to

provide constructive criticism to each other, which can be difficult to do if students do not want to hurt each other's feelings. Nonetheless, the teacher educator maintained that being able to provide feedback and provide their perspective in a kind, respectful way is important, and being able to take constructive feedback is important to engage in science authentically. During the conversation, Mobius brought up a highlight of his day; a student had talked to him, referred to by the pseudonym Armando. Mobius stated:

> Mobius: Today a student chatted with me for the first time, Armando.
>
> Dr. Lake: Maybe he's getting it, or something is connecting with him?
>
> Mobius: I have no idea why he chatted today. I've never even seen his name [on Zoom].
>
> Dr. Lake: When you chat, he doesn't answer?
>
> Mobius: No, he doesn't.

They moved on to a different topic, but Dr. Lake later returned to this topic to discuss how Mobius might build a relationship and help Armando feel like a part of the class community, even if over Zoom. She stated, "Tell Armando in the chat, 'Armando, I was so glad to see you in the chat!'. In order to get to him [the message] – 'I see you'." Mobius later mentioned that another student was participating, and what he did to encourage that: "A student who was participating a lot…today, I really tried to acknowledge that she was participating and highlighted her answers." Dr. Lake encouraged the preservice teachers to bring all students into the discussion, build relationships, and demonstrate care for their students; and really emphasized this with Mobius as related to his interactions with Armando.

Conclusion

This set of findings described ways that the domains of justice-centered science pedagogy were actually enacted through course materials, content taught in the professional issues classes themselves, and in feedback conversations. While all domains of justice-centered science pedagogy were present in the professional issues classes, class resources and materials, and feedback conversations, some of the domains were more prevalent in certain activities. Social justice science issues did not come up frequently in feedback conversations or in class, but were by far the most prominent learning resources on the class website. The professional issues classes discussions were often centered on building relationships and interacting with students positively, both in regards to the preservice teachers' interactions with their students, and the teacher educator's interactions with the preservice teachers. The feedback conversations tended to focus more on the academic expectations domain of justice-centered pedagogy, as the teacher educator frequently discussed the development of skills that are necessary to teach science effectively.

Chapter V: Findings Set 2

Teacher Educator's Understandings and Experiences of Teaching Preservice Teachers Justice-Centered Science Pedagogy

To understand Dr. Lake's beliefs and experiences of teaching reform-based, justice-centered science instruction to the preservice teacher participants, I analyzed data from my interviews with her. I interviewed the teacher educator three times; these interviews occurred in December 2020, February 2021, and June 2021. I coded each interview for segments of the interviews that aligned with the three domains of justice-centered science instruction (Morales-Doyle, 2017), and then compared the coding across all three interviews. The three domains of justice-centered science pedagogy include (1) antiracist and equitable science education (2) social justice science issues, and (3) youth as transformative intellectuals. To support the findings, relevant interview excerpts are also included.

Overall, I found that Dr. Lake's discussion of equitable science education and supporting student access to the NGSS were discussed equally in all three interviews. While discussion about planning, teaching, and grappling with social justice science issues did not come up in the December interview, it came up six times in the second interview, and twice in the interview conducted in June. Topics on youth as transformative intellectuals (and fostering trust and relationships that are required for that) were discussed once in the December interview, three times in the February interview, and four times in the June interview.

While the teacher educator discussed several topics that aligned with the domains of justice-centered science instruction, there was also lengthy discussion on the topic of remote

instruction, and its impact on her perceived ability to effectively instruct and positively interact with the preservice teachers. Teaching about reform-based science instruction is an involved process; in this teacher educator's situation, the remote instruction context presented limitations in what could be taught, how topics could be presented to best fit the needs of the cohort, and sometimes impeded communication between the teacher educator and preservice teachers. Furthermore, a teacher educator's role is to work closely with the preservice teacher to guide them toward becoming an effective teacher, and facilitating this competence often requires giving constructive criticism, as well as facilitating an environment in which preservice teachers (with numerous stressors) can learn together (Ellis & Loughland, 2017). These tensions were exacerbated due to extra stressors that can be attributed to distanced communication due to the Covid-19 pandemic.

The following sections are divided into the three components of justice-centered science instruction. Substantive topics that emerged during interviews will be presented under the relevant component of justice-centered science instruction.

Antiracist and Equitable Science Education

One topic that was present throughout all of the interviews with Dr. Lake were the ways in which she supported the preservice teachers in building the skills to enact antiracist and equitable science education that is accessible and relevant to all students. In science classrooms, reform-minded teachers should recognize that science knowledge is an iterative process constructed in a social context, is centered on sharing and modeling ideas grounded in evidence, and that the generation of scientific knowledge builds over time as evidence and students' revised ideas emerge; thus, teachers must be able to facilitate an environment in which students justify their reasoning and build on others' ideas to move toward an

understanding of the NGSS performance expectations (Bradbury, 2010). This is complex work, which novice teachers often need support in from a teacher educator and cooperating teacher, in order to grow in their reform-based teaching practices.

All three interviews demonstrated that the honing of reform-based teaching skills was a top priority for Dr, Lake. She expressed that the primary way in which she supported preservice teachers in effectively teaching the NGSS was through the use of constructive feedback on their teaching practices. A common practice in teacher education, Dr. Lake stated that she would observe a preservice teacher while they were teaching a lesson, and then meet with them afterwards to discuss what they did well, as well as provide suggestions for improvement. She also stated that she engaged in other feedback activities, such as reading through a preservice teacher's lesson in order to identify ways to modify the lesson to better meet students' needs. Another way that she supported preservice teachers in their growth was through feedback conversations (she referred to them as "one-on-ones"); Dr, Lake viewed one-on-ones as a crucial part of developing the skill set to effectively enact reform-based science instruction. Despite the different terminology, "one-on-ones" are analogous to feedback conversations and was the term that Dr. Lake used; however, both "one-on-ones" and "feedback conversations" are used interchangeably in this section.

In interviews with Dr. Lake, I asked her to speak about the nature of the feedback she gave to the preservice teachers and how she felt they benefitted both her and the development of the preservice teachers. In the January interview, she expressed that one-on-ones were valuable because they gave her a chance to see the wide array of skills and opportunities for growth for each preservice teacher:

> Even only having nine teacher candidates, the span of who they are and what they can do is reflected in the one-on-ones. And that's why I like to do the one-on-ones, because I really, that's what I miss, going out in schools, because then I have a little bit more time.

In this interview, she also expressed that she supported the preservice teachers by targeting the most high-leverage needs, the areas that were most urgent for being able to teach science in reform-based ways. Dr. Lake discussed her approach to delivering high-leverage feedback during the one-on-one feedback conversations.

> I really try to be very diagnostic, like what they need *right now*. What is the biggest bang for the buck, right? For them to work on, because there's, of course, so much they could work on, but what is really the one central thing that really [would make a difference]. . . . and for some, it's the content, to really think through the content that they are teaching. . . . you know, it's a coaching philosophy that you never *tell* your students, you always ask them and you know, make them think about it, and then you say, "Okay, I have half an hour, do this, this, and this because I know it works". And I think actually when I coach, students explicitly said, you know, thank you for actually telling me what I can do because I freak out, and I know I need something, and there is a solution, and some people [supervisors or cooperating teacher] don't give it to me.

Dr, Lake stated that her approach of being more directive was not intended to tell preservice teachers what to do necessarily, but was instead meant to support them and alleviate the potential pressure of simply not knowing what they need to work on. A common approach to delivering feedback is for the teacher educator to open up the conversation by asking the

preservice teacher what they think they need to work on, and then to provide wait time to let them think about it and identify a part of the lesson that they would like to work on (Snead & Freiberg, 2019). While this can be viewed as a way to give preservice teachers autonomy and give them a more significant role in determining their next steps, Dr, Lake stated that this practice can sometimes cause the preservice teacher undue stress and confusion over not being able to identify what parts of their lesson need to be improved. Dr. Lake attributed this to their novice status, and the fact that they were still learning and might not yet have a clear vision of what it would look like to enact best practices, and they might not even be familiar with best practices in the first place. Furthermore, being able to reflect on one's teaching while teaching in-the-moment is a complex skill, and it can be easy to not notice missteps in one's teaching even after the teaching episode; this requires experience and metacognitive decision-making and awareness (Griffith et al., 2016), which they may not have developed yet. Dr. Lake also discussed that the preservice teachers' absolutely had ownership over what they chose to target as the most high-leverage need, and that next steps were co-constructed with them. In the June interview, the teacher educator stated the feedback conversation is " . . . a combination of really asking them what they want to work on and what their struggles are. But give them a few really concrete things to work on, and that can be developed together."

Further, the teacher educator talked at length about the limitations of facilitating these feedback conversations in the context of remote instruction. She stated that the primary issue with this was that when she provided feedback on their teaching practice, she would provide feedback both for the immediate online setting, while also considering that they would need preparation and guidance on teaching in-person as well, as they would have

to do so once social distancing guidelines were lifted. Therefore, giving feedback that was more applicable to teaching in-person did not feel as relevant; a hypothetical example she gave would be advising a preservice teacher to use a strong, dynamic voice; while this is may not be as applicable to the online setting, it is certainly important when one is teaching in a large classroom with a lot of activity going on. However, without a classroom environment to connect that strong voice feedback to and authentic opportunities to implement it (and then see the results), her feedback would not be as meaningful. Thus, advice she gave about the in-person specific classroom context felt difficult because she knew that there was not an in-person context that they could think about, envision how to apply it, and then actually apply it. While several of the preservice teachers had prior work experience as teachers, substitute teachers, or teaching assistants, some had no teaching experience. If they had been learning how to teach in an in-person classroom environment, the teacher educator stated that it would have given them a reference point, a context which they could think about and directly apply the feedback to. She stated that actual in-person classroom experiences and interactions with students would have made her feedback more relevant and meaningful. While she was able to give online feedback about their teaching on remote or hybrid instruction, she was not able to be there and actually show them, which the following excerpt demonstrates,

> It's hard for them to take what you tell them, methods and strategies, and imagine that in the classroom. If you have experience, you take it, and immediately put it in a scene you're familiar with. If you don't have that, it's hard to translate.

She also noted that, without in-person interactions, she was less able to model and clarify what she meant by her feedback. In previous years, she would have given feedback

and then demonstrated the practice for the preservice teacher; for example, she might have demonstrated what it looked like to circulate the classroom and ask questions in order to monitor students' understanding. While she could have done this for remote instruction, it lacked applicability and relevance. The fact that many students in their classes had their cameras off and did not participate often further caused the feedback to feel less meaningful. This limitation is described in the following excerpt:

> Because there are so little interactions [on Zoom], and so little often going on, it's hard to show them alternatives [to their practice]. And for me, it's also, I'm learning with them. What *I* do as a teacher, I cannot do online, I cannot show them. And I cannot move around in the classroom. I cannot get them to move too. I'm still figuring it out. It's really hard on Zoom.

To summarize, the teacher educator viewed supporting preservice teachers in effectively and equitably teaching the NGSS as one of her top priorities. One of the main ways that she attempted to do this is through observing their lessons or reading lesson plans, facilitating a feedback and next steps conversation, and providing demonstrations of the practices on which she gave feedback. While she tried to support preservice teachers in teaching students NGSS content and practices, she expressed that it felt significantly more difficult to help them grow in their abilities to execute reform-based practices and effectively teach the NGSS, given the lack of an in-person classroom environment.

Teaching About Social Justice Science Issues

The teacher educator also viewed teaching preservice teachers about social and environmental justice issues as a central part of her role. One sentiment expressed during interviews was her reflectiveness and desire to "do more" to support the preservice teachers

in making environmental justice topics the anchoring phenomena in their lessons. While she acknowledged that she provided social and environmental justice resources on the course management page, and discussed these topics during the professional issues course, she conveyed that she wanted to provide more for the preservice teachers.

> So last time [class] we talked about environmental justice. And that's what I want to focus on more, because a big part of racism is environmental injustice, if you look at our cities and country. The other thing is, of course, not just racism, also classism. We could also see these things in poor white communities. That's another layer. That's something I really need to bring in more. . . . I have an idea to very consciously bring in science examples that are non-white and reach across America.

In addition to providing more instructional activities and resources centered around equity, antiracism, and environmental justice, the teacher educator also shared that, in the future, she would like to give the preservice teachers more ownership over the environmental justice topics that were discussed in class; to accomplish this, she hoped to have one of them bring a topic each week to discuss with the cohort at their professional issues course. She also shared that she wanted to bring more community members in to talk with the cohort, or arrange more trips for the preservice teachers to engage with organizations centered on environmental justice in the community.

Dr, Lake shared that teaching about and facilitating opportunities for preservice teachers to learn about social and environmental justice was difficult, and there were aspects of this that she would have done differently in retrospect. She shared that she had originally wanted to ask each preservice teacher to bring in a social/environmental justice topic (related to science) to discuss each week, but she was not able to follow through with this

idea. She also discussed that integrating justice-oriented pedagogy was difficult simply because there are so many facets within justice-oriented pedagogy and many avenues to which one could devote their energy. She stated that she struggled with knowing where to allocate her energy the year the interview was conducted, and felt she might struggle with this in the following year as well. She then thought about it and stated that her impact would be science-specific.

> I will make it [justice/antiracism work] very science specific. Because, I have to realize mine [my focus] is in science. And it's enough to teach them [preservice teachers] to teach [justice-oriented] science well, so that all students have access to science and feel that they are capable of doing science and understanding science.

Similarly to the previous section, the teacher educator also discussed the ways in which the remote instruction context limited preservice teachers' opportunities to apply their learnings about social and environmental justice to their classroom experience. Teacher education courses provide a setting for preservice teachers to challenge their prior understanding of justice and consider critical viewpoints; however, sometimes the theories and approaches that preservice teachers have learned cannot be easily applied in their classrooms (Burke & Collier, 2017). Simply learning and theorizing about justice and equity does not necessarily translate to what happens in the classroom; individuals need the opportunity to witness these complexities and grapple with how issues of justice manifest in their classrooms, and then have the experience of navigating those situations and learn from them. With many of the preservice teachers having only remote instruction as a reference (the aforementioned quote from Dr, Lake was from December, when classes were all remote), without a concrete, in-person context in which they could directly apply or make

sense of their newly-acquired knowledge, their knowledge might feel less relevant. Moreover, Dr. Lake expressed repeatedly that an important way to combat inequity in the classroom was to make all students feel acknowledged and seen; however, in a remote instruction context, with many students' cameras off, this was not as easy to accomplish. In the following excerpt, the teacher educator described how a significant part of addressing inequity is having the ability to notice students and bring them into the discussion, which is a skill that she stated was hard to accomplish in a remote context.

> Right now, it's so frustrating because our teacher candidates see things we talk about, they see everything as two-dimensional right now, so they don't really see the real oppressive, unjust things that are going on in a classroom. The students who are the least served, it's harder to get them going online, because you cannot have that person-to-person, human-to-human interaction. . . . Just looking at somebody, having a little smile that shows "I see you, I see you're quiet. And I see that the others are all talking over you. I see that and I will help you". And, you know, all that you can do with body language [in person].

The teacher educator elaborated on this idea of intentionally bringing students into the conversation, and began discussing this idea of being cognizant about including students every opportunity a teacher gets. She referred to this as *microinclusions*, and discussed this as almost the opposite of *microaggressions*, which are subtle acts of racism that typically occur over time. She discussed that a number of scholars examine the concept of microaggressions, and became interested in what a counter action to that would be. She stated that if microaggressions are a way of excluding and being aggressive based on race, and that is wrong and the action to not do. she wanted to know what teachers *should* do. She

expressed that being intentionally welcoming, to include all students, especially the ones who may not participate, or who you know are quieter, might be the way to foster a culturally responsive and inclusive classroom environment. She elaborated:

> *Microaffirmations* is the word you find in the literature, but I've never found the word *microinclusion*. Yeah, and I think that's what we have to work on very consciously. Where are the moments where we can orient students to each other, they can support each other, they can pick something somebody has said, and not "make it my own", but really acknowledge ownership . . . . And honestly be interested in what somebody else is saying, going back to this person, and not always, you know, having some person who is most eloquent saying something. Coming back to the floor, you know, having this person's last word, or, you know, it's really making them [preservice teachers] aware where they can include [students].

While she expressed that the preservice teachers were enthusiastic about this work and making efforts to intentionally include all students, she stated that one barrier to discussing social justice issues deeply with the teacher candidates was a lack of clear communication and the difficulty of having conversations centered on race and racism. Dr. Lake shared an example of a preservice teacher who, from her perspective, accused her of being racist due to a misunderstanding during class. For context, during a class session, Dr. Lake asked the preservice teachers about any difficulties that they had been experiencing with teaching remotely:

> I had one situation. . . . I asked about, you know, troublesome [classroom] situations…what they struggled with online. [A preservice teacher shared that] he

had a student, and he had his camera on, but the student had a baseball bat in his hand, and was kind of doing this [waving baseball bat motion] like for five minutes or something, or even longer. And he [teacher candidate] didn't know, he was just, you know, he wasn't really leading the class, and his [cooperating] teacher wasn't doing anything about it and he felt really uncomfortable, but didn't know what to do with that, and how to react, you know, and how to even interpret that. And then, I tried to give some different ways of interpreting that. And one of my things was, "You know, either this student was just bored, and just wanted to do something and he's a baseball player. But, it could also be that this is a threat to somebody". And then one of my teacher candidates came at me and said, "Where did that come from? How could you think something like that?". And I'm like, "Where is this coming from?". I was totally shocked. And then the class was out. So that was the worst part. Later, one of my teacher candidates is from Denmark [pseudonym for other country]. He talked with her and said, you know, you must understand that for us, in Germany, and in Denmark, a baseball bat is like when somebody would bring a gun out and show that on the video, you would freak out. In Germany and Denmark, we would probably think it's a toy gun. But for us, a baseball bat is, for me in Germany, and he explained something what it means for him in Denmark and for us in Germany, it's a sign of the neo Nazis.

To summarize, when the preservice teacher shared that the student was swinging the bat and he did not know what to do, Dr. Lake opened up the conversation to the preservice teachers to ask how they might interpret that and what they might do in that situation. When she brought up the possibility that it could possibly be a threat to someone (she shared that, in

her culture, baseball bats are associated with neo Nazis), another preservice teacher questioned why she would think that about a student, and Dr. Lake inferred that the preservice teacher presumed that the student was Black and that she was saying that the student was threatening.

The teacher educator continued, explaining that to engage in ongoing work on antiracism and justice, it was critical to also cultivate the ability to really listen, communicate about difficult topics, ask questions, and attempt to understand what individuals actually mean, rather than what one assumes.

> So that's a cultural thing, you know, and this is what we have to work through…what this really shows, these are the *real*, cultural things that clash when we don't listen to each other and *ask* what we assume. You know, she assumed, of course…I'm a racist. And what I want to ask her is, "What did you see? Who was the student you imagined?". And she probably imagined it was a Black student. And I imagined a White student. So even so, all these layers, pictures for certain things, for certain instances, little instances, what kind of pictures they create in our mind, that triggers how we react. Also, I didn't react correctly, right? I should have said, “What makes you react like this? Can you explain what you think I meant? What did you hear?”. You know, it's this idea of, and I could have used that, but time was out, that was not a good thing. But I could have used that and said, “Okay, this is an instance, where what I say, and what I mean, and what you take away, are very, very different than it looks”. [pause] These are actually nuggets that you wish for, and you wish you could make more of a learning event around.

Dr. Lake shared this experience to highlight the complexities of navigating difficult conversations about race and racism. She recognized that the preservice teacher was trying to do the right thing by calling out what she perceived to be racism, but that it is also critical to ask for clarification and try to understand other's interpretations of events in order to truly understand where people are coming from. Situations such as these come up in classrooms, and Dr. Lake expressed not only the need for clarification, but the need to highlight these situations and show preservice teachers how they might navigate them, which she did not feel that she successfully accomplished.

Youth as Transformative Intellectuals

With regard to the last component of justice-centered science instruction, two significant themes that emerged during my interviews with the teacher educator were the ways in which she taught preservice teachers to position students as competent and their ideas as valuable and necessary to advance class discussions. She also shared how she supported preservice teachers in building the relational environment to cultivate students' willingness to share diverse ideas, and fostered an environment in which even "wrong" answers are seen as necessary, valuable, and important to advancing and building on others' ideas and lead to a deeper understanding for all students in the class.

As stated previously, this domain of socially-just science instruction includes the relationship-building skills that are necessary in order to have a trustworthy, inclusive class community that supports each other in their learning, and can also debate respectfully and express varying viewpoints (Emdin, 2020). Another preliminary skill that is necessary to frame students as producers of knowledge is the ability to engage students in discussion and orient students to each other's thinking. Both are necessary in order for students to feel

comfortable and empowered enough to not just simply learn academic content and share their cultures, but to engage authentically with ideas that resonate with them.

The teacher educator felt that building an emotionally-supportive class community was a strength of the teacher candidates, and shared that she put forth effort in helping them to understand the importance of knowing students in an authentic way. When I asked for an example of what she shared with the preservice teachers, she stated:

> Learning to know individual students. That's what you do the whole day, when they come in the classroom. Just, how do you attend to different students in different ways? And there are so many ways. It's a half smile. It's a wink, just saying "I see you". Taking them to the side, the conversations in between, [and] the conversations in the hallway.

She also shared that she witnessed this disposition in the preservice teachers' instruction and interactions with their students. In a subsequent interview, when asked to identify something that she felt they were excelling at, that they would take away front their work with her, she stated:

> Emotional support for the students. So not just doing content, but really taking time to check in with their students, and how important it is to start a lesson on a good, open, even fun note to bring them, bring them slowly to the content. That might be something that they take away.

One foundational part of reform-based science instruction is that teachers should be able to elicit students' ideas about science content and facilitate an environment in which students work with each other's ideas. Throughout the interviews, the teacher educator discussed that creating this context, where students feel comfortable sharing their scientific

ideas, requires that students feel that they are an important part of the classroom, and that they feel welcomed and understood by their teacher. Furthermore, she stated that students need to feel that their ideas are important, even if they are incorrect. During several points in the interviews, the teacher educator referred to student ideas as the real academic content, and that she worked to support preservice teachers to use students' ideas as launching points for discussion, and to build on and connect ideas to create rich scientific understanding that is relevant to students.

The teacher educator was also an advocate of using Ambitious Science Teaching, a repertoire of instructional practices meant to elicit students' ideas, engage them in model-making, root instruction in relevant anchoring phenomena, and foster rigorous sensemaking and explanations about science. During my June interview with her, she described the framework, and explained how it is connected with creating a relational, supportive learning environment:

> [She showed me the Ambitious Science teaching framework.] I put "working together with and on students' ideas" in the center, because we were thinking about bottleneck ideas, so, the hardest ideas for the students. I think for candidates, really the hardest part is that it's not about their own thinking, because they're still the learners, but it's really about the ideas of students. They are the raw material we work with, you know, it's a clay we form. That's what everybody's working with. It's not our ideas, it's not my PowerPoints, that's not what we work with. We work with students' ideas, so I put it in the center. So and then I put a big circle around and building a safe and supportive knowledge-creating community. So really, to how you start out and really have these building norms and have these as the overlaying

> prerequisite. And that enables the work, but this work also enables a safe knowledge-creating community. So it's not either/or; it goes together. You cannot do the one without the other.

The teacher educator also shared the importance of providing anchoring phenomena to give students something to connect their ideas to, to make science issues relevant to their lives, and motivate students to share and generate ideas. The concept of anchoring phenomena is fundamental to ambitious science teaching and the NGSS. The teacher educator described the process of eliciting and building on student ideas in the excerpt below:

> You need to get students' ideas out into the open. You have to make them visible and audible. And to make them visible, what we do is we have anchoring phenomena in the beginning. You know, I did with my students is like, ocean acidification, and then really ask them what they know . . . so to really honor where they are coming from. . . . but you have to listen. Teach your students and yourself to listen for understanding, so that you listen to try to understand what they really mean, independent of what words they're using. And there's wonderful literature about that. Do you know [the article] "The Coat Traps All The Heat?" It's one of my favorite pieces. It's about an elementary classroom. And they tried to teach them thermodynamics. But it's like, they don't give them the words. And the students come up with their own words to describe and explain things. I've seen that work in a classroom, when students become empowered to create their own ideas and not afraid what's right or wrong. And in the beginning, when you elicit students' ideas, it's very clear the rule is that nothing is wrong, everything is a good idea, even if it's a crazy idea. And then students start to play with their ideas and trust that they can

> have ideas. And that's exactly what scientists are doing . . . they throw ideas out so that they can find nuggets in there that can push them further in thinking, outside what they have thought so far, and that is something every student can do. And I think that's an atmosphere you have to create in your classroom: your ideas are important. And for me the most important ideas are wrong ideas, I love them. And I show that because I'm like, thank you, this is so great, because now we have something we can work on. It's a gift to the whole class . . . but that really exists to create this safe classroom, where each idea counts. And then you learn to listen in and then you learn to appreciate ideas that are different from the norm. And with that you have a more just classroom because the ones who are normally marginalized, their ideas, or their way of saying things, their value is not diminished.

In the above excerpt, the teacher educator described creating a classroom culture in which every student's ideas are valued and treated as resources for learning, regardless of whether they are correct or not. By teaching preservice teachers the importance of creating a classroom environment in which all ideas are seen as valid and respected, they may understand the importance of modeling that behavior themselves. Optimally, she stated, they would not only model this, but would have discussions with students about the importance of respecting their peers' ideas, create discussion norms, and reinforce these norms on an ongoing basis.

To summarize, in order for justice-centered science instruction to be enacted in a classroom, it is imperative that the teacher and students have positive, authentic, and trusting relationships. For students to feel that they are producers of knowledge and culture, they must be willing to take risks and share their ideas. They should also be able to honor other

students' ideas. A culture of acceptance is conducive to students feeling that they can experiment, create, and explore their interests, cultures, and academic content in a way that resonates with them. The teacher educator provided modeling and encouragement on how to do this.

Overall Limitation: Decreased Ability to Check-in with Preservice Teachers

To repeat what was discussed in each section above, there was one limitation discussed in the teacher educator's interviews that, from her perspective, hindered her ability to effectively teach and build strong relationships with the preservice teachers. She stated that the online environment, by nature, was a barrier to connecting and communicating with the preservice teachers. When she brought up issues or tried to check in with preservice teachers in previous years, in an in-person classroom, she found that there were many opportunities to do this, the interactions felt casual, and she was easily able to communicate with preservice teachers. However, in an online classroom, she stated that it felt much more significant to ask a preservice teacher if they could talk, meet, or to even email them. A simple check-in suddenly had the gravity of a full-on meeting, which lent a formality to an interaction that did not need to be formal (thereby making it awkward or just causing it to feel more serious).

