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Elementary Teachers' Meanings of Culturally Relevant Science and the Policies That Shape Their Practice

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ELEMENTARY TEACHERS' MEANINGS OF CULTURALLY RELEVANT SCIENCE AND THE POLICIES THAT SHAPE THEIR PRACTICE

by

KATIE WOODBRIDGE

Under the Direction of Laura May, Ph.D. and Natalie King, Ph.D.

ABSTRACT

Most elementary students are not given opportunities to make sense of their own observations or engage meaningfully with science ideas to develop conceptual understanding. Instead, they are subjected to passive approaches to learning or hands-on activities with little relevance to authentic contexts (Roth, 2014). The 2018 survey of the National Academies of Science, Engineering and Medicine (NASEM) reports only 31% of elementary teachers surveyed felt very well prepared to teach science in general, and students most likely to be taught by teachers who feel unprepared are those in high-poverty schools with historically underrepresented race and ethnicity

groups. One way to address these issues is seen in calls to recruit, prepare and retain teachers who view their role through a lens of social justice (Kavanagh & Danielson, 2020; Ladson-Billings, 1995a, 2014; Sleeter, 2001). Culturally relevant pedagogy (CRP) (Ladson-Billings, 1995a) is a framework used by successful teachers of African American students and has since been applied to a range of subject areas and with additional marginalized communities. Yet, though the body of literature is growing, elementary science education has received less attention in CRP research. This critical qualitative study used narrative analysis (Reissman, 2006) to understand (a) what it means to three elementary teachers to teach science in culturally relevant ways and (b) how policies and practices restrict their pedagogies. An analytical framework consisting of CRP and Clandinin & Connelly's (2000) Three-Dimensional Narrative Space yielded insights related to teaching in the wake of the Covid-19 pandemic, team teaching practices, administrative support, and the chilling effects of classroom censorship legislation.

INDEX WORDS: Elementary Science, Elementary Teachers' Culturally Relevant Pedagogy, Elementary Education Policy, Social Justice Science

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A Dissertation

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DEDICATION

This dissertation is for all the students who made me the teacher I am and those I have yet to meet. It is for the teachers I have had the honor of working alongside and the families who trusted me with their children.

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1 THE PROBLEM

In this study, I examined elementary teachers' experiences teaching culturally relevant science in the elementary classroom. The knowledge produced from this study provides insights that can inform elementary teacher preparation programs, education policy, and future research. This research employed a narrative approach within a qualitative design to illustrate the experiences the teachers had in their schools and classrooms. Participants in this study included three educators who were purposefully selected with a criterion sampling technique (Miles & Huberman, 1994). This chapter includes an overview of the context and background, followed by the problem statement, statement of purpose research questions, theoretical framework, research design overview, significance of the study, dissertation outline, and finally definitions of terms used throughout the study.

Background

One of the central issues in science education is the persistence of inequities across the lines of race, class, gender, language, sexuality, and intersecting identities. Science education reformists in the United States have included equitable outcomes for all students and a focus on responding to the needs of the time as far back as the classical studies versus science education debates of the nineteenth century (DeBoer, 1991). As policy and planning sectors advocated for including science in the K-12 curriculum, standards-based reforms reflect attempts to secure its place (Barton, 2002). It has been especially challenging in elementary schools where instructional time, professional development, and testing accountability policies create hindrances for teachers (Plumley, 2018). Au (2011) traced the dominance of standardization and scripted curriculum to the early 1900s. In 2011, *A Framework for K-12 Science Education* was released, the

first step by The National Research Council (NRC) in the creation of the most recent K-12 science standards, the Next Generation Science Standards (NGSS) (NRC, 2012).

Adopted or used as a model for standards in 45 states today, "[t]he overarching goal is for all high school graduates to have sufficient knowledge of science and engineering to engage in public discussions on science-related issues, be careful consumers of scientific and technical information, and enter the careers of their choice" (NASEM, 2022). Yet, those who exit high school and enter science fields remain overwhelmingly white and male (Ferguson & Dunlop, 2019). While case studies on students' race, ethnicity, ability, economic status, and gender are presented in Appendix D of the standards, proffered to support *all* students; Rodriguez (2015) explains the *Framework* and NGSS failed to put forth a roadmap for students to learn about and engage in authentic science experiences reflecting the diversity of scientific practices. By diversity of practices, I am referring to ways of knowing that are not reflected in a structure commonly referred to as *The Scientific Method*, which dictates five steps to investigating. Rather, there are countless ways of obtaining and communicating information that reflect group culture, such as oral traditions. Walls (2016) documents a possible explanation for this failure: In the nature of science (NOS) research studies conducted from 1967-2013; Black, Latino/a, and Native American participants were only represented in one of the 30 studies that reported race. Race was only even reported in 3% of the 112 studies. Ethnically, culturally, and linguistically diverse students are marginalized from science as early as elementary school (Mensah & Jackson, 2018). This begs the question; how can educators use the NGSS as a tool for engaging students of color in authentic science practices if the research it is based upon excluded them?

While exceptions to this picture exist, there is a real urgency to rectify the state of science in elementary schools. If it *is* taught, science privileges a singular way of knowing via overemphasis of the ubiquitous scientific method (Achieve, 2013; NASEM, 2018). Researchers have long called for science teaching practices inclusive of the diverse ways people conduct and put science to use (Eisenhart et al., 1996; Roth & Lee, 2004). This includes science as a tool to fight injustice (Basu et al., 2009). I write this as my TV, social media feed, and daily interactions inform me that today's socio-political climate challenges that aim. As of April 2023, 18 states banned the teaching of Critical Race Theory (CRT), and only seven states have not attempted a ban (Critical Race Theory Ban, n.d.).

The Learning Policy Institute, basing ratings on "compensation, teacher turnover, working conditions, and qualifications" rank Georgia in the least desirable category, lowest of five categories for teaching attractiveness and teacher equity (Learning Policy Institute, 2018, n.p.). At the time of writing, a Georgia school board voted 4-3 to terminate a 5th grade teacher for reading a book deemed in violation of GA HB 1084, the "Protect Students First Act". This law lists nine concepts featuring race and gender as "divisive" and prohibits them from use in not only classroom curriculum but also mandatory trainings for teachers. A tribunal hearing resulted in the recommendation the 5th grade teacher remain employed, and the school district voted to reject that decision. Curriculum resources and professional development programs that focus on social justice issues are under scrutiny, especially if a lens of critical race theory is identified in its materials (i.e., The 1619 Project, Learning for Justice). For critical race scholars (see Morgan, 2022), laws like this are viewed as an infringement on academic freedom and further prevent students from developing the critical competence needed to critique scientific enterprises that harm marginalized communities. Banning critical race theory from professional development materials

has a demonstrated chilling effect on classrooms because curriculum policies at the local level follow them (Lopez, et al., 2021).

The global COVID-19 pandemic brought the critique of scientific enterprise to the fore *during* the "Summer of Racial Reckoning" (Chang et al., 2020) as the Movement for Black Lives took center stage world-wide. As Avraamidou & Schwartz (2023) put it, "[w]e witness a rise of anti-science and 'alternative facts' movement: Pseudoscience, fake news, conspiracy theories and hostile fantasies that undermine scientific evidence" (p. 339). Researchers have documented ways the pandemic exacerbated existing education inequities (Azevedo et al., 2022). Schools, colleges, and universities across the nation responded to racial unrest with statements in support of Black lives, denouncing white supremacy and (re)committing to advancing equity. Though schools are back to in-person learning, the effects of closures continue to impact district- and school-level decisions. Science, once more, is in jeopardy in the elementary classroom, now under the pretense of pandemic learning loss.