According to the teacher educator, these interactions had implications beyond simply being a little awkward or feeling too formal; they were a barrier to preservice teacher learning. The different tone to the discussion caused a rift in communication, hindering her abilities to build or strengthen relationships, give feedback, solve interpersonal problems, and clearly communicate with the preservice teachers. She stated that this communication and connection limitation affected her abilities to teach justice-centered science instruction,

support them in maintaining equitable academic standards and skills in teaching the NGSS, teach social justice issues, and frame students as transformative intellectuals. Because this limitation had an effect on various aspects of her interactions with preservice teachers, and thus could not fit in one domain, I included it in its own section.

Chapter VI: Findings Set Three

Preservice Teachers' Understandings and Enactment of Justice-Centered Science Pedagogy

An aim of this study was to describe preservice teachers' opportunities to learn about and enact justice-centered science pedagogy; to understand this, I analyzed data from interviews with the preservice teachers. By studying their perspectives and triangulating those with the content and learning activities that they engaged in, I aimed to gain a thorough understanding of what learning opportunities were present, what aspects of justice-centered science instruction were taken up more than others, and which domains were not as prevalent as evidenced by their interviews.

The interviews with the preservice teachers included questions about a wide range of topics related to secondary science teaching; major topics included questions about the NGSS practices and cross-cutting concepts, instruction for emergent multilingual learners, their experiences with remote and hybrid instruction, their visions of effective science teaching, and strategies and supports that would help them further develop their teaching skills. It is important to note that the interview protocol did not explicitly contain questions about the domains of justice-centered science teaching, which include (a) antiracist and equitable science education, (b) social justice science issues, and (c) youth as transformative intellectuals. Although these domains were not explicitly referred to, many of the interview questions were broad, with the intent of capturing ideas and experiences that were most meaningful to the preservice teacher. One example is the following question: How have your views of effective teaching changed since starting the teacher education program? Depending on the preservice teacher and the topics and issues they cared most about, or

events that had significance, this question could have been answered with reference to any of the three domains of justice-centered science teaching. In sum, while the preservice teacher interview protocols did not explicitly address justice-centered science teaching, many of the questions could have elicited a wide range of responses on one or more of the domains of justice-centered science pedagogy.

Overview of Preservice Teacher Responses

The preservice teachers' interview transcripts were coded to identify aspects of justice-centered science teaching that emerged during the interviews. I coded all of the interviews in order to identify which preservice teachers discussed justice-centered science teaching most frequently, and whom discussed each domain most frequently. Before presenting these data, it is important to note how I determined what utterances to code. There were several times during the interview when the preservice teachers were asked questions about how they used the NGSS in their classrooms, and were provided with a slide that displayed all of the NGSS practices and crosscutting concepts, which they could then select to respond to. During my coding, I was looking for sufficient depth in their responses about NGSS; therefore, if the preservice teacher simply stated a one-word answer with very little elaboration, I did not code that as *Antiracist and Equitable Science Education*. Ultimately, my intent was to understand what they had learned about the aspects of justice-centered science teaching; while brief answers certainly suffice, they did not necessarily indicate a depth of thinking about and applying justice-centered science teaching to their teacher education courses or placement classes, which is what I was trying to identify. Therefore, I coded any excerpts that brought up the NGSS, framed students as transformative intellectuals (including building relationships and the safe classroom

environment which is conducive to this), and any mention of social justice science instruction or explicit reference to addressing inequity and justice in the classroom. In the next section, I will present a table displaying the frequency with which the preservice teachers discussed justice-centered science instruction.

Table 4

Overall Discussion of Justice-Centered Science Instruction

Preservice teacher	Initial	Fall	Winter	Spring	Total
Rachel	33	50	48	46	177
Turtle Dad	24	31	43	33	131
Sawyer	29	28	30	34	121
Liam	21	20	39	34	114
Stella	22	28	15	33	98
Gil	21	23	21	31	96
Kat	17	22	24	27	90
Mobius	10	22	20	33	85
Kim	14	26	n/a	n/a	n/a

The preservice teacher, Rachel, discussed aspects of justice-centered science teaching substantially more often than the rest of the preservice teachers, discussing these aspects a total of 177 times. Turtle Dad, Sawyer, and Liam also brought up justice-centered science teaching more frequently that the rest of the preservice teacher participants. In order to understand the content of their ideas and use of justice-centered teaching, I established them as focal participants and provide more details about the content of their interview responses in the following section.

To elaborate, I identified five focal participants. I wanted to have a diverse group of preservice teachers; however, the cohort was primarily White, English was their first

language, and they were not first gen college students. Because of this, I included the preservice teachers that did have more diverse backgrounds; Sawyer identified as a Mexican-American, and was a first gen college student; therefore, I included him in the focal group. Liam identified as Japanese, his first language was Japanese, and he was also a first gen college student. Further, Mobius was included as a focal participant because he was a multi-lingual learner; his first language was French. Another reason for including Mobius was that, while he discussed justice-centered science teaching the most infrequently, he also showed the most growth in discussing aspects of this framework from the initial interview to the interview conducted at the end of the school year. Rachel and Turtle Dad were not considered to be preservice teachers of diverse backgrounds; however, they were selected because they most frequently brought up aspects of justice-centered science teaching in their interviews; because of this, I wanted to understand their experiences more deeply, and what caused them to discuss justice-centered science pedagogy more than others.

In regards to the frequency with which each domain of justice-centered science teaching was discussed, *Antiracist and Equitable Science Education* was discussed 636 times, substantially more than *Youth as Transformative Intellectuals* (290 times) and *Social Justice Science Issues* (24 times).

While social justice science issues were not discussed frequently, culturally relevant teaching and equity were discussed much more frequently. I note this because it is important to see preservice teachers from an asset-based perspective (Gray et al., 2022); working with their strengths does more to support them than focusing on deficits, or the infrequency with which they brought up social justice science teaching. In the interviews, it was evident that culturally responsive teaching was a priority to many of them, they learned about this in

their teacher education program, and they expressed that they wanted to learn more. While culturally relevant teaching and equity are not analogous to justice-centered teaching, they are create an environment in which justice-centered teaching can occur, and are a step in the direction of social justice teaching. Therefore, while the low number of instances in which social justice science teaching might suggest the preservice teacher participants were apathetic or neutral about these issues, the interviews contained indicators of a desire to foster a culturally relevant and equitable classroom environment, and a desire for ongoing learning in this area. Mentions of culturally relevant environment and equity from the preservice teachers tended to orient more toward creating a classroom environment in which students had agency and felt that they could discuss their ideas openly; because these aspects more closely aligned with youth as transformative intellectuals, so they were coded as such.

In the following section, I discuss how each of the three dimensions of justice-centered science pedagogy were discussed in the interviews with the preservice teachers. The section is organized into sections for each domain of justice-centered science pedagogy. Under each section, the interviews will be listed chronologically, from the initial interviews, fall, winter, and finally, spring.

Antiracist and Equitable Science Education

Initial Interviews

The initial interviews with the preservice teachers took place while they were taking summer courses in the teacher education program; however, they were not yet teaching in their placement classroom. While preservice teachers teaching in an in-person context might express general apprehensions about teaching, this group of preservice teachers had the added uncertainty of having to teach in a remote instruction context; even as students, many

of them expressed that they had little experience with learning over remote instruction and that they preferred to learn in an in-person context. Although the remote instruction format may seem separate from the idea of maintaining academic expectations, a prevalent theme in the interviews was that remote instruction limited their ability to engage students, thus limiting their abilities to maintain equitable academic expectations and support student learning.

In the initial interviews, one preservice teacher who expressed apprehension about remote instruction was Mobius. While most of the preservice teachers had not had experience with teaching or providing academic support over remote instruction, Mobius had worked as a paraeducator prior to joining the teacher education program and taught students over Zoom in the first few months of the pandemic. Having had experience with remote instruction, Mobius expressed that he felt that remote instruction was inherently more tedious and difficult than in-person instruction and was concerned about how that would affect student engagement:

> Remote instruction is very awkward. I think that it's just genuinely hard to pay attention, even if you really do like what you are learning. I like my classes here, but even I find myself totally off task sometimes. Somehow it just feels kind of more exhausting . . . but I don't know, it's like some weird new kind of exhausting. It's kind of hard to describe. But like, teaching it, I just felt like I wasn't really getting any connection with any of the students, really. In real life, you can kind of gauge if they are genuinely understanding what you're saying or not. With remote instruction, 90% of them have their cameras off. You have no idea if they're understanding what

you're saying, if they're even listening. My thoughts are mostly negative on it [remote instruction].

This sentiment was echoed by Turtle Dad, who mentioned that delivering accessible content and checking for understanding would likely be difficult through a remote instruction format:

> I see some of the challenges as making sure that the content is accessible for everybody. You can see right away in an actual classroom, whether somebody is on the same page or not, but over Zoom, it's like, everybody has the camera off most of the time. It's hard. You can't really see, you just look at a name, and you can't really tell whether they're engaged or not, or like on their phone . . . especially with science, there's just that cop out, "Oh, I'm not a science person, so I don't really need to get this", where they'll be given the individual work to do after zoning out on Zoom, [and then] just kind of being like, "Oh, well, this just isn't for me" and kind of copping out rather than struggling through and actually learning it.

Turtle Dad contrasted the ability to monitor student learning in an in-person classroom and in a remote instruction format, stating that teachers who teach in-person can more easily gauge who is on task and understanding the content because they are in close proximity to students. On a remote instruction format, however, it is not as simple as simply looking around the room and checking in with students, and Turtle Dad was concerned about students who do not think of themselves as good at science; he mentioned that instead of putting in the effort to grapple with topics, knowing that their teacher is able to easily observe their work, remote instruction makes it too easy to not engage in productive struggle when concepts are difficult to understand.

In addition to being concerned about student engagement, the focal group members expressed a lack of familiarity with how to teach certain NGSS practices (at the time of the initial interviews, they had just started their teacher education program courses and had not yet received instruction on the NGSS). For example, Liam stated that he believed asking questions was the most important practice to teach students, but he did not yet understand how to actually get students to ask questions about academic content. He expressed that questions should stem from genuine interest and are thus "spontaneous", and he did not know how to incite the interest and curiosity in science for students, allowing them to ask substantive questions about science content.

At this time, the preservice teachers were being introduced to the NGSS in their summer courses, but did not possess a thorough knowledge of the standards, nor a familiarity of how they would apply them in a classroom setting. Several questions in the interview protocol asked the preservice teachers how they would imagine applying the NGSS practices and crosscutting concepts in their classrooms and which ones they believed were the most important to teach students. However, because of their lack of familiarity with the NGSS, most of their responses to these questions were fairly surface-level. For example, when Mobius was asked to identify the most important standard to teach students, he stated, “Stability and Change”; he stated that he selected this because, in his experience, it was not addressed when he was in high school. Rachel also responded to questions about the NGSS briefly and using vague terms, and admitted that she was not very familiar with this standards framework.

While their knowledge of the NGSS was not yet thoroughly developed, the preservice teachers demonstrated insight into how students would best learn the NGSS.

Although extensive knowledge of the NGSS was not yet present in the interviews, Sawyer demonstrated appreciation for the department of education's approaches to teaching science, as he had taken science education courses at the same university during his undergrad. He shared that he greatly appreciated the ways that the professors presented science pedagogy, which differed from his experiences of science education as a K-12 student. While he conveyed a definite interest in chemistry during his interview, he stated that he was not "in love with chemistry . . . I'm not reading chemistry papers on my own", but instead was inspired by the pedagogical methods that were presented in his courses at the university; thus, he saw teaching chemistry as a means of teaching science in more engaging and ambitious ways than he was exposed to as a student. He elaborated on this point:

> I took some general ed classes for my requirements, and nothing really stood out to me until I decided to take an education course. And once I took that course, it kind of stood out to me, recontextualized my entire education experience in a new way in terms of the systemic issues and these problems and everything that's going on. And I was exposed to . . . inquiry-based learning, and that kind of stuff just really stood out to me, and it felt like, I couldn't experience that [as a student], but I think it'd be awesome if I could help future students experience that. On top of that, it's also the antiracist aspect of it, or in terms of bringing culture into the classroom. I think that's really challenging, but . . . if you can manage to do that, you're just going to make life way better for the students. It's not just about teaching them chemistry, it's about giving them a good learning environment.

Thus, Sawyer expressed an enthusiasm for the instructional and antiracist stances of the department of education. The preservice teachers also discussed aspects of science instruction that may be confusing for students and where student misconceptions might arise. They also discussed strategies they envisioned themselves using to effectively teach the NGSS and maintain academic rigor, give students opportunities to practice higher-order thinking skills, and apply writing and citing evidence to science tasks. One example of this was in Sawyer's interview. In his initial interview, Sawyer expressed an awareness of the ways in which content-specific vocabulary may cause confusion for multilingual learners, and that teachers should be aware of that and provide supports for students while also maintaining high academic standards. When asked what he had learned from his teacher education program so far, Sawyer replied:

> The language in science, especially for ELLs, the language can just be a big barrier of entry. Whether it's the vocabulary, or like the abstract scientific concepts that . . . students are expected to learn. If students aren't really getting a grasp on those foundational level vocabulary, or those foundational level concepts, they're going to really struggle as we continue to move on. Because in science, you have to build and build and build and build. So you know, you have this simple vocab word like "electron". And if you're not understanding what an electron is, you're gonna have a really hard time grasping all of these concepts down the line that all involve electrons. And I would say writing is a bit different in a science course, when you're trying to incorporate writing, but it is necessary. For sure, it shouldn't just be all formulas and problems. Whether that involves sentence frames, or short answer response questions, I think it is important to challenge your students. So not just fill

in blanks or answer simple questions, but to really incorporate their knowledge into longer sentences or paragraph forms of writing.

Sawyer acknowledged misconceptions that might arise for students, discussing that content-specific vocabulary can be a barrier to comprehending the NGSS. While considering what some barriers to comprehension might be, Sawyer also realized the importance of keeping academic tasks rigorous and pushing students to explain their thinking. Sawyer made several additional comments that demonstrated that he prioritized high academic standards that align with the NGSS, while considering possible student misconceptions and meeting them where they are at.

While the focal group expressed that they were not yet familiar or comfortable teaching the NGSS, they expressed that their teacher education program had helped them think about noticing instances when students need more support and equipped them with knowledge of appropriate supports for students. They also expressed hesitations about teaching students over remote instruction, citing that it is simply easier to become disengaged over remote instruction and shared that this might make it difficult to check for understanding. They shared that potential student disengagement and less frequent opportunities to check student work and verbal responses would then make it difficult to effectively teach the NGSS and maintain high, rigorous academic expectations and equitable opportunities for student participation.

Fall Interviews

The interviews following the Fall quarter were conducted in December, and the preservice teachers had had approximately four months of experience of teaching their placement class on a remote instruction format. They also had taken seven teacher education

program courses which were centered on the NGSS and how to enact reform-based science instruction.

In regards to what they learned about becoming effective science educators, the focal group all mentioned their experiences with learning about the NGSS and enacting lessons that aligned with the NGSS and required students to engage in rigorous tasks. Some of them also discussed the importance of facilitating student talk, exploration, and using anchoring phenomena, which entails centering science instruction around a complex and puzzling event; this practice supports student engagement, productive talk, and deep learning (Colley & Windschitl, 2016). When asked what he had learned about effective science instruction from his teacher education courses thus far in the program, Mobius stated:

> I think the biggest thing [that we have learned] would be the anchoring phenomena concept. Other things that we've learned in terms of how to effectively teach science . . . not necessarily *not* giving direct answers, but trying to get there through student answers first, working off of what they give you, letting them talk more about what they're thinking. Exploration is key. We've learned that it's important to give students a groundwork of the basic scientific concepts, then allow them to explore that themselves, and then bring it back to the whole group to make sense of what you've been learning.

In her interview, Rachel also expressed similar ideas as Mobius; she felt that creating relevant and meaningful assignments, facilitating student collaboration, and requiring that students explain their reasoning were important aspects of quality science instruction. She gave a specific example of how she facilitated an NGSS-aligned, rigorous classroom task

which required high-level student reasoning, revising based on feedback and new evidence, and student collaboration:

> So recently, the last thing I got to teach was designing a solution for an environmental problem which touches on one of the engineering standards, which is designing, creating evaluating, and refining solutions . . . and through the project - it was about local issues - and it guided the students through different steps like background research, and they had to identify criteria and constraints based on their background research, draw a model of their solution, do a peer review, revise their solution based off the peer review, and then communicate the solution to others. So, I think it hit a lot of the—not all of them—but like a handful of the different SEPs.

The focal group also discussed various people that supported them in enacting NGSS-aligned instruction, while providing scaffolds for students. Turtle Dad shared that Dr. Lake, the teacher educator in this study, encouraged him to use a summary table (a way of tracking student thinking and visual representation of how learning activities connect to explain phenomena). When his cooperating teacher expressed concern that it might be somewhat difficult for some of their students to complete a summary table, he scaffolded it in order for all students to be able to engage in the activity. Turtle Dad shared that he was then able to implement the summary table, which allowed all students to participate and gave them a tool to reference past lessons, making lessons more cohesive:

> A few weeks ago, Dr. Lake was like, "Hey, let's try to implement a summary table into your teaching". And so, I love reading about the summary tables. I thought they were really great, useful tools and I started talking with my CT [cooperating teacher], and she expressed concerns about how eighth graders aren't necessarily ready for this

> level of summary table. And so, I [made] a really scaffolded one for them to do, but it actually turned out really well. . . . Basically everything I've learned in the science methods class . . . we directly apply it to student teaching with the other classes, like the SDAIE and the EML class. It made me start thinking about these sorts of considerations that I should be taking into account. How can I make this content more accessible for English language learners, and how can I scaffold it differently . . . make it more accessible . . . it's changed the way I think.

The focal group shared that they had learned more this quarter about creating lessons that were aligned with the NGSS and used strategies from their teacher education courses to instruct in reform-based ways, while also scaffolding to make content accessible to all students. While the preservice teachers expressed an enthusiasm for the new practices and theories they were learning in their program, two of them mentioned that they felt that these reform-based practices were not as applicable to the remote instruction context as they might be in an in-person context. They felt the practices were beneficial for student learning and saw value in them, but felt it was difficult to apply them frequently while teaching in a context that was not as conducive to student collaboration, engagement, and checking for understanding.

The preservice teachers also shared that they wanted to learn more about the NGSS, and wanted to see specific examples of what an NGSS-aligned lesson would look like for their grade level and subject. While they stated that they had become more familiar with the NGSS through their teacher education courses and put forth effort to base their lessons on the NGSS, they were unsure if they were doing this correctly. They expressed that they would have liked more guidance from their teacher education program about how to plan an

NGSS-aligned lesson. Some of them stated that they were not seeing this done in their placement classroom either; two of the preservice teachers expressed that their cooperating teachers were not explicit about using the NGSS and did not show them how they incorporated the practices and crosscutting concepts into their teaching. They shared that this was a gap in their learning; they felt that they lacked practical, in-depth knowledge about applying the NGSS, and how to specifically implement the NGSS accurately for their grade level and subject.

The focal group's concerns about remote instruction in the initial interviews were even more prevalent in the Fall interviews, after they had had four months of experience with teaching in that format. All of the teachers in the focal group expressed that it was hard to effectively instruct students due to the fact that engagement was much more difficult over remote instruction. Despite these limitations, the preservice teachers shared that they tried to think outside of the box and come up with ways to engage students and hold them accountable for learning. Rachel shared that one way she did this was by asking students to write their responses in the chat:

> It's hard with online teaching. It's almost like if you don't have students write something down, often most of them won't do it, because it's really easy to turn your video and mic off online. So, we've had it [learning activities] be written just because that way at least they feel a little bit more accountability. Because we can't be in breakout rooms [all] at once. And even if there's a whole class discussion, most of the students won't participate in it.

The Fall interviews demonstrated that the teachers in the focal group had learned rich strategies and practices (i.e., anchoring phenomena, CERs) to support student learning of the

NGSS. However, they expressed that they wanted to learn more about how to specifically apply the NGSS and ensure that their lessons were aligned with the NGSS. They expressed enthusiasm about reform-based practices that they learned in their teacher education program, but felt that they did not have a suitable context to practice these strategies; when they tried, they found that they were difficult to enact effectively using remote instruction.

Winter Interviews

The Winter interviews were conducted in March of 2020; at that point in the school year, they had been enrolled in teacher education courses and participated in their field placement for approximately seven months. Social distancing guidelines became less restrictive at this time, and schools had transitioned to a hybrid format. The preservice teachers had only taught using hybrid instruction for two days when these interviews were conducted; therefore, most of their commentary about teaching was still referring to the wholly remote instruction format.

In the Winter interviews, a prevalent theme throughout the interviews was the difficulty of teaching rigorous, standards-based science in an online format. As previously discussed, the preservice teachers shared that they tried to come up with new strategies to maintain high standards, student accountability, and tried to get creative and come up with activities that would somewhat replace the rich, hands-on learning opportunities that students would have had if they were in an in-person classroom. They found that student engagement and academic performance improved when they used technological tools such as Pear Deck, Desmos, and NEO. However, they felt less successful when trying to recreate labs over a remote instruction context. In the following excerpt, Liam mentioned that he

attempted to do lab simulations with students, but they did not feel as rigorous and meaningful as in-person labs,

> There's no discourse that happens naturally or smoothly. It's just difficult. And we cannot see the reactions from students so fast if they don't have the cameras on. And we also heavily depend on technology, so if technology goes off, we cannot even continue with the lesson . . and I want to do more hands-on things with the students. But all these simulations are just so programmed perfectly that it doesn't, I feel like it doesn't grasp the beauty of science . . . so I feel like science really needs live human communication. I don't think science learning is good with online learning.

The focal group continued to share that they wanted more in-depth instruction from their teacher education program on understanding and aligning their lesson plans with the NGSS. Rachel shared that although she learned about the NGSS and knew she was supposed to use them to guide her instruction, she wanted feedback on whether she was implementing them correctly. She expressed that she would have liked a supervisor or professor in the teacher education program to have looked over her lessons and give her feedback on whether she was accurately addressing the standards. Mobius also expressed the same idea in his interview, stating, "It [NGSS] gets brought up, but I do kind of wish it was more in depth. . . . I feel like, for the most part, we're left up to our own interpretation of what we're reading". This desire for more guidance on understanding and implementing the NGSS also came up in Liam and Sawyer's interviews as well.

While the preservice teachers wanted more guidance in interpreting the NGSS, they stated that their coursework was valuable in teaching them how to support student access to science content. Rachel stated,

> I didn’t know what scaffolding was at all before this program started. Realizing that you can really highly scaffold lessons and not take away the understanding part of it. Scaffolding just makes it [content] more accessible for students. It doesn't minimize their learning.

In addition to learning about scaffolding from their program, the focal group also expressed a knowledge that students can show understanding of content in different ways. Instead of being preoccupied with students needing to use the exact content-specific vocabulary in their responses, the preservice teachers seemed to care more that students were understanding the "big idea" – the process rather than using the exact academic terminology to describe the process. While they still taught the students the canonical terms, they did not gauge a student’s understanding based on whether or not they used the "correct" term. Turtle Dad described this in his interview:

> They [students] were making the right observations, they had that scientific backing, they understood what was going on, but they just didn't have that academic language . . . so, during sensemaking discussions, or when questions ask you, “What happens when the negatively charged particles move through a plate with a positively charged plate at the top, and the negatively charged plate bottom?”, they won't necessarily use the words "attraction" or "repel" or "charges" or “different charges.” They kind of are like, "Oh, it'll go towards, it will go away, they'll move around and stuff". So, we do these discussions, and then I’ll just kind of prompt them [later], like oh, that's what that means.

The preservice teachers demonstrated the knowledge that in order to use the appropriate scaffolds and support student in understanding complex scientific concepts, they had to

listen and be responsive to students. Turtle Dad shared that he viewed an important part of effective science instruction as the willingness and ability to be responsive to students' learning needs and change lesson plans if necessary. He stated that he saw his cooperating teacher do this; for example, if students did not understand the content of a lesson, he shared that she would think of ways to reteach the lessons, or change the next day's lesson entirely to ensure that she would provide students with explanations that made sense to them, and gave them ample time to work with the content.

Overall, the Winter interviews showed a stronger grasp of the NGSS, although the focal group would have liked more guidance in that domain. They shared that checking for understanding was important, and if students did not understand the material, they knew that an appropriate response would be to provide further supports or reteach in a different way.

Spring Interviews

Spring interviews were conducted at the end of the school year, and the preservice teachers had taken the full teacher education course load and taught for a combined full year in various student teaching placements.

The Spring interviews showed evidence of the focal group's expanding visions of teaching – four of the focal group participants reported that they were learning how to plan and provide quality, reform-based learning opportunities for their students, and that this was reflected in student work. When asked what he felt went well over the year, Turtle Dad shared that he felt like his students demonstrated mastery of the science content that he taught. Despite the limitations that remote instruction presented, and the transition to hybrid instruction (and thus balancing teaching in-person and online students), Turtle Dad stated that his class demonstrated competence on their assessments, and performed better

academically than even more experienced teachers in at his placement school site. Sawyer and Rachel also explicitly stated that they felt their students understood much of the class material.

The focal group teachers also expressed an evolving view of what it meant to be an effective teacher, after their experience in the teacher education program and in their field placements. Regarding how his views on effective teaching changed, Turtle Dad stated,

> I used to think that a really effective teacher could just explain things really well, but, I don't know if it was just this program, or just life in general, but it's so much more than that. You have to know your students, you have to be responsive. It's about the planning that you put into your teaching, it's about seeing what they're giving you and working with that to plan your instruction. And just being able to explain things, well, it's just a small part of it.

Sawyer expressed a similar change in his views on effective teaching.

> Before, outside looking in, you kind of see, oh, they're teaching, they're a good teacher. You know they're good at giving the information. They're good at talking to students. But it goes so much more beyond that. . . . There's so many things that go into it, whether it's how I'm communicating with English learners, how I'm scaffolding these worksheets, how my lesson plan is organized in a way that hooks students, engages them, but also, you know, gives them time to breathe and not be so overwhelmed. . . . It's kind of expanded my worldview in that way, all the moving parts. And even things like oh, yeah, I gotta make sure I have a little something for everyone, right? The students that appreciate having fill-in-the-blank notes, the students that appreciate getting hands on, the students that appreciate not having to

raise their hand, right? I can use a Pear Deck. And I plan on using that even in person, because I can get engagement from students, but not necessarily have to cold call. . . . So yeah, I would say . . . I can see [teaching is] a lot of things, when before I just thought very surface-level.

Summary

Overall, the focal group demonstrated a knowledge of tools and practices that would help them effectively teach equitable and reform-based science instruction to their students. The interviews indicated that they learned about and utilized anchoring phenomena, had experience in using appropriate scaffolds to support students' access to the standards, and several of them stated that they felt confident about student learning. The preservice teachers also expressed that remote instruction made it difficult to engage students, which affected student learning and participation. Another limitation of remote instruction was a decreased ability to check students' understanding; because students often had their cameras off, it was difficult to pose questions to determine which students understood the content. Remote instruction also made it difficult for them to monitor student work. The preservice teachers also expressed that they wanted more explicit instruction on how to plan NGSS-aligned lessons, and that more feedback on their lessons during the school year would have helped them determine if they were accurately understanding how to implement the NGSS, and ensure that students were learning NGSS-aligned content.

Teaching About Social Justice Science Issues

In these interviews, I also investigated what the preservice teachers learned about teaching social justice science issues. The teacher education courses discussed antiracist teaching practices and their professional issues course was heavily centered on teaching

them about making issues of social and environmental justice, and how to make these issues their anchoring phenomena.

Initial Interviews

Mentions of social justice science teaching were few in the initial interviews. Mobius and Rachel mentioned that the teacher education courses that they were taking taught them about antiracism and fostering a class environment which centers the experiences of minoritized students. Sawyer mentioned that he was inspired by the antiracist stance from the department of education, as well as the equitable and ambitious pedagogy that they taught to preservice teachers.

Although it is not considered to be analogous with social justice teaching, Rachel also discussed cultural relevant learning environments in the initial interviews. This is presented here because, at this point, the preservice teachers had just started their teacher education program and did not have significant experience with learning about culturally relevant teaching; therefore I wanted to highlight that this was something that they were thinking about, and a step toward justice-centered science pedagogy.

Furthermore, Liam mentioned that, as a student himself, he appreciated teachers and supervisors who were culturally responsive. When asked about the kind of supervisor or teacher that he would learn best from, Liam stated that a good supervisor would be somebody who acknowledged cultural differences in teaching. Liam was from Japan and stated that many teaching practices are different there. He acknowledged that he might come into the program teaching in ways that align with his culture, and wanted a supportive supervisor who nurtured this, while helping him hone new practices from the teacher

education program, opposed to someone who expected him to teach in an entirely different way.

Although the preservice teachers mentioned that they wanted to be culturally responsive educators, Sawyer and Rachel expressed that, because being a culturally responsive teacher felt so important, they were concerned about enacting these practices and ways of interacting correctly. Rachel stated:

> I think that creating an equitable and culturally relevant learning environment would be challenging just because it's such an important part of teaching. . . . It just seems like it would take the most thought and intention and care and knowledge of students.

Sawyer also noted that it felt "daunting" and shared that his relationships with students were integral in enacting culturally responsive pedagogy:

> It's one of those things where I need to be in the classroom and I need to take time to learn . . . and that's another thing about building the relationships with my students. . . . In order to create a culturally relevant or equitable learning environment, I need to have those relationships with my students, so I can understand what their needs are in order to provide them with that kind of environment.

Fall Interviews

Two students brought up social justice teaching during the fall interviews, Liam and Rachel. During the Fall interview, Liam was asked to identify something that went well during his field placement. He shared about the following situation that occurred in his classroom. Liam was facilitating a Kahoot activity, which allows students to change their screenname. A student used this tool inappropriately and used racial slurs, and Liam felt that

he responded to the incident appropriately and created a learning opportunity for all students in the class. His account of this is described below:

> There was an incident where one student acted quite inappropriately during an activity. What he exactly did was that during the Kahoot, he used [changed his name to] one of the victims' names, who lost their lives in this police injustice. . . . I recognized that that was not the time or place to say these things. My cooperating teacher was kind of like suggesting the possibility that this student was kind of [using] the name in honor of this person? But, no – because right after, when I pointed that out, he took down the name. And then he started typing in [a] racial slur to my race. So I knew that this was very inappropriate. So [the] next day, I came back, and I got my cooperating teacher's permission to reserve about fifteen minutes of the last . . . class time. And during that time, I gave a presentation about racism. . . My point was that [we have to] recognize these injustices that have been made in the past . . . We have been trying to make justice out of racial inequality, right? And, so my point was, don't do that. And, just because you have done that in the past . . . doesn't make you like, a bad person forever, like you can change, right? . . . Following that presentation, they [that student] did the same thing. . . . And then, a cool thing happened. In the chat, I saw one student comment, "Hey, please don't do that". And then, a lot of people followed that comment, saying, "That's wrong", "That's not cool". And then like, they even voiced up and unmuted themselves, advocating against . . . that behavior.

Liam went on to discuss the importance of speaking up when people commit racist acts or use racial slurs. He stated that, in a classroom environment, there needs to be a class culture

in place where students feel comfortable condemning racist acts, stating that "we need a safe space to do that". Liam felt that he had contributed to creating that space for his own students, and felt that that was his greatest success thus far during his time in the teacher education program.

Winter Interviews

In the Winter interview, Mobius and Rachel discussed the importance of making science content relevant to students and thought it was especially important that students see themselves and their cultures reflected in the content in a meaningful way. Rachel shared that the teacher education program gave them opportunities to learn about how to do this through periodic seminars. However, she shared that each seminar felt disconnected from the other seminars and from the rest of their courses. Having the seminars be more embedded in the program, having these topics be in taught in every course would have given these ideas more continuity and would have made them more effective and meaningful. I asked if she could give an example of learning opportunities that would make more of an impact, and she shared the following idea:

> I think it'd be great to have a whole year long class series focused on - it's kind of scary to do this, but also so important at the same time. . . . [We're] recording all these videos for the edTPA, have others watch these videos and look for instances . . . are your unconscious biases influencing your decision here? Look at your grades. Are your grades revealing [a] pattern . . . or the feedback you give, or the types of support you give, [is] this offered [only to] certain students? Does that reveal any biases or prejudice that you might have?

Rachel shared that being able to identify any problematic actions or biases in one's teaching would be a crucial first step in being able to objectively view how one interacts and instructs the students in their class. Once biases have been identified, Rachel shared that would be important to then learn strategies for how to "check yourself, and how to stop that from continuing going forward".

Rachel also discussed that teachers should try to connect science content to what their "students are seeing in the news". This sentiment was reflected several times by other focal group teachers, although they shared this throughout the school year, not just in the Winter interviews.

Spring Interviews

Like Rachel and other focal group teachers, Liam also shared that teachers should plan lessons that reflect societal issues and racial and environmental injustices that students witness every day, whether firsthand or from the media. Liam shared how he integrated this into his lessons:

> I brought up some topics that are going on in society . . . current events kind of thing, [or] mental wellness, introducing news and asking for solutions or possible "What would you do?" kind of thing. I feel like these types of questions are more difficult to answer than answering simple physics questions. But students tend to engage more because I think that they find value in what they're talking about.

Later in the interview, Liam further stated that by connecting science content to current events and/or topics that are important to students, learning becomes more meaningful. Students begin to explore their own perspectives on these issues.

Youth as Transformative Intellectuals

Initial Interviews

For the domain of *Youth as Transformative Intellectuals*, I analyzed interview data for evidence that the preservice teachers positioned students as competent, agentic, and directors of their own learning. I also analyzed interviews for instances in which preservice teachers created opportunities for students to take a stand on an issue and express their findings and/or opinions. Other behaviors and stances I coded were teachers' efforts to build relationships and trust with students, draw on students' funds of knowledge, and create the safe space which is necessary for students to feel comfortable sharing their ideas and taking risks, as this environment can have a significant impact on student engagement and ability to engage in scientific reasoning (Aronson & Laughter, 2016; Calabrese Barton & Tan, 2009).

Three preservice teachers, Rachel, Sawyer, and Turtle Dad spoke to this dimension of justice-centered science teaching during the initial summer interviews. Turtle Dad mentioned the importance of creating an environment in which all students feel comfortable sharing their ideas. Rachel and Sawyer expressed that an effective teacher takes on the role of facilitator. Rachel stated:

> I think that an effective teacher is one who can teach from the sidelines, like they've structured their classroom and give students the kind of background experiences and attitudes necessary to really have the students [participate in] activities and discussions, and just different things in the classroom without a lot of direct guidance from the teacher. Just really leaving things open for them to explore and make their own understanding alongside their classmates. Not their own understanding [as an individual], but to work with their classmates to make their own understanding together, collaboratively.

Rachel shared that teachers should allow students to talk, grapple with concepts, and learn from each other. However, if teachers noticed that students were coming to a flawed conclusion, without seeming like they could address the misconception, at that point the teacher should intervene and provide scaffolds and questioning that would support students in understanding the content. Rachel wanted her students to take on a more hands-on and explorative role in their learning, but also wanted them to learn accurate scientific ideas. Rachel did not want to tell them the scientifically-acceptable answer, but wanted to help support them in getting to that understanding themselves.

Sawyer shared that he saw remote instruction as limiting interpersonal relationships in the class, thus, limiting students' abilities to share their ideas and collaborate productively. He stated:

> I think the sense of community can be pretty rough. Because the nature of Zoom doesn't really lend itself to, oh, two students are having a conversation over here. And this group of students is having a conversation over here . . . before the bell or whatever, maybe during some downtime in class . . . And as a teacher, I can't really connect with my students as much . . . I won't be able to create meaningful connections with my students in a way that I would in a classroom. And that's purely because I am the instructor and my time is pretty much limited to Zoom, you understand there's no like, oh, students can come in at lunch, or students can come in after school. It's pretty much when the student sees me, it needs to be through Zoom.

Sawyer then discussed that Zoom felt "professional"; there was a sense of formality to interacting with people on Zoom. Conversations do not feel as spontaneous as they would in an in-person classroom, they often have to be scheduled, and lack the naturalness of in-

person interaction. Without those natural, spontaneous interactions, Sawyer expressed that it is difficult to really get to know one's students and build that sense of community that is necessary for them to feel comfortable sharing their ideas in class.

Fall Interviews

All five of the focal group preservice teachers discussed aspects of youth as transformative intellectuals in their fall interviews. When asked how her views of effective teaching changed since starting the teacher education program, Rachel shared that she experienced a shift in thinking about the role of a teacher and students. She shared that she now worked to have a more student-centered classroom, in contrast to the more directive, teacher-centered instruction that she experienced in high school. Rachel discussed the need for teachers to facilitate students' collective understanding, rather than direct their learning. She recalled,

> I definitely learned a lot more about how to teach the skills and the practices and the process. . . . It's not about lecturing, it's not about memorization at all, [it's] about understanding the process of science and the connections between what they're learning, and really, really having students be the ones who are bringing knowledge into the classroom, bringing ideas and not having the teacher be the one to say this is right or wrong, but having that be a collective kind of sensemaking thing that students did.

While Rachel often put great emphasis on relationship-building, like her colleagues, she sometimes found it difficult to build these connections and engage students through remote instruction. After having taught students for four months using remote instruction, she recalled,

> It's really, really hard connecting with students when they're muted and their video's off and, "I don't know what you look like. I've never talked to you". When I say your name, nothing . . . and I feel like I've learned some ways to connect with them online. But that's just going to be different than the way to connect with them in person.

Despite the difficulties of engaging and connecting with students, Rachel spoke very fondly of her students and shared that she was still able to build relationships with students, although she felt that the online format created a definite barrier to getting to know students.

Indeed, all of the focal group teachers discussed the importance of relationship-building, and Turtle Dad named it as a strength of his, and something that had done well despite the limitations of remote instruction. He shared,

> In all of the classes I've been involved in, I've always been able to get students to talk, which has been nice. Students talk, and I hear a lot of comments from observations that we have a high level engagement and that my CT and I have a good relationship, that helps build, and that was with my other placement too, that helps build relationships with students, which has been fun. Because even if I go observe a class, they'll like, call me out if I'm there. And so it's like, "Ooh, that's nice, that's cool." So facilitating discussions, I learned a lot and developed a lot of skills and like sense making discussions and how to ask as many questions, and how to help them bridge an answer, and bridge their own connections to develop the understanding in order to answer the questions which has been cool. And learn the material through these answering questions.

Turtle Dad also shared that the teacher education program helped him to understand the importance of knowing students authentically, and being able to joke with and get to know students as individuals.

> I've also learned a lot about effectiveness in terms of being real with students. I always thought that you couldn't necessarily be real and joke around and have this fun banter, like down to earth kind of banter with students. . . . I'm learning a lot about just the relationships that need to happen for a teacher to really be effective.

Winter Interviews

After the Winter quarter, the focal group teachers expressed increased comfort with building relationships, facilitating discussion, and getting students to more actively participate. Several of the teachers emphasized the importance of getting their students to share their ideas and participate, and there was a noted flexibility in the way that they allowed students to participate (various technological tools, Zoom chat, etc.). The focal group expressed an overall flexibility in the ways that they worked with students, in order to get equitable student participation.

Furthermore, Rachel, Turtle Dad and Sawyer discussed the teacher-student dynamic, mentioning that the teacher role is inherently framed as the "expert" in the class, and they wondered how they could genuinely position students as more directive and influential in class activities, discussions, and planning. Turtle Dad and Sawyer mentioned that one way to work towards this is to show students their vulnerability, admitting that they make mistakes; the teacher is not always correct, nor do they know everything. They integrated this into their classroom and noted that displaying their own vulnerability helped students in also being okay with making mistakes, leading the way for them to participate more

frequently. By modeling that it is okay to make mistakes and that teachers do so as well, they felt that they were working toward a more equitable learning environment.

Sawyer's drive to foster a more equitable classroom environment also extended to his grading system and ways of assessing students. He discussed wanting to have fair grading practices in which students knew that they could improve their grade and that it is okay to not understand content the first time one is learning it. He stated,

> I keep saying with the grading, it's like this flexibility of time and letting students know like, I'm not going to chastise you for not turning something in. Or if you don't do well on an assessment the first time, that's okay, that's perfectly fine. We all have our off days or, you know, maybe you weren't super good with this information, and you need time to relearn it. You know, just being really receptive to that, and being understanding of students' different learning needs.

Spring Interviews

The topic of relationship-building and creating a respectful classroom culture came up frequently in the spring interviews, and the focal group participants spoke about this as crucial to encouraging students to participate, lead class discussions, and generate knowledge with their classmates.

The focal group stated that they saw these relationship-building behaviors modeled by their supervisor, Dr. Lake. Dr. Lake taught their professional issues course, and they all stated that she created a comfortable environment in which they could share their ideas. Liam mentioned that, when talking about different teaching strategies they could use, she put forth effort to elicit multiple perspectives rather than get one or two ideas and then move on. Liam also stated that she was genuine and showed that she cared, stating, "When I was

in dire need of help, she was there, and she was willing to spend time with me to resolve issues. And that was really great. And I can say I trust her".

In addition to creating a safe, welcoming environment and supporting students in difficult situations, Turtle Dad also shared that he felt able to share his ideas about teaching with her and that she helped nurture the ideas and give feedback on how to best implement them. He stated, "Dr. Lake's awesome. She gives full autonomy, she's very supportive. She'll listen to you and run with your idea".

This disposition of working with and welcoming all ideas was evident in the ways that the focal group participants worked with their own students. One example of this was present in Mobius' interview,

> All of their ideas are legitimate . . . knowing that they can share their ideas and their experiences and stuff like that, without fear, you know, of being pushed back on by their peers or their instructor in a negative way. . . . I think it's always important to push back to some degree, but yeah . . . just know their ideas are welcome.

Sawyer mentioned the importance of creating a classroom environment in which all ideas, even "wrong" ones, are welcome. He shared that making mistakes and learning from them is an important part of the learning process.

> It's okay to be wrong, because learning is a fluid process. And I tell my students like, "I don't expect you guys to know the right answer right now . . . even on exams and assessments, they get retakes . . . even then, it's fine if you don't get it right the first time, the whole point is we're learning. We're making mistakes, we're adapting, we're getting better." Just that idea of like, "I value what you have to say." . . . But I think

> it's about showing them I also don't have all the answers, right? I also am capable of making mistakes, or I need to check my notes, things like that.

In addition to sharing that students should be able to be comfortable making mistakes, he again mentioned that it is important to model that by showing students that he sometimes relies on notes and gets things wrong as well.

Rachel discussed that one way to encourage students to take risks and share their ideas about science is to encourage them to first share about their own experiences and interests. She elaborated that teachers can do this by asking students about specific occurrences in their lives, showing that they remember information about their students, and then thinking to follow up and ask about it.

> Sharing helps build relationships . . . so really making sure that you create an environment that encourages them to share their experiences. So, it's simple things . . . these little things that show them . . . that you know them as individuals. Asking how their sports competition went, if they're feeling better, really showing that you know who they are, you care about them, you remember things about them. I think that is really big for . . . encouraging them to share things about themselves. Once they're doing that just kind of casually, then they will do it for more science-related activities, to relate to understanding of phenomena.

Rachel then stated that it is important that teachers maintain a culture of respect; if students are to continue sharing about themselves and sharing their ideas about science, students have to respect each other. She mentioned that, if a student says something hurtful or disrespectful, that the teacher should address the situation privately. Therefore, she

expressed that building relationships and holding students accountable for being respectful creates the environment in which students feel comfortable discussing science ideas.

Turtle Dad mentioned the importance of positive teacher-student relationships several times in his interview. He acknowledged that "structured time" for building relationships was beneficial. (He gave the example of "Roses and Thorns", in which students sit in a circle and share one positive thing and one negative thing that happened recently.) However, he stated that those interactions "only go so far". He shared that teachers need to try to also have genuine, spontaneous, one-on-one conversations with students if they want students to truly feel that they care about them. He gave an example of how he integrated this into his interactions with his own students,

> I would go to them, one-on-one, and ask them what's up, see how they're doing outside of chemistry. That was a very common one, to say, "How are you doing?" and they're like "Oh, good", like that's it. Like, no, no, "How are you doing *outside* of chemistry?" . . . And I was able to learn all about some. One student who was all online, she had like these tennis tournaments that she was always going to, but she never told me about them until I really showed interest in her life, and that kind of turned that whole relationship around.

Conclusion

To summarize, the three domains of justice-centered science pedagogy were present throughout all of the interviews with the preservice teacher focal group. The most frequently-discussed domain was *Antiracist and Equitable Science Education*, as the focal group frequently discussed the NGSS, scaffolding, and other ways of making reform-based science content accessible to all students. They also shared at length about the importance of

building safe classroom environments in which teachers know their students authentically. They often shared that relationships and a safe, respectful classroom community were crucial for encouraging students to share about themselves and share their ideas about science. They also discussed viewing themselves as facilitators and positioning students as agentic makers of knowledge who generate ideas with their peers, thus directing their own learning with the guidance of their teacher. However, the preservice teachers' views of social justice science teaching was limited. There was no mention of engaging their students in the work of critiquing dominant narratives of who scientists are and the work they do, in engaging students in projects to impact their own lives or community, or disseminating their students' scientific ideas and/or findings.

Chapter VII: Discussion, Connections Across Findings Sets and Implications, Limitations, and Conclusion

Discussion

In this qualitative study, I investigated a teacher educator's efforts to teach justice-centered science instruction to a cohort of preservice secondary science teachers and what they ultimately learned about justice-centered science instruction as a result. The participants were nine secondary science preservice teachers and one teacher educator in a teacher education program at a large university in California. Using Morales-Doyle's (2017) framework, I coded their interviews and observations according to the three domains of justice-centered science pedagogy: (1) antiracist and equitable science education, (2) teaching about social justice science issues, and (3) youth as transformative intellectuals.

I conducted a content analysis of the professional issues course website to understand the quantity and nature of justice-centered content that was presented to the preservice teachers. I also observed four of the professional issues classes in order to understand the nature of the content that was discussed in the course, learning activities that they engaged in, and how they were taking up this work. I observed feedback conversations between the teacher educator and three of the preservice teachers; these conversations were part of a protocol in which the teacher educator would observe the preservice teacher teaching a lesson, and then facilitate a conversation with them afterwards to discuss strengths of their teaching as well as opportunities for growth. These conversations were centered around targeting students' academic needs and making content accessible in order for students to succeed academically, while prioritizing their development of an equity and justice lens through which they interpreted and reflected on their practices. Furthermore, I

conducted several interviews with the teacher educator in order to understand her aims in her work with the preservice teachers, her beliefs and experiences as a justice-oriented teacher educator, and what she felt were some opportunities for growth in her instruction and interactions with the preservice teachers. Lastly, I interviewed preservice teachers to understand how they developed as justice-oriented science teachers.

This study was conducted with the intent of discovering not what a "perfect" justice-centered science education program could look like, but instead with the intent of discovering the successes and challenges of doing this work, from the perspectives of people who are taking steps to do it, learn, and reflect on their practices. One important implication is that integrating justice-centered foci across all courses in teacher education programs would help support continuity and preservice teachers' abilities to learn about and implement justice-centered science in their own teaching. Preservice teachers emphasized the importance of building relationships with students and eliciting all students' ideas to enact reform-based science instruction; this was also evident in interviews with the teacher educator, Dr. Lake. While the aforementioned was a priority for the preservice teachers, however, more explicit instruction in the NGSS and using social justice-centered phenomena would enhance their pedagogical and social justice knowledge and skills and allow them to enact such instruction with their students.

Discussion of Findings Set 1: Content Analysis of Course Website, Observations of Professional Issues Classes, and Feedback Conversations

This section reviews the resources that were available to preservice teachers and what was taught to the preservice teachers in relation to justice-centered science pedagogy. In order to understand the resources and information that was made available to them, I

analyzed three opportunities for learning: (a) resources available on the professional issues course website, (b) enactment of the professional issues course, and (c) feedback conversations. Because these are three distinct learning activities, I discuss substantive findings related to justice-centered teaching within the parameters of those three opportunities for learning.

Resources on the Professional Issues Course Website. There were a total of 89 resources listed on the professional issues course website. Nine resources were intended for the preservice teacher to learn about their new school placement environment; these resources provided guidance on becoming acclimated with the school culture at their field placement, getting to know colleagues, and navigating the logistical aspects of working and learning how to teach in a new environment. While these resources were not explicitly focused on justice-centered science, they provided information to support preservice teachers with getting to know colleagues and understand how to navigate their placement school site. Possessing knowledge of their school, colleagues, and resources better positions preservice teachers to know which colleagues to talk to for certain matters, how to locate teaching resources, and better know how to advocate for themselves and their students. Being knowledgeable about their placement school site and having supports can in turn help them to develop in their practice and provide quality instruction to students (Ronfeldt, 2015).

The professional issues course website also contained 10 resources on antiracist and equitable science education, three resources on youth as transformative intellectuals, and 62 resources on social justice science teaching.

Antiracist and Equitable Science Education. There were a total of 10 resources that were directly related to effective teaching of the NGSS. There were three resources that were utilized as in-class assignments and seven resources that were intended to be used as references; these were made available to the preservice teachers to equip them with valuable instructional strategies and to give them ideas for planning lessons.

At this time (2020-2021 academic year), the school year was very much in transition due to the changing modes of instruction due to the pandemic. Preservice teachers had to learn how to teach reform-based science not only in an online format, but in-person when social distancing guidelines were lifted. The resources on the course website were a combination of tools, resources, and lab simulations that teachers could use with students in a remote instruction format, and there were also experiments and lessons that could be used in an in-person setting. Therefore, while many of these resources were conducive to supporting preservice teachers in not only teaching the NGSS overall, several of them were websites and involved technology tools that could be used in the remote instruction format that the preservice teachers were mandated to use during this time. Therefore, whether the instruction format was remote or in-person, the resources focused on supporting the preservice teachers in developing their notions of scientific inquiry, facilitating discussion, and designing effective reform-based lessons centered on relevant phenomena. This contrasts with the transmission, delivery methods of teaching science that had been a prevalent method of teaching science in past decades (Macalalag et al., 2022) and which some of the preservice teachers reported as the way that they learned science as secondary students. In the interviews, one of the preservice teachers, Sawyer, mentioned that the way that he learned science when he was in school was through labs that felt formulaic and

simply required students to follow certain steps in order to observe a scientific occurrence. Moreover, when I asked Sawyer why he chose to teach chemistry in particular, he emphasized that he was "not in love with chemistry", but that he greatly appreciated the ways that his teacher education program and education department overall approached science education, and stated that that made him want to provide that same schooling experience in science to students in his class.

Sawyer's description of the ways that he experienced science education as a student contrasted with the exploratory, inquiry-based methods of science teaching that were made available on the course website. The resources on the course website emphasized locating authentic, relevant science issues and centering student inquiry around those topics. This aligns with literature calling for instruction that presents students with a problematic situation that serves as the anchoring phenomenon and context for learning, giving students the opportunity to connect new information and experiences to their prior knowledge in a meaningful way (Ashgar et al., 2012; Bybee, 2010). Furthermore, by centering instruction around real-world problems, current events, and/or contemporary issues, students can link the knowledge and skills to be learned to their personal experiences and meaningful learning is encouraged (Burrows et al., 2014; Guzey et al., 2016; Shahali et al., 2017).

To summarize, on the website, effective science teaching was presented as exploratory rather than as the transmission of knowledge from teacher to student, and this was evident in the NGSS-related material and resources that were made available to the preservice teachers.

Teaching Social Justice Science Issues. The vast majority of resources presented on the course website were related to teaching students about social justice science issues; there

was a total of 62 resources which were directly related to using social and environmental justice science issues as anchoring phenomena, teaching science in more socially just ways, and acknowledging the ways in which science has been problematic and created harm to minoritized people, perpetuating social injustice. Some topics that were covered were *Environmental Justice*, *Race and Gender in STEM*, *Indigenous Ways of Knowing*, and *Diversity and Inclusion in the Sciences*. Dr. Lake was able to assemble a robust collection of useful resources centered on supporting preservice teachers in teaching about social justice science issues.

Dr. Lake selected a large number of resources for preservice teachers to learn about and draw from on social justice science issues. She used class time for students to explore the 27 resources in the *Environmental Justice* and *Talking About Race* topics. Dr. Lake also asked the preservice teachers to incorporate ideas from the *Diversity and Inclusion* topic into their lesson plans. Dr. Lake stated that she would have liked to have discussed these resources in more depth, but the pandemic made this more difficult to implement; with so many pressing matters caused by having to navigate teaching and everyday life during the pandemic, it was difficult to create rich learning activities that would allow the preservice teachers to deeply explore the social justice science issues that were presented, ask questions, work with these ideas, and integrate them into their work in their placement sites. Nonetheless, while Dr. Lake expressed that she wanted to do more with these resources, she shared that having them available was still beneficial to the preservice teachers' development, even if they were not discussed as thoroughly as she would have liked.
One reason for not being able to implement as many justice-centered resources is that this is complex work. Identifying resources and designing learning opportunities that will support

preservice teachers in becoming proficient in teaching justice-centered science involves many complexities to work through, as Tzou et al. (2012) stated that it is crucial that curators of "instructional materials think systemically about how scientific enterprises and science learning and teaching intersect with historicized inequities that have limited access, denied opportunities. . . [and] oppressed multiple groups of learners, their families, and their communities" (p. 863).