Teachers face pressure to remedy the impact of the pandemic not only as it pertains to reading and mathematics skills, but also the negative social-emotional effects felt by many after being in isolation and experiencing a great deal of loss. Robbins and Cipollone (2023) denounce a response to the pandemic that centers around revenue loss as a result of supposed lost learning and suggest restorative justice and community engaged teaching as replacements for social emotional learning and testing foci. Ladson-Billings (2021) views post-pandemic teaching as an opportunity not to return to normal because "it is the school that exacerbates the educational disadvantages" (p. 69). While the media's attention to a perceived teacher shortage is at an uptick, Darling-Hammond (2022) states, "Ever since I entered public school teaching in the early 1970s,

the nation has been in a recurring cycle of teacher shortages" (p. 15). While it is possible to speculate, it is imperative that we hear from teachers to understand their experiences teaching science in this critical moment.

Problem Statement

Tate (2001) put forth a framing of opportunity-to-learn as a civil right; showing that time, quality, and technology are instrumental to improving urban science education. Researchers have identified opportunity gaps; those causes and processes that lead to disproportionate outcomes related to achievement between groups of students to de-emphasize test results and better address differences in opportunities (Berry, 2013). Ladson-Billings (2010) lists "expert teachers, personalized attention, high-quality curriculum opportunities, good educational materials, and plentiful information resources" as opportunity gaps in the form of resources that have been denied for centuries. A possible contribution to the closing of such gaps is seen in calls to recruit, prepare and retain teachers who view their role through a lens of social justice (Kavanagh & Danielson, 2020; Ladson-Billings, 1995a, 2014; Sleeter, 2001).

Recruitment and training to teach for equity has been a practice of teacher education programs for some time. However, even when preservice teachers express the viewpoint that their role is connected to broader social justice issues, they do not always enact the practices aligned to it in their student teaching placements (Chen & Mensah, 2018) or during their induction years (Saka et al., 2009; Kavanagh & Danielson, 2020). Further, there are few empirical studies focused on the actual teaching taking place in classrooms after teaching preparation (Sleeter, 2001) and this is echoed by more recent findings on social justice science implementation (see Marco-Bujosa et al., 2020). Though exceptions exist, (i.e., Grimberg & Gummer, 2013; Haverly et al.,

2020), teachers and those who support teachers need more examples that illustrate positive outcomes for elementary students from marginalized groups.

Without a strong theory-to-practice connection in elementary science education, many elementary students do not have access to authentic science experiences in school (Braaten, 2019). From taking part in genuine inquiries into the natural world to using science as a tool for solving problems in their communities, most elementary students are not given opportunities to make sense of their own observations or truly engage with science ideas to develop conceptual understanding (Upadhyay et al., 2017). Instead, they are subjected to passive approaches to learning or hands-on activities with little relevance to authentic contexts (Roth, 2014). Because science instruction that *is* taking place still privileges ways of knowing and using science that are not representative of diverse populations, students of color are inflicted with instruction that fails to recognize their experiences and cultures. It is an outcome of structural racism held up by a system of largely uninterrogated whiteness (Dunac & Demir, 2017) and it contributes to an inability for students with non-dominant identities to see themselves as capable users of science or potential career scientists (Mensah & Jackson, 2018).

One among several asset-based pedagogies seeking to remedy the culture gaps discussed above (i.e. culturally responsive, culturally sustaining, emancipatory, historically responsive), culturally relevant pedagogy (CRP) was introduced as a framework consisting of three dimensions and a set of core beliefs by Gloria Ladson-Billings (1995a) to express what successful teachers of African American students did and what they believed. Since then, it has been taken up and expanded by education researchers across disciplines, including though less prevalent than others, science education. Utilized from the viewpoint that teaching science has social justice implications, teaching in culturally relevant ways does not come without challenges. As the

review of literature will emphasize; state, district, and school policies and practices impact what takes place in classrooms; not the teachers alone. While it is possible to surmise, it is imperative to hear from teachers themselves about their culturally relevant science instruction at this critical time. That is the purpose of this study.