The collection of resources and learning materials that Dr. Lake made available for preservice teachers also demonstrated a focus on intersectionality. Dr. Lake brought in materials that educated preservice teachers on teaching indigenous ways of understanding scientific phenomena, STEM gender and racial inequities, underserved communities that experience environmental injustice, and much more. This aligns with teacher education aims put forth by Annamma and Winn (2019), who stated that teacher educators must assume an intersectional approach in their work with preservice teachers.

Identifying and creating opportunities for the preservice teachers to utilize resources that can address the intersection of race, gender, and class inequality is a significant task that would ideally be co-constructed in collaborative groups (Leonard &Woodland, 2022). Dr. Lake shared that she had colleagues who were also justice-oriented science teacher educators and with whom she had shared and benefitted from their resources. This could be extended to the larger teacher education program, creating dedicated communities of practice, where colleagues are organized in content-similar groups and can meet regularly to discuss justice-centered ideas and resources about classes that are from similar content areas; this would enable them to learn from each other and adjust their instruction based on each other's experiences of teaching the material to students. Miller et al. (2022) described

how a community of microbiology instructors (who all taught the same course) created and rapidly integrated antiracist content and shifted to an online format due to the pandemic. The findings indicated that these communities of practice were integral in creating and implementing justice-centered curricula in their courses:

> Communities of practice offer the benefit of diverse backgrounds that create a collective intelligence and creativity that is unmatched by any individual. As they review materials, community members each apply their own lens of experience. When they test materials in the classroom, they return to their colleagues with feedback from students of even more diverse perspectives, thereby improving the content. (p. 9)

Miller et al. (2020) discussed that establishing a group of colleagues who teach the same subject, curate resources together, and use each other's experiences of teaching it to revise their course was beneficial. Dr. Lake was provided with professional development support from her teacher education program in the form of transformative justice meetings and received support and ideas from colleagues. However, the creation of a specific professional learning community, in which the members work together to locate resources and design learning activities, could provide greater support, given that equity and justice-centered teacher education can be difficult to navigate (Gutman, 2021).

Youth as Transformative Intellectuals. This domain of justice-centered science pedagogy was the least represented on the course website; there were three resources directly related to this. Morales-Doyle's framework calls for students to be positioned as producers of knowledge and to actually have opportunities to present their scientific ideas and findings; this allows students to gain the understanding that scientific findings are not

confined to a classroom, but are meant to be disseminated and be contributed to society. The course website included multiple examples of teachers who planned a problem-posing science project, guided students through sensemaking and generating findings, and facilitated students' public presentation of their work. While the examples were informative and a good start for understanding how teachers can create this opportunity for students, it would be helpful for the preservice teachers to see, specifically, how these units and opportunities to present are planned. Morales-Doyle (2017) emphasized that doing this work well requires a significant investment in time and getting to know one's community, as well as planning using backwards mapping in order to have students' projects culminate into a form of dissemination of their findings. Having resources on the course website that show how teachers plan this process, step-by-step, could be an important scaffold for preservice teachers, and may increase the chance that they will be able to implement these kinds of projects with their own students.

Therefore, one opportunity for growth in teaching preservice teachers about enacting justice-centered science pedagogy is to provide opportunities for them to learn how both the teaching and planning process look in practice. By effectively planning instruction around locally relevant issues, preservice teachers can facilitate an environment in which students understand how communities of color become marginalized due to environmental racism, understand their own agency, and how, as students, they can use science to challenge unjust policies and empower their local communities (Akom et al., 2014; Calabrese Barton, 2003; Dimick, 2012; Morales-Doyle, 2015).

However, some other studies that have exposed preservice teachers to justice-oriented science units and then examined their visions of centering community issues in

their teaching did not actually require preservice teachers to put this into practice (Varelas et al., 2017); preservice teachers were asked about their visions of justice-centered teaching, but did not incorporate what they learned from the community into their teaching and were not expected to plan opportunities for students to present their findings, whether it be though a presentation, social media, blog post, or various other ways finding could be disseminated. Based on student reflections, they noted that some of the preservice teachers were thinking in justice-oriented ways, but not did examine if that learning was also expressed in their teaching or lesson planning. Creating opportunities for preservice teachers to engage in community issues and learn about environmental and social inequity is essential for supporting them in implementing justice-oriented science in their classrooms. However, a next step would be to create assignments and further learning opportunities that allow the preservice teachers to actually try out what they have learned. Providing exposure to and education in local social and environmental justice topics is beneficial but would be enhanced by encouraging preservice teachers to translate this learning into assignments, providing them with opportunities to practice and develop their teaching and planning skills as a justice-centered science educator.

Enactment of the Professional Issues Course. This section discusses how justice-centered topics were presented and discussed in the professional issues classes.

Antiracist and Equitable Science Education. In the classes I observed, there was time allotted for discussions on eliciting and working with students' ideas, sensemaking, and making content comprehensible for all students. One example of this was a class which was focused on explaining and supporting students' sensemaking around the concept of energy; the preservice teachers and teacher educator discussed how “energy” can have varying

definitions depending on the context and discussed discourse moves and activities to support students in understanding energy, specific to the subject that they were teaching.

A major focus in the professional issues classes was on supporting the preservice teachers in teaching science through a remote instruction format. Studies have shown that even preservice teachers have expressed anxiety about using online technology tools; they found that this is due to a lack of extensive knowledge about the logistics of online tools, having infrequent and inconsistent practice with them, as well as not knowing what to do in the event of online tool malfunction (Schmid & Hegelheimer, 2014; Tondeur et al., 2013). Therefore, support in this area was a necessary part of learning how to teach during the pandemic, as well as beyond the pandemic.

In addition to learning about specific tools and online programs they could use to optimize their instruction and teach the NGSS, topics were centered on problems that were created as a result of online instruction (according to Dr. Lake and the preservice teachers). These topics included students not turning cameras on, not turning in their assignments and/or assessments, and preservice teachers not knowing how to hold students accountable for turning in assignments. While these may seem like more logistical issues, in the remote instruction context, these problems are very much connected to the maintenance of high academic standards and successful teaching and learning of the NGSS. For example, if teachers are having difficulty with collecting student work due to not being able to as readily contact the student in the remote instruction format, or if students have their cameras off, it is more difficult to check for understanding and monitor student learning. Furthermore, if the remote instruction context creates confusion about whether or not students are understanding the material, it then becomes difficult to plan lessons, scaffolds, and learning

activities that accurately target student needs (if teachers do not even know what those needs *are*); thus, it becomes more difficult to support students in accessing the NGSS. Therefore, a substantive amount of the professional issues class time was allocated to brainstorming ways to navigate the teaching of NGSS amidst remote instruction challenges.

This aligns with recent research that found that teachers' practices and lessons have had to be significantly altered during the pandemic, requiring teachers to learn how to use new tools, methods of facilitating student discourse, new means of assessing students and checking for understanding, and interacting with students. This sudden shift in pedagogy negatively affected teachers' abilities to engage students in reform-based instruction (Colomo Magaña et al., 2021; Maphosa, 2021; Murphy et al., 2020; Tseng & Chen, 2020). However, these reported negative effects on instruction contrast with a study by Maestrales et al. (2022). In their study of U.S. secondary science students, they found that academic engagement, primarily the aspect of challenge, was enhanced during remote learning. In turn, engagement led to greater feelings of self-efficacy and affect related to science learning. It should be stated that this study did not take place during the emergency shift to remote instruction, but was instead a planned intervention to intentionally engage students in a remote instruction format. Nonetheless, it demonstrated that despite its limitations, science courses taught using remote instruction may be conducted in a way that engages students and increases their feelings of self-efficacy in science.

While learning how to navigate online teaching was a priority, learning the logistics of and teaching through remote instruction undoubtedly detracted from learning the myriad skills and behaviors that go into being an effective teacher in a typical, in-person classroom. This raises the question of the rigorous, responsive teaching practices could have been

covered if time did not need to be allotted to learning how to teach science online. Crucial practices such as orienting students to each other's thinking, posing pressing questions, circulating the classroom to check for understanding – these are all practices that are necessary for high-quality in-person instruction, and this may be a gap for preservice teachers who learned to teach during the pandemic.

Social Justice Science Issues. One way that Dr. Lake taught about social justice science issues was by facilitating discussion about a presentation that some of the preservice teachers attended, titled "Antiracist Teaching for Science Teachers". Dr. Lake asked the preservice teachers who attended to share what they learned, and they shared that they learned the importance of science teachers promoting racial justice. They also shared that they were provided with model antiracist lessons, and the facilitator discussed the ways in science teaching and antiracism intersect.

Dr. Lake also facilitated space for the preservice teachers to discuss and learn about social justice issues broadly. One way Dr. Lake did this was by inviting veteran teachers from the local school district to discuss the tenets of restorative justice and share how preservice teachers could implement restorative justice practices in their classroom. The veteran teachers described what restorative justice was, how preservice teachers could build a classroom community that is restorative rather than punitive, ways that they could teach students to restore harm done using a logical action decided upon by both parties involved in the conflict, and ways that they could cultivate student accountability to the class community. The preservice teachers expressed interest in these practices, asked questions about what this might look like for various scenarios in their classroom, and asked about possible pitfalls in the implementation of restorative justice. While restorative justice is not a

social justice *science* issue, this topic is centered on teaching preservice teachers about a pedagogy and ways of facilitating a classroom environment that is rooted in social justice.

Dr. Lake also arranged for a principal and teachers from a local alternative school to speak with the preservice teachers about their work with their students, who were at-promise youth. This talk was impactful because the principal and teachers described how their school was set up, which entailed new conceptualizations of schooling; they described that schools should be designed *for* student needs rather than requiring that students conform entirely to the teacher's structuring of their classroom or the school's structure. For example, they described that deciding when each content block would take place was a collaborative decision between teachers and students. The teachers shared that, at their school, students were given the choice of which academic subject to start first, what subject to do afterwards, etc. Thus, instead of the teacher creating the schedule for the day, the students were encouraged to consider how they felt and what they wanted to do. Therefore, the preservice teachers had the opportunity to learn about ways that teachers and students can collaborate, equitable decision-making, and allowed them to rethink the ways that power is distributed amongst teachers and students. Moreover, one of the teachers who shared this information also shared that having a more equitable power structure required very little effort on her part; it was fairly easy to accommodate students' choices, yet it made a substantial impact on students' motivation, enthusiasm for engaging in academic tasks, and learning. Similarly to the discussion on restorative justice, this topic was centered on issues of social justice, but not necessarily social justice *science* issues; however, this was beneficial as the preservice teachers had the opportunity to learn about actual examples of teachers and administration

putting equity, justice, and collaborative decision-making into practice, and the positive results on student engagement and learning.

The preservice teachers were engaged and asked several questions about the talks and presentations discussed. In the interviews with preservice teachers, some of them mentioned that they wanted to learn more about social justice and antiracism, although they tended to talk about social justice in broad terms rather than providing specific examples of topics or practices that they wanted to learn more about. They also expressed that the activities and professional development within the teacher education program felt isolated, that they instead wanted them to be more embedded throughout the program, and for there to be more accountability and follow-through on actually ensuring that they are implementing antiracist and socially-just practices in their classrooms.

Youth as Transformative Intellectuals. A significant part of this domain is the prerequisite relationship and trust-building that is required for students to share their ideas and take risks with being "wrong" in the classroom. Student responses, correct or not, are an integral part of moving student thinking forward; thus, building a classroom culture that is conducive to this is a foundational part of justice-centered science pedagogy. Dr. Lake enacted this domain in two distinct ways. First, she framed the preservice teachers themselves as transformative intellectuals and producers of knowledge and culture, modeling ways to do this with their own students. Second, she provided instruction on and encouragement for how they could do this with their own students, despite the remote instruction limitation and not being in the same physical space as students.

Dr. Lake put forth effort to build relationships with the preservice teachers. She often asked how they were doing, typically citing a specific detail in their lives to demonstrate that

she had familiarity with what was going on in their lives outside of the teacher education program. She also regularly asked for their opinions and feedback on how the class should proceed and gave them choice in the activities they engaged in. Dr. Lake's actions are in alignment with numerous studies on the need for university supervisors to authentically get to know the preservice teachers who they work with, citing that a more positive relationship creates the environment in which preservice teachers feel comfortable taking risks, being vulnerable, and reflecting on their practice (Land, 2018; Le & Vasquez, 2011; Long & van Es, 2013; Sheridan & Young, 2017; Tolbert, 2015). Building the trusting relationships that allow and encourage others to feel comfortable being their authentic selves and taking academic/pedagogical risks is foundational to justice-centered science pedagogy, and Dr. Lake modeled that in her interactions with the preservice teachers.

She also highly encouraged them to check in with and get to know their own students. She suggested that they let each student in the Zoom meeting one by one, greeting each of them individually. She shared humorous, engaging anecdotes from her own life and encouraged the preservice teachers to do so as well. She also encouraged them to share about their own lives and experiences with their own students. She shared that the way to get students talking about science ideas is to first get them talking about anything; she advised the preservice teachers to build students' comfort levels first and get them used to talking about topics that interested them in order to foster their abilities to then participate in discussion on rigorous scientific topics. By modeling and supporting the preservice teachers in relationship-building behaviors, she was also helping the preservice teachers to integrate this into their interactions with their own students.

Dr. Lake put forth substantive effort to teach the preservice teachers about the importance of building relationships, empathizing with students, and making students feel cared for. One way to extend for the preservice teachers would be to also explicitly highlight how cultivating these genuine, empathetic relationships intersects with issues of culture, justice, and power dynamics (Warren, 2018). By knowing their students, they become more aware of their student's cultures and how they can integrate those into planning and instruction. Knowing students authentically can also disrupt the power hierarchies that are traditionally seen in classrooms. While this is beneficial and a step toward framing students as producers of knowledge and culture, it would not be characterized as such.

Feedback Conversations.

Antiracist and Equitable Science Education. Maintaining academic expectations and providing high-quality, equitable instruction aligned with the NGSS was a substantive focus of the feedback conversations with the preservice teachers. In these conversations, Dr. Lake provided feedback on preservice teachers' lesson planning, supporting the preservice teachers in creating rigorous science lessons. During one conversation, Dr. Lake noted that Kim's lesson lacked rigor; while that could be seen as potentially positive (because students may have greater likelihood of understanding the content), Dr. Lake explained that the lesson's simplicity might actually cause students to lose interest and thus become disengaged. She then supported this preservice teacher in anchoring the content in an interesting, complex question that would promote student engagement and problem solving. This aligns with research that demonstrates the relationships between rigorous, cognitively demanding tasks and student engagement with those tasks (Russo & Minas, 2020; Tekkumru-Kisa et al., 2019).

Dr. Lake also encouraged another preservice teacher, Mobius, to reflect on his lesson prior to teaching it, to practice the lesson, and imagine what students might say in order to determine if there was a more clear way to pose a certain question or add an additional activity or scaffold to support student understanding. Encouraging preservice teachers to deeply reflect on their lessons and how they will be taught has been cited as an essential part of preservice teacher development (Hammerness & Kennedy, 2019; Timperley, 2013)

During my observations of these feedback conversations, Dr. Lake provided a beneficial balance of feedback that was pertinent to the online instruction setting and practices that would benefit preservice teachers when they transitioned to in-person teaching.

Social Justice Science Issues. Indicators of this domain did not come up during the feedback conversations. The preservice teachers who participated in the feedback conversations did not incorporate elements of social or environmental justice into their lessons, despite having resources available to refer to in their professional issues course. One possible reason for the absence of social justice science issues was the remote instruction context. The preservice teachers frequently shared that the remote instruction context was limiting, one reason for this being that students regularly had their cameras off and/or did not participate. This decreased participation and engagement could have been discouraging for the preservice teachers; it takes time and intentionality to plan lessons around social justice science issues (Morales-Doyle, 2017) and with less interaction with students, it could have felt easier, in their preservice year, to focus on strictly science lessons rather than plan a social justice-oriented lesson. While this could have been the case, the preservice teachers

who engaged in the feedback conversation also did not ask questions about or express an intent to incorporate social justice into their science lessons.

Youth as Transformative Intellectuals. Dr. Lake frequently discussed the need to center student ideas during class discussions and build the prerequisite relationships that are necessary to help students feel comfortable with sharing ideas in class. During the three feedback conversations observed, Dr. Lake encouraged the preservice teachers to create activities that fostered student discussion and encouraged them to get to know and build relationships with their students. For example, when Mobius mentioned that his student, Armando, had talked to him in the Zoom chat for the first time, Dr. Lake encouraged Mobius to really foster that initial connection and continue to engage with and build a positive relationship with Armando. Rather than simply stating that it was great that Armando talked to Mobius for the first time, she framed this more as a "breakthrough" moment and discussed ways to get Armando talking even more. By highlighting the importance of this moment, Mobius was able to see that teacher-student interactions are pivotal, especially when the student does not talk in class. This is important because the way that Mobius proceeded after that interaction with Armando would likely have an impact on whether or not Armando talked in class again. Dr. Lake helped Mobius to see that the more teachers nurture student talk, especially for quieter students, the more likely they will be to talk in class in the future. Moreover, inviting students to share about themselves has been shown to have an impact on their participation and learning in science classrooms. Furberg and Silseth (2022) found that encouraging talk about student resources (student experiences, interests, etc.) enabled students to better express their scientific reasoning, promoted student

participation and curiosity, and positioned students as agentic and accountable participants in class discussions.

During Gil's feedback conversation, he shared that he tried a peer review with his students, which Dr. Lake also highly encouraged. Peer review is a collaborative activity that fosters students' awareness of their own thought processes and approaches to the task, and gives students practice assessing their own and other students' work (Double et al., 2020). Moreover, incorporating peer review allows students to gain multiple perspectives on their work, gives students an ownership and agentic role in class, and allows them to engage in dialogue, which contributes to a collaborative classroom community. By framing this student-to-student talk as valuable for student knowledge construction, Dr. Lake helped Gil to see the importance of teaching students how to engage in discourse and reflect with each other, not simply looking to the teacher for feedback and next steps.

Summary of Findings. The professional issues course partially addressed the three components of justice-centered science pedagogy. There were numerous social and environmental justice resources available to preservice teachers on the course website; however, they could have been utilized more frequently during the class sessions. Issues of social justice also did not come up during feedback conversations, which could be attributed to the remote context or a lack of familiarity with how to actually identify and plan lessons based on social justice science issues. Social justice issues were discussed in the professional issues class, and one topic was explicitly centered on antiracist science education. Antiracist and equitable academic expectations were discussed often during the classes, feedback conversations, and on the course website. Youth as transformative intellectuals came up during discussions of the importance of bringing all students into class

conversations and building relationships. However, there was not discussion about creating opportunities for students to present their scientific findings or to authentically be positioned as producers of knowledge and culture. There were some examples of how science teachers created opportunities for students to engage in social justice science issues or to disseminate their findings in some way the course website, but that was the extent on topics of disseminating or presenting students' findings. It is important to note, however, that there were limited opportunities to present findings to others due to the pandemic and social distancing guidelines. However, avenues such as social media, blog posts, online newsletters, presenting online – these could have been feasible ways to get students to share what they learned and for them to understand that scientific findings are meant to be shared. This highlights the need to give students authentic opportunities to share their scientific findings. The NGSS guides students to engage in higher order-thinking and in hands-on activities in order to mirror what scientists really do, but this could be even more authentic if students get the actual experience of disseminating the results of their experiments and problem solving.

Discussion of Findings Set 2: Teacher Educator Interviews

Antiracist and Equitable Science Education. Based on the interviews with Dr. Lake, supporting the preservice teachers in providing equitable, rigorous science instruction was a priority for her. One facet of her pedagogy that she discussed was the manner in which she conducted feedback conversations, and she referred to her approach as "very diagnostic"; she stated that there were a number of teaching practices that a preservice teacher could work on at any given time, so she wanted to provide feedback on the most timely, high-leverage practices that would be the most impactful for the preservice teacher's

development at that time. This is similar to numerous studies on teacher educator feedback, which discuss that one of the most important criteria for effective feedback is being able to clearly define and communicate one or two specific pieces of feedback in order to support the preservice teacher in working to improve their practice, while not overwhelming them with too many action steps (Long et al., 2013; Mok & Staub, 2021; Zeichner & Liston, 1987). While Dr. Lake defined her own practice as being more directive, she shared that she frequently asked for preservice teachers' thoughts on what went well and what they believed were opportunities for growth; after identifying their concerns about the lesson, Dr. Lake elicited their ideas to co-construct next steps for them to work on or try to integrate into their subsequent lessons. This is also in alignment with research that found that there is a need to balance directive feedback with facilitating opportunities for preservice teacher agency and co-constructing their own plan for next steps, based on teaching practices that they would like to improve on (Ellis et al., 2020; Lyon et al., 2018; Tolbert, 2015).

However, Dr. Lake stated that the remote instruction context created a barrier to giving feedback. She stated that, while feedback in itself is helpful, it helps to also be able to model the practice that one wants preservice teachers to implement. She shared that it is important that preservice teachers have the opportunity to see certain practices modeled, as this helps to clarify what that teaching technique would actually look like in practice. Because feedback conversations and class instruction was held predominantly online, it was more difficult to model a practice that she wanted the preservice teacher to try out. Studies about modeling teaching practices through remote instruction are largely absent from the literature; however, studies have shown that it is difficult to support preservice teachers in remote contexts in facilitating student group work and eliciting student thinking (Hartshorne

et al., 2020; Jones, et al., 2021), both of which are necessary in order to enact justice-centered science teaching.

Social Justice Science Issues. Dr. Lake curated numerous resources on social justice science issues for the preservice teachers. Some of the resources were discussed during the professional issues classes and used for assignments, while others were used as references and exposure of potentially new ways of teaching justice-oriented science for the preservice teachers.

One important finding was the difficulty of facilitating conversations around complex and sensitive topics such as race. Dr. Lake shared that a preservice teacher became upset during a class session, wrongly perceiving that Dr. Lake had said something racist in class. A preservice teacher mentioned that one of their students had been waving a bat around during a Zoom class session, and Dr. Lake opened this topic up to the preservice teachers, asking, "What might this behavior mean? What would you do?" At one point she suggested that it would be beneficial to ask the student to put the bat away, both because it was distracting, and because students could find it potentially threatening. Dr. Lake stated that it is important to note that, in her culture, baseball bats are considered to be a symbol of the neo-Nazis. Because this had been a part of her life experience, she noted in class that this action could *possibly* be perceived as threatening to other students who saw the student swinging the bat around over Zoom. A different preservice teacher spoke up, essentially stating that Dr. Lake was portraying the student as dangerous, that she was being punitive, and that that was a racist thing for her to say (the first preservice teacher who shared about his student had never mentioned the student's race). Dr. Lake attempted to address the situation, but the preservice teacher continued to defend their point about Dr. Lake saying

something racist. The class session ended, and Dr. Lake did not get a chance to try to clarify or rectify the situation, and she expressed regret about not doing so. Dr. Lake shared this situation with me to discuss how complex and difficult these conversations can be, and that in this case, there were two entirely different situations happening: Dr. Lake saw the potential for the baseball bat to incite fear, and thought it needed to be put away because other students could be perceive that action as threatening (in addition to it simply being distracting). Meanwhile, the preservice teacher, likely believing that the student swinging the bat around was Black or Latinx, claimed that Dr. Lake was being racist and felt that the student was not doing anything wrong, that they were simply playing or needed to move around during class. Therefore, both parties had two very different perspectives occurring, and the only way to come to a shared understanding would be to ask questions and try to understand the other's point of view. Dr. Lake shared that if she could have done it over again, she would have absolutely asked the preservice teacher for clarification about what she was feeling and experiencing in this situation. Dr. Lake expressed that these moments are difficult, but hold potential to truly understanding where the other person is coming from. She shared that she appreciated that the preservice teacher was trying to call out a perceived racial injustice, but that was not at all what was happening for her. The preservice teacher was quick to speak up (which is important), but she also did not entirely understand the situation. This was a complex situation with assumptions and misunderstanding, but situations like these are not unique. This topic was not explicitly related to social justice science issues, but social justice more broadly; this occurrence demonstrates the need for effective communication, especially when it comes to topics relating to race.

Navigating situations involving race and racism in the classroom has been cited as challenging for teachers, and it is important to really listen and try to understand during these conversations (Alexakos et al., 2016). Alexakos and colleagues stated:

> It is challenging to have conversations on sensitive sociocultural topics associated with discrimination and injustice, as they are not only discomforting but also imbued with strong personal emotions like anger, jealousy, fear, and sadness . . . In science education, there are few teacher preparation programs with the courage and support to confront thorny issues . . . The types of conversations that need to happen when discussing thorny issues are raw and subdural, honest and transparent. (p. 752)

Alexakos et al. (2016) developed a heuristic for navigating difficult discussions which supports teacher educators in preparing preservice teachers for "radical listening . . . becoming more mindful (becoming aware, showing compassion), welcoming different perspectives and learning from the ''other,'' . . . [helping] frame teaching and learning practices and ways of carrying out discourse" (p. 742). Because many teacher education programs are putting issues of race and inclusivity at the forefront of their programs, it follows that more difficult conversations may begin to emerge in teacher educators' and preservice teachers' conversations. Equipping teacher educators with tools to help them navigate these conversations (and make them available to preservice teachers) may allow for more empathetic, clear, and productive conversations.

This heuristic outlines optimal ways to facilitate conversations as a teacher and teacher educator. However, their study did not take into account the added complexity of having difficult conversations in an online context, which is the context in which Dr. Lake and the preservice teacher had this exchange. Nuances in vocal tone, posture, and gestures

are significantly more evident in in-person conversations, and these expressive behaviors provide additional information about the participants' feelings and dispositions and allow the conversation to be more clearly understood by the participants (Benedicto et al., 2022). I note this because the remote context and decreased ability to interactional nuances could have contributed to the preservice teacher and Dr. Lake's conversation going awry. Nonetheless, support in navigating conversations about race and social justice would be beneficial for both teacher educators and preservice teachers.

The interviews with Dr. Lake also revealed that she wanted to be thoughtful and intentional about how she integrated justice-centered science pedagogy. Although it did not come to fruition in the ways that she had hoped, she wanted to make racial and environmental injustices a prominent aspect of her work with preservice teachers. She shared that she reflected on her curriculum and pedagogy in order to include justice-centered science; this aligns with research on culturally relevant teacher educator practices, which found that in order for preservice teachers to develop a justice-oriented lens in which they interrogate their own practices and curriculum, teacher educators need to model and engage in this work as well (Mensah & Jackson, 2018).

This orientation towards justice-centered teaching contrasts with teacher educators who may utilize a more "colorblind" approach, eschewing potentially difficult conversations and creating curricula materials that address injustice in favor of more historically-accepted ways of teaching science instruction (Gay, 2010; Nieto, 2010). Instead of adopting this disposition, Dr. Lake demonstrated that she did not have all the answers and was learning just as the preservice teachers were, showed intentionality and reflection on her practice, and displayed a drive for ongoing learning in justice-centered science pedagogy. When I asked

what can be done to foster a classroom environment which centers the experiences and epistemologies of students of diverse backgrounds, Dr. Lake shared that teachers should make every effort to include students, *especially* the ones who are more quiet or may be disengaged during class. She stressed the importance of initiating conversations with students in impromptu moments – asking about how their sports game went, what they did over the weekend, making observational comments, and even simply smiling and greeting them individually. Dr. Lake shared that the more that teachers let students know that they care about them and *see* them (Dr. Lake emphasized the message "I *see* you" in her work with students), the more students will feel that they are in an environment in which they are cared for, and that every part of them – their personality, their interests, their culture – every facet of every student is welcome. Dr. Lake referred to these as "microinclusions", a term she conceptualized as an antithesis to "microaggressions". She stated that she grappled with ways to combat overt racism and microaggressions, and tried to identify the small actions that teachers can incorporate that accomplish the opposite of microaggressions. Dr. Lake's ideas about microinclusions were shared with the preservice teachers she worked with; although she did not use the same terminology, she frequently brought up the importance of initiating conversations with students; bringing all students into the conversation; and helping students feel seen, understood, and cared for in their classroom.

Youth as Transformative Intellectuals. Dr. Lake spoke at length about the importance of eliciting students' ideas, positioning students as knowledgeable, and creating an environment in which all students feel that their ideas are welcomed, "especially the 'wrong' ones" noting that those are "the clay we work with". Dr. Lake frequently emphasized the importance of eliciting *all* ideas, sharing with preservice teachers that even

in highly scientific professional settings, some ideas that are generated are absolutely preposterous. She stressed that this elicitation and sharing of all ideas is a critical aspect of the work of science and strove to nurture this in preservice teachers as well. Dr. Lake encouraged preservice teachers to see student ideas as generative, viewing students through an asset-based lens; she saw this as integral to promoting student learning. This emphasis on fostering asset-oriented teachers to promote student learning was substantiated by Larkin (2012), who found that teaching is likely to be more effective when teachers subscribe to a belief system that values all student ideas and views them as resources for learning. Further, Dr. Lake stated that this practice was essential to centering students from marginalized backgrounds and positioning them as students who are capable of engaging in rigorous science learning. This notion aligns with Agarwal and Sengupta-Irving (2019), who wrote about the importance of eliciting all student ideas and nurturing epistemic diversity:

> We see encouraging intellectual agency as also encouraging learners' epistemic or cultural expressions of reasoning by inviting them to draw on their history of experiences with disciplinary ideas beyond schools. This explicitly elevates students' unfettered thoughts and contributions, particularly when distant from what is normatively defined, without undoing their potential as local intellectual authorities. (p. 354)

Summary of Findings Set 2. To summarize, Dr. Lake shared that she put forth effort to engage the preservice teachers in learning about justice-oriented science. She provided support in equitable academic expectations, primarily by teaching the preservice teachers about the NGSS. She spoke at length about framing students as producers of knowledge and as transformative intellectuals, and discussed the importance of highlighting all students'

ideas. She expressed that teaching about social justice science issues is difficult; she was able to bring in many resources to teach the preservice teachers about social justice as related to science, but wanted to have integrated them more. She also expressed that she had wanted to work on these ideas and cultivate more justice-centered conversations with the preservice teachers.

Discussion of Findings Set 3: Preservice Teacher Interviews

Antiracist and Equitable Science Education. The preservice teachers displayed enthusiasm about many activities and strategies that they learned in their teacher education program, and believed that these practices promoted equitable access to and comprehension of the NGSS. Some activities that were mentioned as supporting student learning of the NGSS were summary tables, lab simulations, and CER (claim, evidence, reasoning) writing assignments. They also expressed an interest in ambitious science teaching, which they stated was a frequently discussed topic in professional issues, as well as other courses in the teacher education program. The preservice teachers discussed the importance of planning for students' learning of science concepts, eliciting students' ideas, and pressing students for evidence-based explanations. The concept of anchoring phenomena came up in interviews, and preservice teachers put forth effort to create lessons around a relevant and puzzling problem. Several of the preservice teachers cited ambitious science teaching as one of the most memorable and impactful aspects of their preparation to enact effective and equitable science teaching. This is consistent with research that describes teacher education programs as an integral part in supporting preservice science teachers to utilize reform-based practices (Aminger et al., 2021; Moon et al., 2021).

Preservice teachers mentioned that students participated in these activities (i.e., students completed CERs), but there was little mention throughout the interviews of whether or not students demonstrated competence in a given performance expectation through their assessment of the activity. While specific comments about student learning were not present, three preservice teachers in the focal group (Turtle Dad, Rachel, and Sawyer) shared that student learning and growth was evident overall. Turtle Dad specifically stated that students demonstrated comprehension of the NGSS, based on his analysis of students' formative assessments.

One reason for this could be the remote instruction context; a prominent theme throughout all of the preservice teacher interviews was that the remote instruction format made it difficult to gauge if students were actually understanding the science content. One major way that teachers checked for understanding was by asking questions about the content-specific topics students had learned about. The preservice teachers asked their students questions during lessons, but stated that they often got few or no student responses. The preservice teachers stated that students often had their cameras off, which made it difficult to know which students were paying attention. Some of the preservice teachers mentioned that they did not even know if students were in front of their computers; they would call on certain students and there would be no response, which led them to believe that some students may have just logged in to the Zoom class session, but were doing something else or had walked away entirely.

Being able to check for student understanding with effective formative assessment practices is a critical component of teaching and learning (Ruiz-Primo & Furtak, 2007). Posing questions to students, doing over-the-shoulder checks of student work, checking in

during group work – these informal assessments are opportunities to gather data about the extent to which students are grasping the content that is being taught. These data points are crucial, because once a teacher has an understanding of what the student comprehends, they can take next steps, whether that be responding with a different question, providing a scaffold, or asking for the whole class's attention in order to model or clarify something. These are just a few examples, but there are many actions that teachers can take to not direct, but guide student learning and ensure that important concepts and skills are being comprehended by their students. Without having this in-the-moment, formative data on student learning, it was difficult to make the pedagogical decisions that were so crucial to supporting students in comprehending complex NGSS practices.

The remote context also made it difficult for the preservice teachers to successfully enact the ambitious teaching practices that they had learned about. They were enthusiastic about the practices that they had learned from their teacher education program, but found them difficult to integrate in their work with actual students given the online context. While they were eager to try out these practices and expressed confidence that they would transfer to an in-person classroom, they stated that these practices felt somewhat impractical and non-transferrable to an online science classroom context. This was likely due to the difficulty with maintaining student engagement and eliciting student ideas in the remote context. Reform-based science teaching requires that students engage in discourse and sensemaking activities, but this is difficult to facilitate when many students have their cameras off or are simply not participating.

The preservice teachers also discussed the need for more in-depth instruction and learning activities to help them gain further expertise in the implementation of the NGSS.

They discussed the need for expansion in two learning domains. First, they expressed that they wanted their teacher education courses to go into greater depth about how to deconstruct a performance expectation, and to identify the smaller skills that are necessary to work toward the larger standard. They also expressed that they wanted to see this specifically with their own grade level and subject. The preservice teachers shared that it would be ideal if this were integrated in their teacher education program courses throughout the year, not just in one or two courses.

This aligns with research on the need for explicit instruction in teacher preparation courses. A reform-based approach to teaching requires that teachers build an initial repertoire of planning and teaching strategies to both elicit and respond to students' ideas (Hammerness & Kennedy, 2019). Novice teachers often fail to engage students in ambitious science practices such as generating ideas, testing ideas, or creating models (Jacobs et al., 2008). Engaging preservice teachers in explicit instruction on lesson design, reflection, and revision of lessons in the methods courses can help them develop in their practices (Karisan et al., 2019).

While they could have benefitted from more in-depth instruction on the NGSS, the preservice teachers stated that the teacher education program emphasized the importance of the NGSS and the need to base instruction on these reform-based standards. Thus, it was evident that the NGSS was a priority and an integral part in their visions of effective science instruction. As such, the preservice teachers shared numerous examples of the ways in which they made efforts to integrate NGSS into their teaching. Therefore, the teacher education program equipped them with the knowledge of the importance of the NGSS, and the rich learning opportunities that alignment with the NGSS offered. To optimize this

learning and their integration of the NGSS in their lesson plans and units, preservice teachers shared that they could have benefitted from more feedback on their lesson plans. Essentially, they wanted to know if they were integrating the NGSS correctly, and if the learning activities they had planned were rigorous and provided equitable student access to the NGSS. Thus, the teacher education program instilled some knowledge of and the importance of basing instruction on the NGSS, but further instruction and feedback on lesson plans could have been of benefit to the preservice teachers.

One major reason that explicit instruction in planning and teaching was so important was because three of the five focal preservice teachers expressed that their cooperating teacher either did not explicitly refer to the NGSS or did not incorporate the NGSS so as to continue teaching in the way that they had previously taught. This aligns with research by Beyer and Davis (2012), who found that many preservice teachers in their study struggled with analyzing lesson plans in a reform-oriented way during student teaching. This occurred, in part, because the preservice teachers navigated the university and K-12 settings that conveyed conflicting ideas about best practices for science teaching.

Social Justice Science Issues. Although they had questions about how to incorporate social justice into their classrooms, all of the preservice teachers shared that they believed that fostering a culturally sustaining classroom environment was a crucial part of being an effective teacher. In their initial interviews, two preservice teachers shared that they thought teaching in culturally responsive and equitable ways might be challenging, citing that it seemed important, complex, and required ongoing work and really knowing one's students.

While they rarely discussed the utilization of justice-centered science instruction in their classrooms, the preservice teachers talked at length about how they worked to ensure an equitable learning environment for emergent multilingual learners (EMLs). They spoke frequently about the funds of knowledge (Esteban-Guitart & Moll, 2014) that EMLs bring to the classroom, and scaffolds and other supports that they utilized to help EMLs in accessing the academic science content. They specifically noted that content-specific vocabulary was sometimes a barrier to understanding, and three of the focal preservice teachers expressed that they were more concerned that students understood the scientific concepts that were being taught, rather than using the exact scientific terminology. One preservice teacher, Turtle Dad, explained that he taught a lesson about force, which included many content-specific terms. He asked students to solve a problem and construct an explanation, and one student explained the concept accurately, but did not use any of the "correct" terminology. However, it was clear to Turtle Dad that the student had complete understanding of the idea. He highlighted the student's idea in front of the whole class, noting that his explanation was perfectly valid even without the scientifically-accepted vocabulary. While he noted that the student was correct, he also reiterated the student's explanation using content-specific vocabulary (he presented the content-specific vocabulary as options, "You could refer to that as _____", rather than mandatory). Encouraging the use of alternate terms that support student sensemaking is further substantiated by Brown and Spang (2008), who studied a teacher's use of science language and its influence on students' use of science language. The authors found that because the teacher included vernacular alternatives to science terms, "students were given a vision of science that was connected to their collective experience. . .

. Using a hybrid discourse had the potential to become an additive component of their discursive identity as opposed to being oppositional" (p. 731).

Beyond the context of EML instruction, however, creating lessons that explicitly centered social justice science issues instruction was rarely addressed. Rachel expressed wanting more guidance and cohesive professional development in order to be able to provide culturally relevant and justice-centered science instruction. Similarly to how the preservice teachers wanted more explicit instruction in teaching and planning the NGSS, she wanted more consistent direction in knowing what a justice-oriented lesson or unit should look like. This aligns with research that demonstrates the importance of providing explicit instruction on how to plan justice-centered units, in order to support preservice teachers' "pedagogical design capacity" (Brown & Livstrom, 2020).

Sawyer and Turtle Dad also discussed that they put forth effort to ensure a lessened power dynamic between teacher and student, hoping to model not simply equitable talk amongst students, but to be mindful of their own positionality and shift that in order to facilitate equity between the students and teacher as well. This demonstrates an awareness of what Rivera Maulucci (2013) referred to as a "positional identity [which includes] the dialectical notion that individuals have agency to position themselves in particular ways in particular social contexts" (p. 457). Sawyer and Turtle Dad were keenly aware of the inherent power that the role of the "teacher" has, and stated that they did not want this to be a barrier to student participation. Sawyer contemplated this substantively; he mentioned that he actively thought about ways to lessen the power dynamic not in a superficial way, but in a way that truly offered students agency and influence over the everyday discussions and logistics in the classroom. He also considered ways of doing this while providing students

with scientifically-correct information, as he wanted to honor students' thinking and also guide them toward scientifically-accepted explanations. While they shared efforts toward ensuring equity for EMLs and lessening the teacher-student power dynamic, overall there were few explicit references to *Teaching Social Justice Science Issues*.

Youth as Transformative Intellectuals. All of the preservice teachers in the focal group emphasized the importance of eliciting student ideas, orienting students to each other's thinking, and framing students as knowledgeable and capable of directing their own learning. They viewed student talk and collaborative sensemaking as critical to understanding the NGSS.

Positive teacher-student relationships are a necessary part of cultivating a classroom environment in which students feel that their ideas are valued and feel authentically framed as a producer of knowledge and culture. The preservice teachers prioritized positive teacher-student relationships, as all of the preservice teachers in the focal group mentioned building relationships, trust, and community. The initial interviews tended to be more hypothetical, or what their vision of relationship-building would be like; the interviews conducted later in the school year demonstrated evidence and actual examples of positive interactions with students and preservice teachers' efforts to get to know students and build community.

During the interviews, as introduced above, Sawyer and Turtle Dad expressed that they wanted ways to more authentically alter the inherent power dynamic between themselves and their students. This aligns with Calabrese Barton and Tan (2020), who emphasized the importance of supporting teachers in developing teaching that positions students as agentic and stated, "Teachers need support in developing strategies to notice and make present the lives of their students as integral to disciplinary learning, and as powerful

lenses for exposing/restructuring the injustices that position youth as marginal to learning" (p. 438).

Similarly to the other domains of justice-centered science pedagogy, the remote instruction format created a limitation to building relationships with students and encouraging them to talk and share ideas with the class. This was especially evident in the fall interviews; student teaching was relatively new to the preservice teachers, as was the technology that needed to be used during remote instruction. While the preservice teachers talked more positively about building relationships and gave more examples of this in the winter and spring interviews (they were hybrid in spring; thus, better teacher-student relationships make sense), the barriers of remote instruction to relationship-building were a common theme in all interviews. The preservice teachers shared that students often had their cameras off, which made it very difficult to get to know students. Depending on their cooperating teachers' preferences, some of the preservice teachers shared that they made it mandatory to turn on their cameras, although they expressed hesitation about doing this; they shared that it did not feel equitable to make every student show their home to everyone else in the class. Even if cameras were on, there was still a limitation due to the physical distance. They expressed that this felt like a detriment to relationship-building because it was difficult to get students to share about themselves; if they did, it felt brief and surface-level. This was also a barrier to building a classroom community. In turn, it was difficult to facilitate discussions amongst students and get them to share their ideas. As the year progressed and the preservice teachers gained more familiarity with technology and their students, they were more easily able to build relationships and facilitate discussions, despite remote instruction.

The preservice teachers in the focal group also shared that they did not feel effective at building a home-school partnership, with reasons varying from not knowing how to talk to parents about sensitive topics, to language barriers. This aligns with Willemse et al. (2018), who stated that novice teachers report that the most significant challenge is establishing relationships with families and communities.

Connections Across All Findings Sets and Implications

There were several themes that emerged in the preservice teachers' interviews that also came up in my interviews with Dr. Lake, as well as in my observations of their professional issues class. In this section, I will highlight similarities across data sets, and will discuss implications for teacher educators, preservice teachers, and teacher education programs.

Provide Preservice Teachers With Explicit Instruction in Justice-Centered Pedagogical Design

While Dr. Lake provided numerous resources on justice-centered science instruction in her professional issues course, the preservice teachers rarely discussed using these resources in their teaching, except for one preservice teacher who discussed using the "Energy" resources. With the exception of one preservice teacher who discussed social justice at times, justice-centered science teaching did not come up as a substantive theme in their interviews. The preservice teacher, Rachel, stated that she found the social justice science resources to be beneficial, but would have liked more assignments and tasks that required the preservice teachers to actually implement these practices and new ideas that they learned about in their professional issues course in their classrooms.

While justice-centered science teaching is oriented around the teaching of social justice science issues, it also requires that teachers are able to design instruction that effectively addresses the NGSS and upholds high and equitable academic standards. This was one area in which the preservice teachers wanted more guidance. Several of the preservice teachers from the focal group expressed that they were not sure if they were covering the standard performance expectations correctly; some of them explicitly asked for more direct instruction in deconstructing an NGSS crosscutting concept – they wanted to understand the smaller skills and practices that students would need to master and build learning activities that would culminate to student mastery of the NGSS concept. While they put in effort to teach the NGSS, they were not certain that they were doing this correctly. Moreover, several of the preservice teachers reported that their cooperating teacher did not model or inconsistently modeled teaching the NGSS. Therefore, one opportunity for growth conveyed from both preservice teachers and Dr. Lake is to provide more individualized and direct instruction on the NGSS and teaching with socially-just science phenomena in their teacher education courses. Incorporating this more explicitly into courses may have made Dr. Lake's guidance on social justice science teaching more concrete and prepared them to enact justice-centered science pedagogy more effectively in their student teaching placement and future classrooms.

Moreover, while the preservice teachers did not explicitly state that they planned for justice-centered science instruction, they did express an intent to honor all students' language usage during class discussions, stating that EML students' ideas were valid and generative. This is an important step in positioning all students as producers of knowledge and culture; this practice could be nurtured further by providing preservice teachers with

workshop-based information and dialogue on language, literacy, and culture (Charity-Hudley & Mallinson, 2017). The creators of this workshops shared the benefits of such workshops:

> When attuned to issues of cultural and linguistic diversity, STEM educators are able to build on their strengths as dedicated teachers to engage in culturally and linguistically responsive education. . . . [There is a] need to provide more K-12 STEM educators with more opportunities to receive professional development grounded in multicultural education/culturally responsive teaching, so that they can develop the skill – not just the sentiment – necessary to most effectively serve students from underrepresented groups and close opportunity gaps in U.S. STEM education.

Justice-Centered Communities of Practice for Teacher Educators

Dr. Lake shared that she was able to assemble numerous resources that covered many aspects of justice-centered science teaching; however, she stated that she did not have the time or capacity to create several assignments or facilitate discussion about many of the materials, which is understandable given the unstable environment of teaching during the pandemic. This desire to integrate the resources into the preservice teachers' instruction to a greater extent was echoed by Rachel, who expressed wanting more opportunities to implement these resources in her work with students.

An issue with this was the time and capacity that it takes to plan for this instruction. Dr. Lake shared that she received several ideas, materials, and feedback from colleagues; however, there was not a collaborative space to plan and receive feedback specifically for the content of the courses she taught. Providing structured time to locate justice-centered

science resources and materials, plan instruction and assignments, and consider the ways this content would be facilitated would provide more guidance and mirrors the collaborative planning around justice-oriented teaching that Miller et al. (2022) described.

Dr. Lake was able to locate numerous justice-centered resources and come up with several learning activities to reinforce the concepts; however, discussion about these resources with colleagues could have supported her in determining which resources should be highlighted in class, as well as the most efficacious ways to use them. For example, perhaps a fellow instructor located what they thought would be a quality resources for social justice teaching, but when they actually taught it, it was not as effective as they had anticipated. They could share this with the group, and then the other instructors could make that change to the lessons they would teach in the future.

This could be difficult to implement, given that university instructors are often the only ones teaching a given course during a quarter; therefore, putting this into practice in the exact same way that the authors described may require addressing logistical issues. However, creating even a modified version of professional development that meets the needs of the instructors at that particular university could prove beneficial and lead to greater justice-centered teaching resources and practices. For example, if a university offers a course once per quarter, and there are three quarters per academic year, the instructors who teach that course could share resources, plan, create assignments that require preservice teachers to integrate justice-oriented science in their classrooms, and give each other feedback on the efficacy of their teaching and assignments. While this may require significant planning and attention to logistics, it may support the instructors in curating materials and utilizing more effective pedagogies than they could have planned alone.

Moreover, collectively sharing these responsibilities may further promote equity within the workplace, allowing for distributed responsibility and the generation of colleagues' diverse ideas and perspectives.

With such professional development, instructors would likely become more intentional and effective over a period of years. While this does require a time commitment and may make instructors feel somewhat less autonomous, it is important to recognize that justice-centered teaching, while not a new field, requires attention, care, feedback, collaboration and time in order to do it well – just like any other domain of teaching. By creating intentional communities of practice that actually examine each other's work, plan together, and bring feedback to the group, teaching justice-centered pedagogy can become as honed and reflected on as any other academic subject, and instructors who are accountable for reflecting and planning together will likely provide higher-quality instruction, preparing the next cohort of teachers to be adept at enacting justice-centered science instruction in their classrooms.

Antiracism and Justice-Centered Pedagogy as the Foundation of all Teacher Education Courses

Another connection among the finding sets was the notion that justice-centered instruction should be embedded in every course in the teacher education program. Rachel shared that she wanted more continuity in social justice in the teacher education courses. Dr. Lake also mentioned that the preservice teachers found it frustrating to go to separate equity and diversity meetings, and that it would be beneficial to just include that in all teacher education courses somehow. Thus, a social justice lens should not be included in one course, or just science teacher education courses, but in every course in the program. This is aligned

with numerous teacher education studies that emphasize the importance of making every course oriented toward equity and justice. Gorski (2012) posited that teaching about race and social justice in a single course or in isolated meetings is not sufficient, and preservice teachers need more consistent and frequent opportunities in teacher education to learn about matters of race and social justice (Milner, 2006). Embedding social justice learning in every teacher education course and highlighting justice-oriented issues that are specific to the course could provide the continuity that would support preservice teachers in actually enacting social justice instruction.

Relationships as Central to Justice-Centered Teaching

Both Dr. Lake and the preservice teachers discussed the importance of building relationships with their students, and noted that this led to more student engagement and an increased willingness to share ideas in class. Building trust, cultivating empathy, and initiating conversations with students are a few of the actions that help to build these relationships, which are integral to fostering an environment in which students can engage in deep learning (Legette et al., 2022). However, the importance of these relationship-building behaviors and dispositions are often not explicitly stated or taught (Warren, 2018). It is often assumed that teachers can just build relationships with students, but this is not always the case. Particularly in the context of white teachers teaching minoritized students, support on relational behaviors may be necessary (Eisele, 2021). Thus, the explicit attention that Dr. Lake devoted to building relationships with students should be integrated into all teacher education courses.

Expanded Opportunities to Learn From Community and Integrate Local Science Issues

While the preservice teachers had the opportunity to learn about examples of justice-centered science instruction and how teachers enacted this in their communities, they did not go out into their communities and do this themselves. McCullough and Ramirez (2012) noted that teacher education programs should provide opportunities for preservice teachers to build connections between school, families, and the community, specifically with community science events or family science nights. Building home-school connections increases preservice teachers' enthusiasm for teaching, increases students' engagement and excitement for learning science, and helps preservice teachers feel more confident in using culturally responsive activities and interacting with their students' family members. Certainly, the pandemic was a major reason why the preservice could not engage in this work, as all schools, non-profits, and other community organizations were closed or had strict social distancing guidelines. However, having an understanding of local issues is integral to justice-centered science teaching; when these opportunities to interact and participate in community issues arise, it would be beneficial for preservice teachers to participate.

In a subsequent article related to justice-centered science pedagogy, Morales-Doyle and Frausto (2012) acknowledged that one of the key barriers to implementing the community piece of the framework are time constraints (given the day-to-day demands of teaching), as well as administration that might discourage the use of community-based science in favor of district curriculum. This highlights the importance of introducing this justice-centered science in teacher education programs, as this might not be implemented or even encouraged at the schools preservice teachers end up working at.

Moreover, Morales-Doyle also noted that is takes time to become familiar with a community in order to teach social justice science issues that are relevant to that community. This again points to the need to be introduced to this early on in one's career in order for this to be feasible for teachers - by understanding this early on in their career, during their teacher education program, they may begin to think about the communities that they hope to teach in, which community organizations they might learn from in order to engage with the community and create projects for students.

Remote Instruction Limited Enactment of all Domains of Justice-Centered Science Pedagogy

One of the most prominent themes throughout the interviews with Dr. Lake and the preservice teachers was the detrimental impact that remote instruction had on their abilities to positively interact with students, engage students in sensemaking discussions, and create meaningful intellectual communities in which students worked with each other to explore scientific phenomena (Sintema, 2020). Preservice teachers noted that providing high-quality instruction was difficult because many students did not participate, and it was easy to not participate because they could turn their cameras off. In turn, if students were not engaged, this made it more difficult for the teachers to check if students understood the material. This is not to say that the preservice teachers were not able to effectively teach students, but they felt it was much more challenging than it would have been if they were teaching in person, and they felt that there were some students that they were never able to really get through to due to the remote context.

Barring some continued mask mandates, schools have largely gone back to "normal" instruction. However, the implementation of remote instruction caused teachers, students,

and administration to become more familiar with it and will likely lead to school districts and teachers pursuing opportunities to move instruction (or parts of instruction) to an online format. Teachers and students have now become more proficient in using platforms such as Google Classroom, Zoom, and Peardeck, among many other platforms. These online tools will likely be utilized now that in-person teaching has resumed. However, additional planning, resources, professional development, and research is needed to ensure that the domains of justice-centered science instruction are enacted through these platforms.

Online learning in teacher education may be more prevalent than ever, so this research also raises the question of how teacher education programs can prepare preservice teachers for enacting rigorous instruction in an online format, and even how they learn to do this themselves. As we move even more in the direction of online educational formats, it is important to think about how rich learning opportunities (community-based science, ambitious science teaching practices, etc.) can be translated to an online format and not lose their powerful impact in the process.

Cultivate Teacher Educators' and Preservice Teachers' Capacity and Ability to Navigate Conflict

There were two instances of conflict centered around race issues in this study; one occurred with the preservice teacher, Liam, and one with Dr. Lake. While Liam felt that he had navigated the conversation and planned an effective presentation to further educate students on race issues, Dr. Lake felt that she could have navigated the interaction with a preservice teacher better. These instances demonstrate that conflict is a part of social justice education, and both teacher educators and preservice teachers should be given opportunities to learn how to manage and navigate conflict in order to foster growth. Leonardo and Porter

(2010) state that the classroom should be "redefined as a place of risk", not for risk and discomfort's sake, but to encourage and allow growth for participants (p.135) Drawing on their work as social justice discussion facilitators, Arao and Clemens (2013) proposed a brave space framework, and argue that people who are concerned with facilitating conversations around social justice should shift their terminology from cultivating "safe spaces" to "brave spaces". Using such a framework may support people in various education roles to foster productive and valuable conversations about social justice and race issues.