Statement of Purpose and Research Questions

I concur with DeBoer (2019) who said, "I believe that a major task of science educators is to document and compare what actually happens in schools with the best thinking about what should happen there and to resolve the discrepancies that arise out of that study" (n.p.). CRP is a worthwhile framework from which to understand what is happening in schools for this very purpose. I focus on practices and policies in schools as mechanisms for creating support for or inhibiting teachers' use of CRP in their science instruction. The research questions are as follows:

1. What does it mean for elementary teachers to teach science in culturally relevant ways?
2. How do teachers navigate school practices and policies to teach science in their elementary classrooms?

Theoretical Framework

Two theories make up the lens for my study: Critical theory (Freire, 1970) and CRP (Ladson-Billings, 1995a). These work in tandem: Critical theory critiques social order to transform unjust social structures (Freire, 1970). Ladson-Billings' (1995) CRP was informed by civil rights work, critical theory, and Black feminist thought. Critical *pedagogy*, incorporating critical theory, centers the role of the educator in reproducing inequity and maintains students should question inequities and injustices to facilitate their own learning. Ladson-Billings' (1995) CRP advances critical pedagogy by focusing on collective rather than individual empowerment. Collective empowerment is advanced by naming the conceptions of self and others, social relations,

and knowledge that distinguish successful teachers of African American students from other teachers. She contends a theory of CRP is needed because "…earlier sociolinguistic explanations have failed to include the larger social and cultural contexts of students, and the cultural ecologists have failed to explain student success" (p. 35). There are three characteristics of CRP: academic excellence, cultural relevance, and sociopolitical or critical consciousness. In the paragraphs that follow, I present the critical framing of my study, followed by CRP.

Critical Theory

While consensus on cultural critique did not arise from the Frankfurt school, it is frequently discussed as the origin of critical theory with the works of Horkheimer, Adorno, Marcuse; and German philosophers Marx, Kant, Hegel, and Weber, united under notions of challenging injustice and subjugation. Several critical theories exist with bountiful interpretations and critiques of each (Kincheloe & McLaren, 2011). As a result, there is no singular, agreed-upon set of tenets that guide critical theory, thus I include those critical theorists' works and positions that shaped my study. My study works from Kincheloe & McLaren's (2011) definition of critical social theory as "concerned in particular with issues of power and justice and the ways that the economy, matters of race, class, and gender, ideologies, discourses, education, religion, and other social institutions, and cultural dynamics interact to construct a social system" (p. 288) by focusing on culturally relevant science education.

Critical education researcher Peter McLaren's analysis of capitalism and science education resonates with Freire's (1974) argument that class analysis, in some form, is a requirement for understanding oppression (Macedo, 2014). He states, "If we conceptually undress the role science plays in the larger society, we can see how it stabilizes dominant social relations" (Barton, 2001, p. 848). McLaren proffers key questions to the science education research community,

one of which is: “How is the social practice…of science education organized? (Barton, 2001, p. 848). This question constitutes but one critical angle for understanding how the entanglement of science and capitalism is reproduced through education. Penaloza et al. (2023) highlight the need to make power relations explicit in science education, citing historical racial, colonial, and patriarchal biases and denial of people’s practical knowledge.

Understanding how science stabilizes dominant social relations is an issue of Freire’s (1970) concept of “conscientization.” Conscientization is “a new awareness of one’s oppressed state and insight into the suppressive methodologies of the oppressors” (Kaak, 2011, p. 132). Through praxis, reflecting specifically on suppressive methodologies, one gains a sense of responsibility and thus acts for social change. Kaak (2011) explains Freire’s philosophy in an application of Freirean leadership pedagogy, which “exists within the awareness that the institutional models of leadership are a means to oppressing would-be leaders as well as the cause for the ongoing oppression of others” (p. 135). In the United States, public institutions of schooling are organized by hierarchy, each institutional level accountable to the next through policy requirements and institutional practices that shape the culture of the given context.