Limitations

There were several limitations to this study. First, while Dr. Lake expressed an orientation toward social justice science issues and expressed a commitment to culturally relevant and equitable ways of teaching (and teaching this to preservice teachers), she had not intentionally set out to explicitly teach justice-centered science pedagogy. Therefore, all of the resources she identified were not curated out of an obligation to enact justice-oriented pedagogy; instead, I noticed the teacher educator's orientation toward justice-centered science, and then examined how her teaching and resources fit into Morales-Doyle's framework. Similarly, the interview questions for both the teacher educator and preservice teachers in this study did not directly address the domains of justice-centered pedagogy.

A second limitation was that preservice teachers were not observed teaching in their student teaching placements. While I was able to observe the professional issues course, I was not granted access to any secondary classrooms during the study because of pandemic restrictions. Having the opportunity to observe how the preservice teachers taught and interacted with students could have provided additional insight into their enactment of justice-centered science pedagogy.

Furthermore, this study would have been enhanced with perspectives from more preservice teachers of diverse backgrounds. However, only two of the preservice teachers in this study identified as being a preservice teacher of color, and one other preservice teacher identified as White, but English was not his first language. Therefore, these data are based on predominantly White and native English speaking preservice teachers. This highlights the need for better recruitment and retention of preservice teachers of color, as most teacher education studies involving the sciences are centered around the experiences of White preservice teachers (Mensah & Jackson, 2018).

Conclusion

This study explored a justice-minded science teacher educator's efforts to enact the domains of justice-centered science pedagogy, and preservice teachers' uptake and beliefs about this justice-centered teaching in the complicated context of the Covid-19 pandemic. Justice-centered science pedagogy orients classroom activities toward antiracist and equitable science education, social justice science issues, and framing youth as transformative intellectuals. A justice-centered classroom fosters student exploration of and proficiency in the NGSS, while simultaneously valuing individual student backgrounds, ideas, and experiences, as academic achievement occurs more readily when students' cultural and linguistic assets are valued (Valenzuela, 1999). A truly justice-centered classroom can only happen with the development of a relational infrastructure where teachers develop respectful relationships built on trust and sharing in real responsibilities in the classroom, and "students see and feel teachers treating them with respect and, in turn, leave their classrooms with a paradigm of compassionate human relationships" (North, 2009, p. 107).

Dr. Lake provided numerous resources and learning opportunities for the preservice teachers to learn about justice-centered teaching. While the preservice teachers discussed building relationships with students, eliciting all students' ideas, and the importance of implementing the NGSS frequently in their interviews (although they still expressed wanting more explicit instruction), teaching about social justice science issues came up infrequently.

Recommendations for Future Research

Morales-Doyle and Frausto (2021) stated that their framework for justice-centered, youth participatory science may be perceived as "formulaic" (p. 63), where teachers simply need to follow their steps in order to meet this practice. They acknowledge that they are not trying to oversimplify this, stating the demands every teacher faces. I acknowledge that aspect, and agree that justice-centered science pedagogy should not become relegated to a checklist. To mitigate that, I believe that more examples of how teachers actually do this work would be helpful. By seeing a diverse range of ways that teachers go about engaging in this work, other teachers may see an example that resonated with them and seems feasible for their classroom, school, and community contexts. I agree that building these connections, organizing with the community, and planning and backwards mapping are time-consuming. However, seeing various ways that teachers have gone about building relationships with the community and planning may help provide direction for teachers who want to engage in this work, but may find the time commitment or logistics to be daunting. The more examples of implementing this, the more teachers can learn how to integrate this in a way that works for their community and their students. More studies in justice-centered science instruction are needed, particularly in the ways that teacher educators work with preservice teachers to foster justice-centered science knowledge and pedagogy. I

recommend further case studies to examine how teacher educators amass the resources to teach this, how preservice teachers take up this work, and results on student learning and wellbeing in the classroom. Research should also be conducted on existing projects to enhance the justice-centered learning of future science teachers (for example, the professional development discussed in Charity-Hudley & Mallinson, 2017).

An additional recommendation is for teacher education program and/or school district funds to be allocated for teachers and students to conduct action research on the justice-centered science units that they facilitate or engage with. Teachers are responsible for the planning and teaching of these units, and have great insight into how these units can best be implemented, what modifications could be made, and may anticipate logistical issues with implementing justice-centered teaching. Moreover, interviews with students on how they are experiencing this justice-centered science teaching could provide insight into how teachers are implementing these units, and ways to make it them even more relevant, engaging, and purposeful from students' perspectives. One example of something a student might bring up is the dissemination aspect of social justice science. A student may want to present their findings in public, but may not feel that they are an effective public speaker and may need support in that; thus, student interviews could reveal prerequisite skills that are necessary to actually enact what Morales-Doyle is advocating for. Having this knowledge could allow teachers to set aside time for students to learn about and practice public speaking and articulating their findings in a clear and engaging way.

Research is also needed in the ways in which teacher educators are prepared by institutions to enact this work. Professional development and regular meetings about equity and justice are absolutely valuable and necessary; however, establishing communities of

practice or another iteration of this support system could help make this learning more transferrable to their work with preservice teachers (i.e., instructors could come up with optimal readings, questions for discussion, and learning activities). Furthermore, this would be equity in action, as it utilizes a collaborative structure and calls for the input of a group of instructors, in order to have a greater impact on preservice teachers' justice teaching competencies.

This study is a small contribution to the growing body of research that envisions equity and social justice as integral to effective science education and teacher education (Bianchini, 2017; Calabrese Barton, 2003; Emdin, 2011; Morales-Doyle & Gutstein, 2019; Tan & Calabrese Barton, 2010). Further research is needed to examine the practices of teacher educators and teacher education programs engaged in social justice science teaching, as well as the learning and experiences of preservice teachers who are engaged in this work. Research should also focus on the effects on science learning and experiences of inclusion and justice for students who learn in justice-oriented classrooms.

References

Adah Miller, E., Makori, H., Akgun, S., Miller, C., Li, T., & Codere, S. (2022). Including teachers in the social justice equation of project□based learning: A response to Lee & Grapin. *Journal of Research in Science Teaching*.

Agarwal, P., & Sengupta-Irving, T. (2019). Integrating power to advance the study of connective and productive disciplinary engagement in mathematics and science. *Cognition and Instruction, 37*(3), 349-366.

Alexakos, K., Pride, L. D., Amat, A., Tsetsakos, P., Lee, K. J., Paylor-Smith, C., ... & Smith, T. (2016). Mindfulness and discussing "thorny" issues in the classroom. *Cultural Studies of Science Education, 11*(3), 741-769.

Allen, J. M., & Wright, S. E. (2014). Integrating theory and practice in the pre-service teacher education practicum. *Teachers and teaching, 20*(2), 136-151.

Annamma, S. A., & Winn, M. (2019). Transforming our mission: Animating teacher education through intersectional justice. *Theory Into Practice, 58*(4), 318-327.

Aminger, W., Hough, S., Roberts, S. A., Meier, V., Spina, A. D., Pajela, H., ... & Bianchini, J. A. (2021). Preservice secondary science teachers' implementation of an NGSS practice: Using mathematics and computational thinking. *Journal of Science Teacher Education, 32*(2), 188-209.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of science teacher education, 13*(1), 1-12.

Archer, L., MacLeod, E., & Moote, J. (2020). Going, Going, Gone: A Feminist Bourdieusian Analysis of Young Women's Trajectories in, Through and Out of Physics, Age 10–19. In *Physics Education and Gender* (pp. 9-28). Springer, Cham.

Aronson, B., & Laughter, J. (2016). The theory and practice of culturally relevant education: A synthesis of research across content areas. *Review of Educational Research, 86*(1), 163-206.

Assunção Flores, M., & Gago, M. (2020). Teacher education in times of COVID-19 pandemic in Portugal: national, institutional and pedagogical responses. *Journal of Education for Teaching, 46*(4), 507-516.

Atwater, M. M., Butler, M. B., Freeman, T. B., & Carlton Parsons, E. R. (2013). An examination of Black science teacher educators' experiences with multicultural education, equity, and social justice. *Journal of Science Teacher Education, 24*(8), 1293-1313.

Aziza, M. (2018). An analysis of a teacher's questioning related to students' responses and mathematical creativity in an elementary school in the UK. *International Electronic Journal of Elementary Education, 10*(4), 475-487.

Bahr, N., & Mellor, S. (2016). *Building quality in teaching and teacher education*. Australian Council for Educational Research, Camberwell, Victoria.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research, Inc.

Banks, J. A. (2013). The construction and historical development of multicultural education, 1962–2012. *Theory into practice, 52*(sup1), 73-82.

Banks, T. (2015). Teacher Education Reform in Urban Educator Preparation Programs. *Journal of Education and Learning, 4*(1), 60-71.

Barton, A. C. (2003). Kobe's story: Doing science as contested terrain. *International Journal of Qualitative Studies in Education, 16*(4), 533-552.

Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 46*(1), 50-73.

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

Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching, 53*(7), 1082-1112.

Beyer, C. J., & Davis, E. A. (2012). Developing preservice elementary teachers' pedagogical design capacity for reform□based curriculum design. *Curriculum Inquiry, 42*(3), 386-413.

Bianchini, J. A., Dwyer, H. A., Brenner, M. E., & Wearly, A. J. (2015). Facilitating science and mathematics teachers' talk about equity: What are the strengths and limitations of four strategies for professional learning?. *Science Education, 99*(3), 577-610.

Bianchini, J. A. (2017). Equity in science education. In *Science education* (pp. 453-464). Brill.

Bishop, R., Ladwig, J., & Berryman, M. (2014). The centrality of relationships for pedagogy: he whanaugatanga thesis. *American Educational Research Journal, 51*(1), 184-214.

Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school–community partnerships as contextual

scaffolds. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 38*(8), 878-898.

Boylan, M., & Woolsey, I. (2015). Teacher education for social justice: Mapping identity spaces. *Teaching and teacher education, 46*, 62-71.

Bradbury, L. U. (2010). Educative mentoring: Promoting reform□based science teaching through mentoring relationships. *Science Education, 94*(6), 1049-1071.

Broad, K., & Tessaro, M. L. (2009). Voices from the field: Associate teachers and teacher candidates in learning conversations. Field experiences in the context of reform of Canadian teacher education programs, 67-78.

Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A "content□first" approach to science teaching. *Journal of Research in Science Teaching, 45*(5), 529-553.

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education, 92*(4), 708-732.

Brown, J. C., & Livstrom, I. C. (2020). Secondary science teachers' pedagogical design capacities for multicultural curriculum design. *Journal of Science Teacher Education, 31*(8), 821-840.

Brown, M. (2009). Toward a theory of curriculum design and use: Understanding the teacher-tool relationship. *Mathematics teachers at work: Connecting curriculum materials and classroom instruction, 14*(2), 17-37.

Burke, A., & Collier, D. R. (2017). 'I was kind of teaching myself': teachers' conversations about social justice and teaching for change. *Teacher Development, 21*(2), 269-287.

Buxton, C. A. (2010). Social problem solving through science: An approach to critical, place-based, science teaching and learning. *Equity & excellence in education, 43*(1), 120-135.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and engineering teacher, 70*(1), 30.

Calabrese Barton, A., & Tan, E. (2018). A longitudinal study of equity-oriented STEM-rich making among youth from historically marginalized communities. *American Educational Research Journal, 55*(4), 761-800.

Calabrese Barton, A., & Tan, E. (2020). Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher, 49*(6), 433-440.

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based professional development: What does it take to support teachers in learning about inquiry and nature of science?. *International Journal of Science Education, 35*(12), 1947-1978.

Cao, Y., Postareff, L., Lindblom-Ylänne, S., & Toom, A. (2019). Teacher educators' approaches to teaching and connections with their perceptions of the closeness of their research and teaching. *Teaching and Teacher Education, 85*, 125-136.

Charity Hudley, A. H., & Mallinson, C. (2017). "It's worth our time": A model of culturally and linguistically supportive professional development for K-12 STEM educators. *Cultural Studies of Science Education, 12*(3), 637-660.

Chen, J. L., & Mensah, F. M. (2018). Teaching contexts that influence elementary preservice teachers' teacher and science teacher identity development. *Journal of Science Teacher Education, 29*(5), 420-439.

Chubbuck, S. M., & Zembylas, M. (2016). Social justice and teacher education: Context, theory, and practice. In *International handbook of teacher education* (pp. 463-501). Springer, Singapore.

Chung, M., and J. Miller. 2011. Do We Live in a Box of Crayons? Looking at Multicultural Metaphors Written by Teachers. *Multicultural Education 18*(4), 39–45.

Clark, S. K. (2010). Pre-Service Teacher and Elementary Student Partnerships During a Reading Methods Course: Does it Make a Difference?.

Clarke, A. (2006). The nature and substance of cooperating teacher reflection. *Teaching and teacher education, 22(*7), 910-921.

Cochran-Smith, M., & Villegas, A. M. (2015). Framing teacher preparation research: An overview of the field, part 1. *Journal of Teacher Education, 66*(1), 7-20.

Cochran-Smith, M., & Villegas, A. M. (2016). Preparing teachers for diversity and high-poverty schools: A research-based perspective. In *Teacher education for high poverty schools* (pp. 9-31). Springer, Cham.

Cofré, H., González-Weil, C., Vergara, C., Santibáñez, D., Ahumada, G., Furman, M., ... Pérez, R. (2015). *Science teacher education in South America: The case of Argentina, Colombia and Chile. Journal of Science Teacher Education, 26*(1), 45-63.

Cohen, J., & Berlin, R. (2020). What constitutes an "opportunity to learn" in teacher preparation?. *Journal of Teacher Education, 71*(4), 434-448.

Colley, C., & Windschitl, M. (2016). Rigor in elementary science students' discourse: The role of responsiveness and supportive conditions for talk. *Science Education, 100*(6), 1009-1038.

Colomo Magaña, E., Cívico Ariza, A., Ruiz Palmero, J., & Sánchez Rivas, E. (2021). Problematic use of ICTS in trainee teachers during COVID-19: A sex-based analysis. *Contemporary Educational Technology, 13*(4).

Copland, F. (2010). Causes of tension in post-observation feedback in pre-service teacher training: An alternative view. *Teaching and Teacher Education, 26*(3), 466-472.

Crawford, B. A. & Lunetta,V. (Fall, 2002). Promoting the development of a personal philosophy of teaching in prospective secondary science teachers. *Pennsylvania Teacher Educator, 1*, 68-74.

Crowley, R. M., & Smith, W. (2015). Whiteness and social studies teacher education: Tensions in the pedagogical task. *Teaching Education, 26*(2), 160-178.

Cutri, R. M., Mena, J., & Whiting, E. F. (2020). Faculty readiness for online crisis teaching: transitioning to online teaching during the COVID-19 pandemic. *European Journal of Teacher Education, 43*(4), 523-541.

Darling-Hammond, L. (2006). Constructing 21st-century teacher education. *Journal of teacher education, 57*(3), 300-314.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). *The Sage handbook of qualitative research*. sage.

Devitt, A. (2022). Forwarding a 'science-ethics nexus' to critique and reorient science education pedagogy toward greater social and ecological justice. *Cultural Studies of Science Education*, 1-8.

DiAngelo, R., & Sensoy, Ö. (2010). "OK, I get it! Now tell me how to do it!": Why we can't just tell you how to do critical multicultural education. *Multicultural Perspectives, 12*(2), 97-102.

Dimick, A. S. (2012). Student empowerment in an environmental science classroom: Toward a framework for social justice science education. *Science Education, 96*(6), 990-1012.

Dinkelman, T. (2011). Forming a teacher educator identity: Uncertain standards, practice and relationships. *Journal of education for teaching, 37*(3), 309-323.

Domínguez, M. 2017. ""Se Hace Puentes Al Andar": Decolonial Teacher Education as a Needed Bridge to Culturally Sustaining and Revitalizing Pedagogies." In *Culturally Sustaining Pedagogy: Teaching and Learning for Justice in a Changing World*, edited by D. Paris and H. S. Alim, 225–245. New York, NY: Teachers College Press.

Double, K. S., McGrane, J. A., & Hopfenbeck, T. N. (2020). The impact of peer assessment on academic performance: A meta-analysis of control group studies. *Educational Psychology Review, 32*(2), 481-509.

Doucet, F. (2017). What does a culturally sustaining learning climate look like?. *Theory Into Practice, 56*(3), 195-204.

Duschl, R. A., & Duncan, R. G. (2009). Beyond the fringe: Building and evaluating scientific knowledge systems. In *Constructivist instruction: Success or failure?* (pp. 311-332). Routledge Taylor & Francis Group.

Edwards, A. (1995). Teacher education: Partnerships in pedagogy?. *Teaching and Teacher education, 11*(6), 595-610.

Eisele, R. J. (2021). *White Teachers in a Perceived White District Discussing Race and Racism in Their Classrooms* (Doctoral dissertation, California State University, Fresno).

Ell, F., Haigh, M., Cochran-Smith, M., Grudnoff, L., Ludlow, L., & Hill, M. F. (2017). Mapping a complex system: what influences teacher learning during initial teacher education?. *Asia-Pacific Journal of Teacher Education, 45*(4), 327-345.

Ellis, N. J., Alonzo, D., & Nguyen, H. T. M. (2020). Elements of a quality pre-service teacher mentor: A literature review. *Teaching and Teacher Education, 92*, 103072.

Ellis, N. J., & Loughland, T. (2017). 'Where to next?'Examining feedback received by teacher education students. *Issues in Educational Research, 27*(1), 51-63.

Emdin, C. (2010). Affiliation and alienation: Hip□hop, rap, and urban science education. *Journal of Curriculum Studies, 42*(1), 1-25.

Emdin, C. (2011). Moving beyond the boat without a paddle: Reality pedagogy, Black youth, and urban science education. *Journal of Negro Education, 80*(3), 284-295.

Emdin, C. (2020). A ratchetdemic reality pedagogy and/as cultural freedom in urban education. *Educational Philosophy and Theory, 52*(9), 947-960.

Esteban-Guitart, M., & Moll, L. C. (2014). Funds of identity: A new concept based on the funds of knowledge approach. *Culture & Psychology, 20*(1), 31-48.

Fairbanks, C. M., Freedman, D., & Kahn, C. (2000). The role of effective mentors in learning to teach. *Journal of teacher education, 51*(2), 102-112.

Fazio, X., & Volante, L. (2011). Preservice science teachers' perceptions of their practicum classrooms. *The Teacher Educator, 46*(2), 126-144.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers college record, 103*(6), 1013-1055.

Feiman-Nemser, S. (2008). Teacher learning: How do teachers learn to teach?. In *Handbook of research on teacher education* (pp. 696-705). Routledge.

Finkel, L. (2018). Infusing social justice into the science classroom: Building a social justice movement in science education. *Educational Foundations, 31*, 40-58.

Forbes, C. T. (2013). Curriculum-dependent and curriculum-independent factors in preservice elementary teachers' adaptation of science curriculum materials for inquiry-based science. *Journal of Science Teacher Education, 24*(1), 179-197.

Forsythe, M. E., & Chan, Y. W. (2021). Justice-centered education amid the COVID-19 pandemic. *The Journal of Environmental Education, 52*(5), 347-357.

Freire, P. (1970). Cultural action and conscientization. *Harvard educational review, 40*(3), 452-477.

Freire, P. (1972). *Pedagogy of the oppressed*. New York: Herder and Herder.

Furberg, A., & Silseth, K. (2022). Invoking student resources in whole-class conversations in science education: A sociocultural perspective. *Journal of the Learning Sciences, 31*(2), 278-316.

Furtak, E. M. (2017). Confronting dilemmas posed by three□dimensional classroom assessment: Introduction to a virtual issue of Science Education. *Science Education, 101*(5), 854-867.

Furtak, E. M., & Penuel, W. R. (2019). Coming to terms: Addressing the persistence of "hands□on" and other reform terminology in the era of science as practice. *Science education, 103*(1), 167-186.

Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of teacher education, 53*(2), 106-116.

Gay, G. (2010). Acting on beliefs in teacher education for cultural diversity. *Journal of teacher education, 61*(1-2), 143-152.

Gonzales, P., Guzmán, J. C., Partelow, L., Pahlke, E., Jocelyn, L., Kastberg, D., & Williams, T. (2004). Highlights from the Trends in International Mathematics and Science Study (TIMSS), 2003. NCES 2005-005. *US Department of Education*.

Goodwin, A. L., & Kosnik, C. (2013). Quality teacher educators= quality teachers? Conceptualizing essential domains of knowledge for those who teach teachers. *Teacher Development, 17*(3), 334-346.

Goodwin, A. L., Smith, L., Souto-Manning, M., Cheruvu, R., Tan, M. Y., Reed, R., & Taveras, L. (2014). What should teacher educators know and be able to do? Perspectives from practicing teacher educators. *Journal of Teacher Education, 65*(4), 284-302.

Goodwin, A. L., & Darity, K. (2019). Social justice teacher educators: What kind of knowing is needed?. *Journal of Education for Teaching, 45*(1), 63-81.

Gorski, P. C. (2009). What we're teaching teachers: An analysis of multicultural teacher education coursework syllabi. *Teaching and teacher education, 25*(2), 309-318.

Gorski, P. C. (2012). Perceiving the problem of poverty and schooling: Deconstructing the class stereotypes that mis-shape education practice and policy. *Equity & Excellence in Education, 45*(2), 302-319.

Gorski, P. C. (2016). Making better multicultural and social justice teacher educators: A qualitative analysis of the professional learning and support needs of multicultural teacher education faculty. *Multicultural Education Review, 8*(3), 139-159.

Gray, D. L., McElveen, T. L., Green, B. P., & Bryant, L. H. (2020). Engaging Black and Latinx students through communal learning opportunities: A relevance intervention

for middle schoolers in STEM elective classrooms. *Contemporary Educational Psychology, 60*, 101833.

Gray, R., Rogan□Klyve, A., & Canipe, M. M. (2022). Investigating the impact of eliciting and being responsive to students' initial ideas on productive disciplinary engagement across a unit. *Science Education, 106*(2), 312-334.

Griffith, R., Bauml, M., & Quebec-Fuentes, S. (2016). Promoting metacognitive decision-making in teacher education. *Theory Into Practice, 55*(3), 242-249.

Grinath, A. S., & Southerland, S. A. (2019). Applying the ambitious science teaching framework in undergraduate biology: Responsive talk moves that support explanatory rigor. *Science Education, 103*(1), 92-122.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re□imagining teacher education. *Teachers and Teaching: theory and practice, 15*(2), 273-289.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of qualitative research, 2*(163-194), 105.

Gunning, A. M., & Mensah, F. M. (2011). Preservice elementary teachers' development of self-efficacy and confidence to teach science: A case study. *Journal of Science Teacher Education, 22*(2), 171-185.

Gutman, M. (2021). Leading a Professional Learning Community for teacher educators: inquiry into college principals' motives and challenges. *Teacher Development, 25*(3), 263-277.

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research (J-PEER), 6*(1), 2.

Haas, B., Kreis, Y., & Lavicza, Z. (2021). Integrated STEAM Approach in Outdoor Trails with Elementary School Pre-service Teachers. *Educational Technology & Society, 24*(4), 205-219.

Hammerness, K., Darling-Hammond, L., & Bransford, J. (2005). How teachers learn and develop. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 358–389). San Francisco: Jossey-Bass.

Hammerness, K., & Kennedy, B. (2019). Teaching practices grounded in foundational knowledge, visions, and contexts. *The New Educator, 15*(1), 66-83.

Harlow, D. B. (2012). The excitement and wonder of teaching science: What pre-service teachers learn from facilitating family science night centers. *Journal of Science Teacher Education*, 23(2), 199-220.

Harrington, C., Erete, S., & Piper, A. M. (2019). Deconstructing community-based collaborative design: Towards more equitable participatory design engagements. *Proceedings of the ACM on Human-Computer Interaction, 3*(CSCW), 1-25.

Hartshorne, R., Baumgartner, E., Kaplan-Rakowski, R., Mouza, C., & Ferdig, R. E. (2020). Special issue editorial: Preservice and inservice professional development during the COVID-19 pandemic. *Journal of Technology and Teacher Education, 28*(2), 137-147.

Hiebert, J., & Morris, A. K. (2012). Teaching, rather than teachers, as a path toward improving classroom instruction. *Journal of teacher Education, 63*(2), 92-102.

Hopkins, M., & Spillane, J. P. (2014). Schoolhouse teacher educators: Structuring beginning teachers' opportunities to learn about instruction. *Journal of Teacher Education, 65*(4), 327-339.

Jacques, L. A., Cian, H., Herro, D. C., & Quigley, C. (2020). The impact of questioning techniques on STEAM instruction. *Action in Teacher Education, 42*(3), 290-308.

Jones, T. M., Diaz, A., Bruick, S., McCowan, K., Wong, D. W., Chatterji, A., ... & Spencer, M. S. (2021). Experiences and perceptions of school staff regarding the COVID-19 pandemic and racial equity: The role of colorblindness. *School Psychology, 36*(6), 546.

Kang, H., & Anderson, C. W. (2008). Teacher candidates' interpretations of problems of practice in science teaching. In *annual AERA conference, New York, NY*.

Kang, N. H. (2008). Learning to teach science: Personal epistemologies, teaching goals, and practices of teaching. *Teaching and Teacher Education, 24*(2), 478-498.

Karisan, D., Macalalag, A., & Johnson, J. (2019). The Effect of Methods Course on Preservice Teachers' Awareness and Intentions of Teaching Science, Technology, Engineering, and Mathematics (STEM) Subject. *International Journal of Research in Education and Science, 5*(1), 22-35.

Karlström, M., & Hamza, K. (2019). Preservice science teachers' opportunities for learning through reflection when planning a microteaching unit. *Journal of Science Teacher Education, 30*(1), 44-62.

Kaur, B. (2012). Equity and social justice in teaching and teacher education. *Teaching and Teacher Education, 28*(4), 485-492.

Kidd, W., & Murray, J. (2020). The Covid-19 pandemic and its effects on teacher education in England: how teacher educators moved practicum learning online. *European Journal of Teacher Education, 43*(4), 542-558.

Kincheloe, J. L. (2011). The knowledges of teacher education: Developing a critical complex epistemology. In *Key works in critical pedagogy* (pp. 227-243). Brill.

Kitchen, J., & Brown, N. (2022). Blind Spots and Eye-Openers: Attending to the Concerns of Racialized Teacher Candidates in a Social Justice Course. *Studying Teacher Education, 18*(1), 98-118.

Koc, I. (2012). Preservice science teachers reflect on their practicum experiences. *Educational Studies, 38*(1), 31-38.

Kohli, R., Dover, A. G., Jayakumar, U. M., Lee, D., Henning, N., Comeaux, E., ... & Vizcarra, M. (2022). Toward a healthy racial climate: Systemically centering the well-being of teacher candidates of color. *Journal of Teacher Education, 73*(1), 52-65.

Kretchmar, K., & Zeichner, K. (2016). Teacher prep 3.0: A vision for teacher education to impact social transformation. *Journal of Education for Teaching, 42*(4), 417-433.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American educational research journal, 32*(3), 465-491.

Ladson-Billings, G. (2000). Fighting for our lives: Preparing teachers to teach African American students. *Journal of teacher education, 51*(3), 206-214.

Ladson-Billings, G. (2021). I'm here for the hard re-set: Post pandemic pedagogy to preserve our culture. *Equity & Excellence in Education, 54*(1), 68-78.

Land, C. L. (2018). Examples of c/critical coaching: An analysis of conversation between cooperating and preservice teachers. *Journal of Teacher Education, 69*(5), 493-507.

Larkin, D. (2012). Misconceptions about "misconceptions": Preservice secondary science teachers' views on the value and role of student ideas. *Science Education, 96*(5), 927-959.

Lave, J., & Wenger, E. (1991). Learning in doing: Social, cognitive, and computational perspectives. *Situated learning: Legitimate peripheral participation, 10.*

Le, P. T. A., & Vásquez, C. (2011). Feedback in teacher education: Mentor discourse and intern perceptions. *Teacher development, 15*(4), 453-470.

Lee, O., & Buxton, C. A. (2010). Diversity and Equity in Science Education: Research, Policy, and Practice. *Multicultural Education Series. Teachers College Press.*

Lee, O., Miller, E. C., & Januszyk, R. (2014). Next generation science standards: All standards, all students. *Journal of Science Teacher Education, 25*(2), 223-233.

Legette, K. B., Rogers, L. O., & Warren, C. A. (2022). Humanizing student–teacher relationships for black children: Implications for teachers' social–emotional training. *Urban Education, 57*(2), 278-288.

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

Leonard, J., Barnes-Johnson, J., Dantley, S. J., & Kimber, C. (2011). Teaching science inquiry in urban contexts: The role of elementary preservice teachers' beliefs. *The Urban Review, 43*(1), 124-150.

Long, J. J., van Es, E. A., & Black, R. W. (2013). Supervisor–student teacher interactions: The role of conversational frames in developing a vision of ambitious teaching. *Linguistics and Education, 24*(2), 179-196.

Lortie, D. 1975. *Schoolteacher: A Sociological Study*. London: University of Chicago Press.

Loughran, J. (2014). Professionally developing as a teacher educator. *Journal of teacher education, 65*(4), 271-283.

Lehesvuori, S., Hähkiöniemi, M., Viiri, J., Nieminen, P., Jokiranta, K., & Hiltunen, J. (2019). Teacher orchestration of classroom interaction in science: exploring dialogic and authoritative passages in whole-class discussions. *International Journal of Science Education, 41*(17), 2557-2578.

Lehesvuori, S., Ramnarain, U., & Viiri, J. (2018). Challenging transmission modes of teaching in science classrooms: Enhancing learner-centredness through dialogicity. *Research in Science Education, 48*(5), 1049-1069.

Lyon, E. G., Stoddart, T., Bunch, G. C., Tolbert, S., Salinas, I., & Solis, J. (2018). Improving the preparation of novice secondary science teachers for English learners: A proof of concept study. *Science Education, 102*(6), 1288-1318.

Macalalag, A. Z., Sahin, I., Johnson, J., & Bicer, A. (2022). Internalization of STEM Education.

Maestrales, S., Marias Dezendorf, R., Tang, X., Salmela□Aro, K., Bartz, K., Juuti, K., ... & Schneider, B. (2022). US and Finnish high school science engagement during the COVID□19 pandemic. *International Journal of Psychology, 57*(1), 73-86.

Maphosa, V. (2021). Teachers' perspectives on remote-based teaching and learning in the COVID-19 era: Rethinking technology availability and suitability in Zimbabwe. *European Journal of Interactive Multimedia and Education, 2*(1), e02105.

Mark, S., Id-Deen, L., & Thomas, S. (2020). Getting to the root of the matter: pre-service teachers' experiences and positionalities with learning to teach in culturally diverse contexts. *Cultural Studies of Science Education, 15*(2), 453-483.

Marshall, D. T., Shannon, D. M., & Love, S. M. (2020). How teachers experienced the COVID-19 transition to remote instruction. *Phi Delta Kappan, 102*(3), 46-50.

Martin, A. M., & Hand, B. (2009). Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study. *Research in Science Education, 39*(1), 17-38.

Matias, C. E., Montoya, R., & Nishi, N. W. (2016). Blocking CRT: How the emotionality of whiteness blocks CRT in urban teacher education. *Educational Studies, 52*(1), 1-19.

McCollough, C., & Ramirez, O. (2012). Cultivating culture: Preparing future teachers for diversity through family science learning events. *School Science and Mathematics, 112*(7), 443-451.

McGinnis, J. R., Parker, C., & Graeber, A. O. (2004). A cultural perspective of the induction of five reform□minded beginning mathematics and science teachers. *Journal of Research in Science Teaching, 41*(7), 720-747.

McIntosh, M. J., & Morse, J. M. (2015). Situating and constructing diversity in semi-structured interviews. *Global qualitative nursing research, 2*, 2333393615597674.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. Jossey-Bass.

Mensah, F. M. (2011). A case for culturally relevant teaching in science education and lessons learned for teacher education. *Journal of Negro Education, 80*(3), 296-309.

Mensah, F. M. (2013). Retrospective accounts in the formation of an agenda for diversity, equity, and social justice for science education. In *Moving the equity agenda forward* (pp. 317-335). Springer, Dordrecht.

Mensah, F. M. (2021). Culturally relevant and culturally responsive. *Science and Children, 58*(4), 10-13.

Mensah, F. M. (2022). "Now, I see": Multicultural science curriculum as transformation and social action. *The Urban Review, 54*(1), 155-181.

Mensah, F. M., & Jackson, I. (2018). Whiteness as property in science teacher education. *Teachers college record, 120*(1), 1-38.

Mervis, J. (2022, Mar 1). *The Toll of White Privilege*. Science. https://www.science.org/content/article/how-culture-of-white-privilege-discourages-black-students-from-becoming-physicists.

Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in philosophy and education, 27*(4), 283-297.

Michaels, S., & O'Connor, C. (2012). Talk science primer. *Cambridge, MA: TERC*.

Milner, H. R. (2006). Preservice teachers' learning about cultural and racial diversity: Implications for urban education. *Urban Education, 41*(4), 343-375.

Mok, S. Y., & Staub, F. C. (2021). Does coaching, mentoring, and supervision matter for pre-service teachers' planning skills and clarity of instruction? A meta-analysis of (quasi-) experimental studies. *Teaching and Teacher Education, 107*, 103484.

Moon, S., Carpenter, S. L., Hansen, A. K., Bushong, L., & Bianchini, J. A. (2021). Examining the effects of undergraduate STEM teacher recruitment and teacher education programs on preservice secondary science and mathematics teacher readiness and teacher performance assessment (edTPA) scores. *School Science and Mathematics, 121*(8), 452-465.

Morales□Doyle, D. (2017). Justice□centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education, 101*(6), 1034-1060.

Morales-Doyle, D., & Frausto, A. (2021). Youth participatory science: a grassroots science curriculum framework. *Educational Action Research, 29*(1), 60-78.

Morales-Doyle, D., Frausto Aceves, A., Canales Salas, K., Chappell, M. J., Rajski, T. G., Aguilera, A., ... & Lopez, D. (2022). Reflections on Teaching and Learning Chemistry Through Youth Participatory Science. In *Reimagining Science Education in the Anthropocene* (pp. 229-242). Palgrave Macmillan, Cham.

Morales-Doyle, D., & Gutstein, E. R. (2019). Racial capitalism and STEM education in Chicago Public Schools. *Race Ethnicity and Education, 22*(4), 525-544.

Mortimer, E., & Scott, P. (2003). *Meaning Making In Secondary Science Classroom*s. McGraw-Hill Education (UK).

Mosley Wetzel, M., Taylor, L. A., & Vlach, S. K. (2017). Dialogue in the support of learning to teach: a case study of a mentor/mentee pair in a teacher education programme. *Teaching Education, 28*(4), 406-420.

Moye, M. J., Henkin, A. B., & Egley, R. J. (2005). Teacher□principal relationships: Exploring linkages between empowerment and interpersonal trust. *Journal of Educational Administration, 43*(3), 260-277.

Murphy, C., Smith, G., Mallon, B., & Redman, E. (2020). Teaching about sustainability through inquiry-based science in Irish primary classrooms: the impact of a professional development programme on teacher self-efficacy, competence and pedagogy. *Environmental Education Research, 26*(8), 1112-1136.

Murray, J., & Male, T. (2005). Becoming a teacher educator: Evidence from the field. *Teaching and teacher education, 21*(2), 125-142.

Murray, J., Swennen, A., & Shagrir, L. (2009). Understanding teacher educators' work and identities. In *Becoming a teacher educator* (pp. 29-43). Springer, Dordrecht.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2015. *Science teachers learning: Enhancing opportunities, creating supportive contexts*. Committee on Strengthening Science Education through a Teacher Learning Continuum. Board on Science Education and Teacher Advisory Council, Division of Behavioral and Social Science and Education. Washington, DC: National Academies Press.

Newman Jr, W. J., Abell, S. K., Hubbard, P. D., McDonald, J., Otaala, J., & Martini, M. (2004). Dilemmas of teaching inquiry in elementary science methods. *Journal of Science teacher education, 15*(4), 257-279.

NGSS Lead States. 2013. Next Generation Science Standards*: For States, By States*. Washington, DC: The National Academies Press.

Nguyen, T. D., Pham, L. D., Crouch, M., & Springer, M. G. (2020). The correlates of teacher turnover: An updated and expanded meta-analysis of the literature. *Educational Research Review, 31*, 100355.

Nieto, S. (2000). Placing equity front and center: Some thoughts on transforming teacher education for a new century. *Journal of teacher education*, *51*(3), 180-187.

Nieto, S. (2017). Becoming Sociocultural Mediators: What All Educators Can Learn from Bilingual and ESL Teachers. *Issues in Teacher Education, 26*(2), 129-141.

North, C. E. (2009). The promise and perils of developing democratic literacy for social

Oliveira, A. W. (2010). Engaging students in guided science inquiry discussions: Elementary teachers' oral strategies. *Journal of Science Teacher Education, 21*(7), 747-765.

Osborne, J. F., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. Y. (2016). The development and validation of a learning progression for argumentation in science. *Journal of research in science teaching, 53*(6), 821-846.

Owen, P. M. 2010. Increasing Preservice Teachers' Support of Multicultural Education. *Multicultural Perspectives, 12*(1), 18–25.

Paris, D., & Alim, H. S. (2014). What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard educational review, 84*(1), 85-100.

Philip, T. M., & Benin, S. Y. (2014). Programs of teacher education as mediators of White teacher identity. *Teaching Education, 25*(1), 1-23.

Pressley, T., & Ha, C. (2021). Teaching during a pandemic: United States teachers' self-efficacy during COVID-19. *Teaching and Teacher Education, 106*, 103465.

Pulido, I. B., Miglietta, A., Cortez, G. A., Stovall, D., & Aviles de Bradley, A. (2013). Re-Framing, Re-Imagining, and Re-Tooling Curricula from the Grassroots: The Chicago Grassroots Curriculum Taskforce. *Current Issues in Comparative Education, 15*(2), 84-95.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?. *Educational researcher, 29*(1), 4-15.

Reyes, G., Radina, R., & Aronson, B. A. (2018). Teaching against the grain as an act of love: Disrupting white eurocentric masculinist frameworks within teacher education. *The Urban Review, 50*(5), 818-835.

Reiser, B. J. (2013). *What Professional Development Strategies Are Needed for Successful Implementation of the Next Generation Science Standards?* White paper presented to the Invitational Research Symposium on Science Assessment. K-12 Center at ETS.

Resnick, L. B. (2017). Toward a cognitive theory of instruction. In *Learning and motivation in the classroom* (pp. 5-38). Routledge.

Rivera Maulucci, M. S. (2013). Emotions and positional identity in becoming a social justice science teacher: Nicole's story. *Journal of Research in Science Teaching, 50*(4), 453-478.

Roberts, T. G. (2006). Developing a model of cooperating teacher effectiveness. *Journal of Agricultural Education, 47*(3), 1.

Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices? A critique of the next generation science standards. *Journal of Research in Science Teaching, 52*(7), 1031-1051.

Rogoff, B., Callanan, M., Gutiérrez, K. D., & Erickson, F. (2016). The organization of informal learning. *Review of Research in Education, 40*(1), 356-401.

Ronfeldt, M. (2015). Field placement schools and instructional effectiveness. *Journal of Teacher Education, 66*(4), 304-320.

Rowan, L., Brownlee, J. L., & Ryan, M. (2019). Teaching teachers: what [should] teacher educators "know" and "do" and how and why it matters. *Asia-Pacific Journal of Teacher Education, 47*(3), 210-215.

Rowe, M. B. (1974). Relation of wait□time and rewards to the development of language, logic, and fate control: Part II□Rewards. *Journal of research in science teaching, 11*(4), 291-308.

Ruiz□Primo, M. A., & Furtak, E. M. (2007). Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry. *Journal of research in science teaching, 44*(1), 57-84.

Russ, R. S. (2017). Integrating conversations about equity in "Whose Knowledge Counts" into science teacher education. *The Physics Teacher, 55*(6), 365-368.

Russo, J., & Minas, M. (2020). Student Attitudes Towards Learning Mathematics Through Challenging, Problem Solving Tasks:"It's so Hardin a Good Way". *International Electronic Journal of Elementary Education, 13*(2), 215-225.

Sahin-Taskin, C. (2018). Effects of active learning environments supported with self-and peer assessment on pre-service teachers' pedagogical and self-efficacy beliefs. *Asia-Pacific Journal of Teacher Education, 46*(5), 421-440.

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). London, England: Sage.

Sasaki, R., Goff, W., Dowsett, A., Paroissien, D., Matthies, J., Di Iorio, C., ... & Puddy, G. (2020). The Practicum Experience during Covid-19–Supporting Pre-Service Teachers Practicum Experience through a Simulated Classroom. *Journal of Technology and Teacher Education, 28*(2), 329-339.

Schmid, E. C., & Hegelheimer, V. (2014). Collaborative research projects in the technology-enhanced language classroom: Pre-service and in-service teachers exchange knowledge about technology. *ReCALL, 26*(3), 315-332.

Shahali, E. H., Halim, L., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2017). Primary school teachers' understanding of science process skills in relation to their teaching qualifications and teaching experience. *Research in Science Education, 47*(2), 257-281.

Sheridan, L., & Young, M. (2017). Genuine conversation: The enabler in good mentoring of pre-service teachers. *Teachers and Teaching, 23*(6), 658-673.

Sheth, M. J. (2019). Grappling with racism as foundational practice of science teaching. *Science Education, 103*(1), 37-60.

Sintema, E. J. (2020). Effect of COVID-19 on the performance of grade 12 students: Implications for STEM education. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(7), em1851.

Sleeter, C. E. (2017). Critical race theory and the whiteness of teacher education. *Urban Education, 52*(2), 155-169.

Smith, S. (2006). Encouraging the use of reflexivity in the writing up of qualitative research. *International Journal of Therapy and Rehabilitation, 13*(5), 209-215.

Smith, P. M., & Hackling, M. W. (2016). Supporting teachers to develop substantive discourse in primary science classrooms. *Australian Journal of Teacher Education (Online), 41*(4), 151-173.

Snead, L. O., & Freiberg, H. J. (2019). Rethinking student teacher feedback: Using a self-assessment resource with student teachers. *Journal of Teacher Education, 70*(2), 155-168.

Song, S. Y., & Swearer, S. M. (2016). The cart before the horse: The challenge and promise of restorative justice consultation in schools. *Journal of Educational and Psychological Consultation, 26*(4), 313-324.

Spradley, James P. 1979. *The Ethnographic Interview*. New York: Holt, Rinehart and Winston.

Stegman, S. F. (2007). An exploration of reflective dialogue between student teachers in music and their cooperating teachers. *Journal of Research in Music Education, 55*(1), 65-82.

Stroupe, D., & Gotwals, A. W. (2018). "It's 1000 degrees in here when I teach": Providing preservice teachers with an extended opportunity to approximate ambitious instruction. *Journal of Teacher Education, 69*(3), 294-306.

Tan, E., & Barton, A. C. (2008). Unpacking science for all through the lens of identities-in-practice: The stories of Amelia and Ginny. *Cultural Studies of Science Education, 3*(1), 43-71.

Tekkumru-Kisa, M., Schunn, C., Stein, M. K., & Reynolds, B. (2019). Change in thinking demands for students across the phases of a science task: An exploratory study. *Research in Science Education, 49*(3), 859-883.

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American educational research journal, 50*(3), 574-615.

Timperley, H. (2001). Mentoring conversations designed to promote student teacher learning. *Asia-Pacific Journal of Teacher Education, 29*(2), 111-123.

Timperley, H. (2013). *Learning to practise: A paper for discussion*. Wellington: Ministry of Education.

Titu, P., Ring-Whalen, E. A., Brown, J. C., & Roehrig, G. H. (2018). Exploring changes in science teachers' attitudes toward culturally diverse students during an equity-focused course. *Journal of Science Teacher Education, 29*(5), 378-396.

Tobin, K. (1993). Referents for making sense of science teaching. *International Journal of Science Education, 15*(3), 241-254.

Tolbert, S. (2015). "Because they want to teach you about their culture": Analyzing effective mentoring conversations between culturally responsible mentors and secondary science teachers of indigenous students in mainstream schools. *Journal of Research in Science Teaching, 52(*10), 1325-1361.

Tolbert, S., Schindel, A., & Rodriguez, A. J. (2018). Relevance and relational responsibility in justice□oriented science education research. *Science Education, 102*(4), 796-819.

Tondeur, J., Roblin, N. P., Van Braak, J., Fisser, P., & Voogt, J. (2013). Technological pedagogical content knowledge in teacher education: In search of a new curriculum. *Educational studies, 39*(2), 239-243.

Trigos-Carrillo, L., & Rogers, R. (2017). Latin American influences on multiliteracies: From epistemological diversity to cognitive justice. *Literacy Research: Theory, Method, and Practice, 66*(1), 373-388.

Tsai, C. C. (2006). Reinterpreting and reconstructing science: Teachers' view changes toward the nature of science by courses of science education. *Teaching and Teacher Education, 22*(3), 363-375.

Tseng, C. J., & Chen, T. C. (2020). Impact of Web-Based Teaching on the Learning Performance of Education and Training in the Service Industry during COVID-19. *Contemporary Educational Technology, 12*(2).

Tuck, E. (2009). Re-visioning action: Participatory action research and Indigenous theories of change. *The Urban Review, 41*(1), 47-65.

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

Valenzuela Jr, A. (1999). Gender roles and settlement activities among children and their immigrant families. *American Behavioral Scientist, 42*(4), 720-742.

Varelas, M., Morales□Doyle, D., Raza, S., Segura, D., Canales, K., & Mitchener, C. (2018). Community organizations' programming and the development of community science teachers. *Science Education, 102*(1), 60-84.

Vick, M. (2006). "It's a Difficult Matter": Historical perspectives on the enduring problem of the practicum in teacher preparation. *Asia□Pacific Journal of Teacher Education, 34*(2), 181-198.

Villegas, A. M., & Lucas, T. (2002). Preparing culturally responsive teachers: Rethinking the curriculum. *Journal of teacher education, 53*(1), 20-32.

Wang, J. (2001). Contexts of mentoring and opportunities for learning to teach: A comparative study of mentoring practice. *Teaching and Teacher Education, 17*(1), 51-73.

Warren, C. A. (2018). Empathy, teacher dispositions, and preparation for culturally responsive pedagogy. *Journal of Teacher Education, 69*(2), 169-183.

Whalen, J. (2020). Should teachers be trained in emergency remote teaching? Lessons learned from the COVID-19 pandemic. *Journal of Technology and Teacher Education, 28*(2), 189-199.

Willemse, T. M., Thompson, I., Vanderlinde, R., & Mutton, T. (2018). Family-school partnerships: a challenge for teacher education. *Journal of Education for Teaching, 44*(3), 252-257.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?. *Science education, 87*(1), 112-143.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model□based inquiry as a new paradigm of preference for school science investigations. *Science education, 92*(5), 941-967.

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation, 19*(3), 321-332.

Yin, R. K. 2014. *Case Study Research: Design and Methods.* Los Angeles, CA: Sage

Zehr, H. (2015). Changing lenses: *Restorative justice for our times*. MennoMedia, Inc..

Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college-and university-based teacher education. *Journal of teacher education*, 61(1-2), 89-99.

Zeichner, K. (2016). Advancing social justice and democracy in teacher education: Teacher preparation 1.0, 2.0, and 3.0. *Kappa Delta Pi Record, 52*(4), 150-155.

Zeichner, K., & Liston, D. (1987). Teaching student teachers to reflect. *Harvard educational review, 57*(1), 23-49.

Appendix A: Interview Protocols

Summer Science and Mathematics Teacher Candidate Interview Protocol
July 2020

Thank you for agreeing to be interviewed today. The purpose of this interview is to learn about some of the successes and challenges you are experiencing as a teacher candidate. We are studying science and mathematics teacher education to better support beginning teacher learning. We ask that you try to be as candid and specific as possible.

The information from this interview will not affect your course grades, your teaching placements, or your standing in the Teacher Education Program. If there is a question you do not wish to answer, you can ask that it be skipped. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well.

We expect the interview to last about 60 minutes. It is divided into 8 parts. Do I have your permission to begin recording the interview?

[Turn on record.]

Today is [Date] at [Time]. This is the initial interview with [Participant Initials] and the interviewer is [Interviewer Name].

Background Information (warm up questions/minimal probing)

First, I'd like to ask you a few background questions about your interests in and experiences with teaching.

1. What are some reasons why you decided to become a teacher?
    a. Why did you decide to teach *biology, chemistry, physics, or mathematics* in particular?
    b. Why did you decide to enroll in the UCSB teacher education program?

2. Where would you like to teach at the completion of your program and why?
   a. What are the three most important characteristics in a school you would select given any you could choose?
   b. What particular grade level (e.g., high school, junior high) and courses would you like to teach (e.g., honors, AP, conceptual physics, marine science) and why?

Conceptions of Science or Mathematics Teaching and Learning (warm up questions/minimal probing)

These next few questions ask about your conceptions of effective math or science teaching and learning.

3. What have you learned about *effective math or science instruction* from your teacher education program so far?
   a. What more would you like to learn?

4. What have you learned about *how students learn* from your teacher education program so far?
   a. What more would you like to learn?

Science and Engineering Practices and Crosscutting Concepts (SKIP IF MATH)

These next few questions are about the *Next Generation Science Standards* in science.

5. Are you already familiar with the *NGSS*?
   a. If so, what have you learned about the eight science and engineering practices from the *NGSS* in your prior courses or experiences?

6. [Go to a PPT slide] These are cards with the eight science and engineering practices from the *NGSS*.
   a. Which **two** do you envision most often implementing in your student teaching placements? How would you implement them?
   b. Out of all eight, which **one** do you think is most important to teach students? Why?
   c. Which **one or two** practices do you think you need more help to understand or implement? Why?

7. [Go to next PPT slide] These are cards with the seven crosscutting concepts from the *NGSS*.
   a. Which **two** do you envision most often implementing in your student teaching placements? How would you implement them?
   b. Out of all seven, which **one** do you think is most important to teach students? Why?

c. Which **one or two** crosscutting concepts do you think you need more help to understand or implement? Why?

Mathematical Practices (SKIP IF SCIENCE)

These next few questions are about the *Common Core State Standards* in mathematics.

5. Are you already familiar with the *Common Core*?
   a. If so, what have you learned about the mathematical practices from the *Common Core* in your prior courses or experiences?

6. [Go to a PPT slide] These are cards with the eight mathematical practices from the *Common Core*.
   a. Which **two** do you envision most often implementing in your student teaching placements? How would you implement them?
   b. Out of all eight, which **one** do you think is most important to teach students? Why?
   c. Which **one or two** practices do you think you need more help to understand or implement? Why?

Remote Instruction Teaching and Learning

The current social distancing guidelines have caused instruction to shift to an online platform. The next few questions are about your thoughts on remote instruction.

8. What experiences have you had with *learning* through remote instruction before starting the teacher education program?
   1. What experiences have you had with *teaching* through remote instruction before starting the teacher education program?

9. How do you feel about *learning how to teach* through remote instruction?
   a. What do you see as some potential benefits?
   b. What do you see as some potential challenges?

10. How do you feel about *teaching students* through remote instruction?
    a. What do you see as some potential benefits?
    b. What do you see as some potential challenges?

Teacher Candidate Development

The next few questions are about your views on effective teaching, and how you see yourself developing your skill set as a teacher.

11. What do you think are the characteristics of an effective teacher?
    1. What do you think will help you to develop those skills?

12. [Go to a PPT slide] Various teacher responsibilities are listed on this slide. When you think about learning how to teach throughout the upcoming school year, which of these responsibilities do you foresee as coming easily to you? Why?

    a. Do any of these seem like they might be challenging for you? Why?
    b. What might help you to grow in those areas?

13. Imagine that you are in the middle of the school year and you had a particularly challenging day. Perhaps a lesson did not go well, or students weren't listening to you, etc. What would you do?
    a. If you wanted support, who would you go to and why?
    b. Is there anything else you might do? If yes, what else?

14. Imagine that you are having a conversation with your field work supervisor – they observed one of your lessons, and it did not go as well as you had hoped. How would you like them to support you in order to help you grow in that area?
    a. What would help you to feel encouraged?
    b. Is there anything that might make you not as receptive to their feedback?
    c. What else could they do or say to support you?

Multilingual Learners

The next few questions discuss your experience and readiness to teach multilingual learners in your future classroom. Multilingual learners may also be referred to as English learners, English language learners, or English as a second language students.

15. What do you see as the strengths of multilingual learners in science or mathematics classrooms?
    1. What challenges do you think multilingual learners in these classrooms encounter?

16. What are the characteristics of an effective teacher of multilingual learners?
    a. Do you have specific knowledge, skills, or traits that you feel will benefit you as a teacher of multilingual learners?
    b. What do you think you will learn in the teacher education program to help you develop additional knowledge, skills, or traits?

17. What have you learned about effective math or science instruction for multilingual learners from your teacher education program so far?
    a. In particular, what have you learned in your summer course ED 319 Academic Language course that will be helpful in thinking about teaching multilingual learners?
b. What more would you like to learn about teaching multilingual learners?

18. When considering working in a remote instruction environment, what adjustments do you imagine having to make to challenge or support multilingual learners?

a. On a scale of 1 through 5, with 5 being the most prepared, how prepared do you feel to engage in effective instruction with multilingual learners in a remote instruction environment? Why?

Wrap-Up

19. Do you have any questions for me?

20. [Put demographic survey link in the chat: https://forms.gle/gR3Bg2jnJ83gnBBT8]. Please take a few minutes to fill out our demographic survey.

Thank you!

Science and Mathematics Teacher Candidate Interview Protocol
End of Fall 2020

Thank you for agreeing to be interviewed today. The purpose of this interview is to learn about some of the successes and challenges you are experiencing as a teacher candidate. We are studying science and mathematics teacher education to better support beginning teacher learning. We ask that you try to be as candid and specific as possible.

The information from this interview will not affect your course grades, your teaching placements, or your standing in the Teacher Education Program. If there is a question you do not wish to answer, you can ask that it be skipped. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well.

We expect the interview to last about 60 minutes. It is divided into 7 parts. Do I have your permission to begin recording the interview?

[Turn on record.]

Today is [Date] at [Time]. This is the initial interview with [Participant Initials] and the interviewer is [Interviewer Name].

Placement Information (warm up questions/minimal probing)

First, I'd like to ask you a few questions about your student teaching placements.

1. In which course(s) were you placed this fall (e.g., what discipline, grade, CP/Honors/AP, etc.)? I assume these courses were all remote, yes?

2. What is one success and one challenge you have had in your student teaching this fall?

3. In which course(s) will you be placed this spring (e.g., what discipline, grade, CP/Honors/AP, etc.)? Will these courses in person, hybrid, or remote?

Conceptions of Science or Mathematics Teaching and Learning (warm up questions/minimal probing)

These next few questions ask about your conceptions of effective math or science teaching and learning.

4. What have you learned about *effective math or science instruction* from your *teacher education courses* and *field placements* so far?
   b. What more would you like to learn?

5. What have you learned about *how students learn* from your *teacher education courses* and *field placements* so far?
   b. What more would you like to learn?

Science and Engineering Practices, Crosscutting Concepts, and Core Ideas (SKIP IF MATH)

These next few questions ask about the *Next Generation Science Standards* in science.

1. What have you learned about the eight science and engineering practices and the seven crosscutting concepts from the *NGSS* in your current courses?

2. How have the NGSS practices and crosscutting concepts been implemented in your placement(s) by *your cooperating teacher(s)*?

3. How have you incorporated these NGSS practices and crosscutting concepts in your *own teaching*?

9. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight science and engineering practices from the *NGSS*.
   a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
   b. Out of all eight, which **one** do you think is most important to teach students? Why?
   c. Which **one or two** practices do you think you need more help to understand or implement? Why?

10. [Go to next PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the seven crosscutting concepts from the *NGSS*.
   a. Which **two** do you most often implement in your student teaching placements? How do you implement them?

b. Out of all seven, which **one** do you think is most important to teach students? Why?
c. Which **one or two** crosscutting concepts do you think you need more help to understand or implement? Why?

11. What is one example where you engaged students in connecting "old" and "new" science core ideas? By old, I mean content students already learned in your class or in a previous class. By new, I mean content you were currently covering.
a. What instructional practices did you use to do so?
b. How has your TEP coursework and/or field placements helped you engage students in making these content connections?

Mathematical Practices and Content Standards (SKIP IF SCIENCE)

These next few questions ask about the *Common Core State Standards* in mathematics.

6. What have you learned about the mathematical practices from the *Common Core* in your current courses? What are you seeing in your placements?

7. How have the mathematical practices been implemented in your placement(s) by *your cooperating teacher(s)*?

8. How have you incorporated these mathematical practices in *your own teaching*?

9. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight mathematical practices from the *Common Core*.
a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
b. Out of all eight, which **one** do you think is most important to teach students? Why?
c. Which **one or two** practices do you think you need more help to understand or implement? Why?

10. What is one example where you engaged students in connecting "old" and "new" mathematical ideas? By old, I mean content students already learned in your class or in a previous class. By new, I mean content you were currently covering.
a. What instructional practices did you use to do so?
b. How has your TEP coursework and/or field placements helped you engage students in making these content connections?

Remote Instruction Teaching and Learning

The next few questions are about your experiences with teaching and learning how to teach through remote instruction this year.

12. I'm interested in your experiences as a student *learning how to teach* through remote instruction. This includes teacher ed courses and consulting with content and site supervisors.
    a. What are some positive things about learning how to teach while taking online courses? What is a specific example of a concept or skill that was fairly easy for you to grasp through remote instruction?
    b. How has learning how to teach been challenging with the courses being online? What is a specific example of a concept or skill that was more difficult to understand through remote instruction?
    c. How has what you've learned in your courses translated to your work in the classroom?

13. Overall, how do you feel about *teaching your students* through remote instruction?
    a. Teacher candidates often have varying responsibilities in their placement classroom, depending on what subject they teach, their cooperating teacher's preferences, etc. Can you describe a typical day of teaching your class on Zoom, noting the parts of the day that you are responsible for, as well as any other responsibilities you may have?
    b. What has been going well? Please give examples.
    c. What has been challenging? Please give examples.

Teacher Candidate Development

The next few questions are about your views on effective teaching, and how you see yourself developing your skill set as a teacher.

14. How has your understanding of what makes an effective teacher changed since starting the program (if at all)?

15. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] Various teacher responsibilities are listed on this slide. When you think about your work in the classroom, which areas do you feel successful in? Why?
    a. Are any of these areas challenging for you? Why?
    c. What might help you to grow in those areas?

16. Think of a particularly challenging day/situation while teaching your placement class. Perhaps a lesson did not go well, or students weren't listening to you, etc.
    a. What happened that day?
    b. What did you do to improve for next time?
    c. If you wanted support, who did you go to and why?
17. Imagine that you are having a conversation with your field work supervisor – they observed one of your lessons, and it did not go as well as you had hoped. How would you like them to support you in order to help you grow in that area?
    a. What helps you to feel encouraged?

b. Are there any ways of coaching or providing support that have been particularly helpful for you?
c. Is there anything that might make you not as receptive to their feedback?

Multilingual Learners

The next few questions discuss your experience and readiness to teach multilingual learners. Multilingual learners may also be referred to as English learners, English language learners, or English as a second language students.

18. What do you see as the strengths of multilingual learners is science or math classrooms?
    a. What challenges do you think multilingual learners in these classrooms encounter?
    b. What are the characteristics of an effective teacher of multilingual learners?

19. What benefits have you encountered in teaching multilingual learners in a remote instruction environment? If you have not MLs yet, what are some potential benefits to teaching multilingual learners in a remote instruction environment?

20. What have you learned about effective math or science instruction for multilingual learners from your teacher education program so far?
    a. In particular, what have you learned in your fall course ED 361 that was helpful in thinking about teaching multilingual learners?
    b. What more would you like to learn?

21. How did ED 361 and other Fall 2020 coursework shape your understanding of ways you can engage multilingual learners?
    a. How did the COVID-19 learning environment affect your knowledge regarding multilingual learners?

22. When considering working in a remote instruction environment, what adjustments do you imagine having to make to challenge or support multilingual learners?
    a. On a scale of 1 through 5, with 5 being the most prepared, how prepared do you feel to engage in effective instruction with multilingual learners in a remote instruction environment? Why?

Wrap-Up

23. Do you have any questions for me?

Thank you!

Science and Mathematics Teacher Candidate Interview Protocol
End of Winter 2021

Thank you for agreeing to be interviewed today. The purpose of this interview is to learn about some of the successes and challenges you are experiencing as a teacher candidate. We are studying science and mathematics teacher education to better support beginning teacher learning. We ask that you try to be as candid and specific as possible.

The information from this interview will not affect your course grades, your teaching placements, or your standing in the Teacher Education Program. If there is a question you do not wish to answer, you can ask that it be skipped. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well.

We expect the interview to last about 60 minutes. It is divided into 7 parts. Do I have your permission to begin recording the interview?

[Turn on record.]

Today is [Date] at [Time]. This is the initial interview with [Participant Initials] and the interviewer is [Interviewer Name].

Placement Information (warm up questions/minimal probing)

First, I'd like to ask you a few questions about your student teaching placements.

4. In which course(s) were you placed this winter (e.g., what discipline, grade, CP/Honors/AP, etc.)? I assume these courses were all remote, yes?

5. What is one success and one challenge you have had in your student teaching this winter?

6. For spring, will you be in person, hybrid, or remote? How are you feeling about the possibility/reality of being in person?

Conceptions of Science or Mathematics Teaching and Learning (warm up questions/minimal probing)

These next few questions ask about your conceptions of effective math or science teaching and learning.

4. What have you learned about *effective math or science instruction* from your *teacher education courses* and *field placements* so far?
   c. What more would you like to learn?

5. What have you learned about *how students learn* from your *teacher education courses* and *field placements* so far?
   c. What more would you like to learn?

Multilingual Learners

The next few questions discuss your experience and readiness to teach multilingual learners. Multilingual learners may also be referred to as Emergent multilingual learners, English learners, English language learners, or English as a second language students.

6. What do you see as the strengths of multilingual learners in science or math classrooms?
   a. What challenges do you think multilingual learners in these classrooms encounter?
   b. What are the characteristics of an effective teacher of multilingual learners?

7. Tell me about how you have interacted with multilingual learners in your placement.
   a. How does your cooperating teacher work with multilingual learners?
   b. How are you engaging multilingual learners in your instruction?
   c. What teaching practices are you using in your day-to-day instruction to work with multilingual learners?
   d. How have you modified instruction to work with your multilingual learners?
      i. For example, do you provide digital materials in Spanish? Are you purposefully grouping multilingual learners in breakout rooms?
   e. How do you see remote instruction affecting the learning of multilingual learners?
8. How are you implementing what you learned from your ED 361 and other TEP coursework in your student teaching placement related to engaging multilingual learners in remote instruction?

9. When considering working in a remote instruction environment, what adjustments do you imagine having to make to challenge or support multilingual learners?
   a. On a scale of 1 through 5, with 5 being the most prepared, how prepared do you feel to engage in effective instruction with multilingual learners in a remote instruction environment? Why?

Remote Instruction Teaching and Learning

The next few questions are about your experiences with teaching and learning how to teach through remote instruction this year.

10. I'm interested in your experiences as a student *learning how to teach* through remote instruction. This includes teacher ed courses and consulting with content and site supervisors.
    a. What are some positive things about learning how to teach while taking online courses? What is a specific example of a concept or skill that was fairly easy for you to grasp through remote instruction?
    b. How has learning how to teach been challenging with the courses being online? What is a specific example of a concept or skill that was more difficult to understand through remote instruction?
    c. How has what you've learned in your courses translated to your work in the classroom?

11. [Might put in the past tense if teachers are hybrid.] Overall, how do you feel about *teaching your students* through remote instruction?
    a. Teacher candidates often have varying responsibilities in their placement classroom, depending on what subject they teach, their cooperating teacher's preferences, etc. Can you describe a typical day of teaching your class on Zoom, noting the parts of the day that you are responsible for, as well as any other responsibilities you may have?
    b. What has been going well? Please give examples.
    c. What has been challenging? Please give examples.

Teacher Candidate Development

The next few questions are about your views on effective teaching, and how you see yourself developing your skill set as a teacher.

12. How has your understanding of what makes an effective teacher changed since starting the program (if at all)?

13. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] Various teacher responsibilities are listed on this slide. When you think about your work in the classroom, which areas do you feel successful in? Why?
    a. Are any of these areas challenging for you? Why?
    d. What might help you to grow in those areas?

14. Think of a particularly challenging day/situation while teaching your placement class. Perhaps a lesson did not go well, or students weren't listening to you, etc.

a. What happened that day?
b. What did you do to improve for next time?
c. If you wanted support, who did you go to and why?

15. Imagine that you are having a conversation with your field work supervisor – they observed one of your lessons, and it did not go as well as you had hoped. How would you like them to support you in order to help you grow in that area?
d. What helps you to feel encouraged?
e. Are there any ways of coaching or providing support that have been particularly helpful for you?
f. Is there anything that might make you not as receptive to their feedback?

Science and Engineering Practices, Crosscutting Concepts, and Core Ideas (SKIP IF MATH)

These next few questions ask about the *Next Generation Science Standards* in science.

17. What have you learned about the eight science and engineering practices and the seven crosscutting concepts from the *NGSS* in your current courses?

18. How have the NGSS practices and crosscutting concepts been implemented in your placement(s) by *your cooperating teacher(s)*?

19. How have you incorporated these NGSS practices and crosscutting concepts in your *own teaching*?

20. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight science and engineering practices from the *NGSS*.
a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
b. Out of all eight, which **one** do you think is most important to teach students? Why?
c. Which **one or two** practices do you think you need more help to understand or implement? Why?

21. [Go to next PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the seven crosscutting concepts from the *NGSS*.
a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
b. Out of all seven, which **one** do you think is most important to teach students? Why?
c. Which **one or two** crosscutting concepts do you think you need more help to understand or implement? Why?

Mathematical Practices and Content Standards (SKIP IF SCIENCE)

These next few questions ask about the *Common Core State Standards* in mathematics.

17. What have you learned about the mathematical practices from the *Common Core* in your current courses? What are you seeing in your placements?

18. How have the mathematical practices been implemented in your placement(s) by *your cooperating teacher(s)*?

19. How have you incorporated these mathematical practices in *your own teaching*?

20. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight mathematical practices from the *Common Core*.
    a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
    b. Out of all eight, which **one** do you think is most important to teach students? Why?
    c. Which **one or two** practices do you think you need more help to understand or implement? Why?

Wrap-Up

22. Do you have any questions for me?

Thank you!

Science and Mathematics Teacher Candidate Interview Protocol
End of Spring 2021

Thank you for agreeing to be interviewed today. The purpose of this interview is to learn about some of the successes and challenges you are experiencing as a teacher candidate. We are studying science and mathematics teacher education to better support beginning teacher learning. We ask that you try to be as candid and specific as possible.

The information from this interview will not affect your course grades, your teaching placements, or your standing in the Teacher Education Program. If there is a question you do not wish to answer, you can ask that it be skipped. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well.

We expect the interview to last about 60 minutes. It is divided into 7 parts. Do I have your permission to begin recording the interview?

[Turn on record.]

Today is [Date] at [Time]. This is the initial interview with [Participant Initials] and the interviewer is [Interviewer Name].

Placement Information (warm up questions/minimal probing)

First, I'd like to ask you a few questions about your student teaching placements.

7. In which course(s) were you placed this spring (e.g., what discipline, grade, CP/Honors/AP, etc.)? I assume these courses were all hybrid, yes?

8. What is one success and one challenge you have had in your student teaching this spring?

Conceptions of Science or Mathematics Teaching and Learning (warm up questions/minimal probing)

These next few questions ask about your conceptions of effective math or science teaching and learning.

3. Looking back over your TEP year, what did you learn about *effective math or science instruction* from your *teacher education courses* and *field placements*?
    g. What more would you like to learn as a beginning teacher?

4. Looking back over your TEP year, what have you learned about *how students learn* from your *teacher education courses* and *field placements*?
    d. What more would you like to learn as a beginning teacher?

Multilingual Learners

The next few questions discuss your experience and readiness to teach multilingual learners. Multilingual learners may also be referred to as Emergent multilingual learners, English learners, English language learners, or English as a second language students.

5. What do you see as the strengths of multilingual learners in science or math classrooms?
    a. What challenges do you think multilingual learners in these classrooms encounter?
    b. What are the characteristics of an effective teacher of multilingual learners?

6. Tell me about how you have interacted with multilingual learners in your placement.
    a. How does your cooperating teacher work with multilingual learners?
    b. How are you engaging multilingual learners in your instruction?
    c. What teaching practices are you using in your day-to-day instruction to work with multilingual learners?
    d. How have you modified instruction to work with your multilingual learners?
        i. For example, do you provide digital materials in Spanish? Are you purposefully grouping multilingual learners in breakout rooms?
    e. How do you see remote or hybrid instruction affecting the learning of multilingual learners?
7. How are you implementing what you learned from your spring methods course and other TEP coursework in your student teaching placement related to engaging multilingual learners in remote or hybrid instruction?

8. When considering working in a hybrid instruction environment, what adjustments do you imagine having to make to challenge or support multilingual learners?
    a. On a scale of 1 through 5, with 5 being the most prepared, how prepared do you feel to engage in effective instruction with multilingual learners in a hybrid instruction environment? Why?
    b. What do you see as the major differences between supporting multilingual learners in hybrid vs remote contexts?

Hybrid Teaching

The next few questions are about your experiences with teaching students through hybrid instruction this year.

9. Overall, how do you feel about *teaching your students* through hybrid instruction?
    a. Can you describe a typical day of teaching your in-person students, as well as the students on Zoom?
    b. What has been going well?
    c. What has been challenging?

10. Please think back to when you were only doing remote instruction. If you had difficulty with engaging students over remote instruction, what did you do to try to overcome that?

Creating Relational Context for Ambitious Science Teaching (SKIP IF MATH)

These next few questions are about your experiences surrounding creating a relational context for ambitious science teaching.

11. What does your content supervisor do to build relationships and make you feel comfortable sharing ideas with your cohort? Can you give a specific example?

12. What do you think makes students feel willing to share about their lives, ideas, and experiences in class?
    a. What do you think makes students feel comfortable sharing their ideas when it comes to science?
    b. What specific things do you do to build relationships with your students and create an environment in which they feel comfortable sharing their ideas in class?
    c. Where did you learn this from? (TEP courses, working with students, cooperating teacher, etc.)
    d. How have your interactions and relationships with students changed from being only online to being in-person/hybrid?

Teacher Candidate Development

The next few questions are about your views on effective teaching, and how you see yourself developing your skill set as a teacher.

13. How has your understanding of what makes an effective teacher changed since starting the program (if at all)?

14. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] Various teacher responsibilities are listed on this slide. When you think about your work in the classroom, which areas do you feel successful in? Why?
    a. Are any of these areas challenging for you? Why?
    e. What might help you to grow in those areas?

15. Imagine that you are having a conversation with your field work supervisor – they observed one of your lessons, and it did not go as well as you had hoped. How would you like them to support you in order to help you grow in that area?
    d. Are there any ways of coaching or providing support that have been particularly helpful for you?
    e. Is there anything that might make you not as receptive to their feedback?

Science and Engineering Practices, Crosscutting Concepts, and Core Ideas (SKIP IF MATH)

These next few questions ask about the *Next Generation Science Standards* in science.

21. What have you learned about the eight science and engineering practices and the seven crosscutting concepts from the *NGSS* in your current courses?

22. How have the NGSS practices and crosscutting concepts been implemented in your placement(s) by *your cooperating teacher(s)*?

23. How have you incorporated these NGSS practices and crosscutting concepts in your *own teaching*?

24. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight science and engineering practices from the *NGSS*.
    a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
    b. Think back (if you can) to your edTPA lessons. Of the practices that you planned to have students engage with, which two do you think were the most important for their understanding of the phenomena they were studying?
    c. Out of all eight, which **one** do you think is most important to teach students? Why?
    d. Which **one or two** practices do you think you need more help to understand or implement? Why?

21. [Go to next PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the seven crosscutting concepts from the *NGSS*.
    a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
    b. Again, please think back, if you can, to your ed TPA lessons. Which combination of CCCs did you plan for in your EdTPA lessons?

c. Out of all seven, which **one** do you think is most important to teach students? Why?
d. Which **one or two** crosscutting concepts do you think you need more help to understand or implement? Why?

Mathematical Practices and Content Standards (SKIP IF SCIENCE)

These next few questions ask about the *Common Core State Standards* in mathematics.

17. What have you learned about the mathematical practices from the *Common Core* in your current courses? What are you seeing in your placements?

18. How have the mathematical practices been implemented in your placement(s) by *your cooperating teacher(s)*?

19. How have you incorporated these mathematical practices in *your own teaching*?

20. [Go to a PPT slide. Encourage TCs to circle or underline on the cards.] These are cards with the eight mathematical practices from the *Common Core*.
    a. Which **two** do you most often implement in your student teaching placements? How do you implement them?
    b. Out of all eight, which **one** do you think is most important to teach students? Why?
    c. Which **one or two** practices do you think you need more help to understand or implement? Why?

Wrap Up and Demographic Questions

The last part of our interview will ask about your demographic information. Before we move into that, I wanted to ask if you have anything else you'd like to add or if you have any questions for me?

For these final questions, I will provide options for you to answer, but you may respond with another option if none of these accurately answer the question. You may also choose "prefer not to answer" for each question.
[interviewer note: you do not need to list letter of each option. For instance, on number one, you simply will say, "How would you describe your gender? Male, female, nonbinary, transgender, other, or prefer not to answer?"]

1. How would you describe your gender?
    a. Male
    b. Female
    c. Nonbinary
    d. Transgender
    e. Other [if "Other", ask teacher candidate, "How would you describe your gender?" without options]

f. Prefer not to answer

2. How would you describe your ethnic background?
    a. African-American/Black
    b. Asian/Pacific Islander
    c. Latinx or Hispanic
    d. Indigenous American
    e. Multiple ethnic backgrounds [if "Multiple ethnic backgrounds", ask teacher candidate, "How would you describe your ethnic backgrounds?"]
    f. White/Caucasian
    g. Other [if "Other", ask teacher candidate, "How would you describe your ethnic background?" without options]
    h. Prefer not to answer

3. How would you describe your linguistic fluency?
    a. English-speaking, monolingual
    b. Bilingual [if "Bilingual", ask teacher candidate, "What is your primary or first language? What is your second language?"]
    c. Multilingual [if "Multilingual", ask teacher candidate, "What is your primary or first language? What are your secondary languages?"]
    d. Other [if "Other", ask teacher candidate, "How would you describe your linguistic fluency?" without options]
    e. Prefer not to answer

4. Did you qualify for federal or state student aid, such as Pell Grant?
    a. Yes
    b. No
    c. I don't know
    d. Prefer not to answer

5. In the research project(s) you have consented, you may be referred by a pseudonym, which is meant to maintain confidentiality between yourself and your responses. If you would like to choose your pseudonym, what pseudonym would you like used in research publications, if needed? If you prefer not to choose one, the research team will assign a pseudonym for you.
    a. [If preference is given] - how would you like that spelt?
    b. [If no preference is give] - the research team will select a pseudonym for you, if needed, but you are welcome to reach out to the research team if you decide at a later time to select a pseudonym.

6. Would you be willing to have members of the research team contact you in the following school year?
    a. Yes
    b. No
    c. Prefer not to answer

Thank you!

Initial Interview with Teacher Educator

Thank you for participating in this interview. The purpose of this interview is to learn about your approach to teaching teacher candidates. I'm interested in teacher preparation and am looking at the smaller interactions and feedback conversations that help a preservice teacher develop their teaching skills.

If there is a question you do not want to answer, you may skip it. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well. I expect the interview to last about 45 minutes. It is divided into three parts. Do I have your permission to begin recording the interview?

Background and Teaching Approach
The first few questions are about your background and approach to teaching.

1. Please tell me about your background.
   a. What brought you to UC Santa Barbara?

2. You are a professor and you work closely with the teacher candidates in various capacities. How would you describe your role/s?

3. Can you describe your approach when working with teacher candidates?
   a. What do you hope for teacher candidates to get out of your work with them?

Distance Teaching and Learning
The next few questions are about distance teaching and learning.

4. How do you feel about teaching *K-12 students* through distance learning?
   a. What are some challenges?
   b. What are some benefits?

5. How do you feel about teaching and supporting *teacher candidates* through distance learning?
   a. What are some potential challenges?
   b. What are some potential benefits?

6. If social distancing guidelines are lifted and you begin to teach teacher candidates in-person later in the year, how might that shift how you support teacher candidates?

Conversations With Teacher Candidates

The next few questions are about your interactions and conversations with teacher candidates.

7. Can you describe a typical feedback conversation with a teacher candidate?
   a. Do you use a feedback protocol? If so, what does that look like?
   b. Does that make for a more productive conversation? If so, how?

8. Describe a successful feedback conversation.

9. Can you think of a time when a feedback conversation did not go so well, or didn't produce the outcome that you had hoped for? Can you tell me about that?

10. Are there any "roadblocks" that prevent a productive conversation? Can you tell me about them?

11. Imagine that you observed a teacher candidate's lesson, and it did not go well. You want to have a conversation about how they might improve. How would you approach the conversation? What would you say to them? Please feel free to think of a specific time that this has happened, and use that as an example.
    a. How would you follow up with them? Any other next steps?
    b. What would you do if the "issue" continued?

12. Have you ever worked with a teacher candidate who was resistant to feedback? What did you do or say to help them take up that feedback?

13. Is there anything else that I should know about the ways that you interact with and/or support teacher candidates?

Interview wrap-up

14. Do you have any questions for me?

15. Is there anything else you would like me to know?

Thank you!

Second Interview with Teacher Educator (Third interview follows same protocol)

Thank you for participating in this interview. The purpose of this interview is to learn about your approach to teaching teacher candidates.

If there is a question you do not want to answer, you may skip it. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well. I expect the interview to last about 45 minutes. It is divided into three parts. Do I have your permission to begin recording the interview?

Distance Teaching and Learning

The next few questions are about distance teaching and learning.

1. How do you feel about teaching and supporting *teacher candidates* through distance learning?
   a. What have been some positives?
   b. What are TCs doing well?
   c. You talked a lot about not being able to build community as easily last time, have there been any other challenges?

2. If social distancing guidelines are lifted and you begin to teach teacher candidates in-person later in the year, how might that shift how you support teacher candidates?

Preparing Teachers for Socially Just/Antiracist Teaching

3. In what ways do you prepare teachers to enact this in their classroom?

4. Do you think doing this through distance learning specifically poses any challenges? What might those be?

5. What have been the successes in this area? Any challenges?

Conversations With Teacher Candidates

The next few questions are about your interactions and conversations with teacher candidates.

6. Can you think about all of the one-on-one conversations you've had with TCs this year, and give me an example of a feedback conversation that went well.

7. Can you think of one that didn't go so well, or didn't produce the outcome that you had hoped for? Can you tell me about that?
   a. Why do you think it went that way?
   b. What would have made it go better?

8. Thinking back on this year, are there any "roadblocks" that prevent a productive conversation? Can you tell me about them?

9. Have you ever worked with a teacher candidate who was resistant to feedback? What did you do or say to help them take up that feedback?

10. Is there anything else that I should know about the ways that you interact with and/or support teacher candidates?

Interview wrap-up

11. Do you have any questions for me?

12. Is there anything else you would like me to know?

Thank you!