Freire’s (1968) conception of dialogue, the very essence of learning, requires five conditions: Humility, hope, faith, love, and critical thinking. “True dialogue…helps to foster revolutionary commitment and therefore represents a practical necessity for authentic revolutionary leaders” (Leach, 1982, p. 190). Education is political; indeed Freire’s (1980) *Pedagogy in Process* was written in letters to Mario Cabra, a Guinea-Bissau educational administrator (Leach, 1982). Freire asserts that education requires revolution, which rests on dialogue and praxis and results in becoming human. Along those same lines, Ladson-Billings’ (1995) theory of CRP builds on humanizing pedagogy and challenging deficit-centered teaching and learning.

Culturally Relevant Pedagogy

Prior to research from a resource pedagogy perspective (i.e. Moll & Gonzalez, 1994; Gutiérrez et al., 1999), research from perspectives of difference and deficit abounded; positioning cultural practices outside of white, middle class norms as inferior (Paris, 2012). The theory of CRP began with a question that had not been asked: "What is *right* with Black students and what happens in classrooms where teachers, parents, and students get it right?" (Ladson-Billings, 2021, p. 2). Ladson-Billings' (2014) succinct description of CRP is:

> I identified three major domains of their work: academic success, cultural competence, and sociopolitical consciousness. Briefly, by *academic success* I refer to the intellectual growth that students experience as a result of classroom instruction and learning experiences. *Cultural competence* refers to the ability to help students appreciate and celebrate their cultures of origin while gaining knowledge of and fluency in at least one other culture. *Sociopolitical consciousness* is the ability to take learning beyond the confines of the classroom using school knowledge and skills to identify, analyze, and solve real-world problems (p. 139).

Further, there is a commonly held set of beliefs among successful teachers of African American students, and the research has grown to include students and teachers from additional groups, expanding views of culture and the heterogeneity of experience. The beliefs that the teachers hold surround three propositions: (a) the conceptions of self and others, (b) the manner in which social relations are structured, and (c) the conceptions of knowledge (Ladson-Billings, 2021).

Conceptions of self and others, for culturally relevant teachers, requires believing that every student can achieve, pedagogy is an artform, teachers are community members giving back to the community, and teaching is an act of pulling knowledge out rather than banking (Freire,

1974). Teachers' social relations are marked by fluid student-teacher relationships, connectedness with students, the creating of a learning community, and collaborative responsibility and learning. Their knowledge beliefs include the dynamic nature of knowing, that it is viewed critically, teachers are passionate about learning and knowledge, assessment is multifaceted, and scaffolding is the teacher's responsibility. Important especially to science education, Ladson-Billings (1995a) states, "For the teachers in this study, knowledge was about doing." Doing science is cultural, despite the singular approaches reflecting dominant epistemologies most found in classrooms (Aikenhead, 2002; Smith et al., 2022).

CRP has inspired new research since its inception with culturally *sustaining* pedagogy (CSP) (Paris, 2012) rising to the fore as a necessary shift. CSP is a framing of pedagogy that seeks to better encompass an ensuring of the maintenance and value of languages and cultures that comprise our multilingual, multiethnic society and classrooms. Paris (2012) asserts the terms that existed at the inception of CSP did not "guarantee in stance or meaning that one goal of an educational program is to maintain heritage ways and to value cultural and linguistic sharing across difference" (p. 95). According to Paris (2021), key features of CSP include (a) critical centering of community languages, practices, and knowledges; (b) intergenerational collaboration and accountability; (c) reciprocal relationships with Indigenous communities, land, and each other; and (d) attending to internalized false beliefs about the value of communities of color and the false notion that sustaining lifeways and critically approaching dominant practices is an either/or choice. Paris (2021) reflects on the collective projects advancing the maintenance of Black, Indigenous, Latinx, Asian, and Pacific Islander cultures, finding more is needed to repurpose education through an understanding of "subject areas and disciplines (from STEM to history to the arts) as grounded in service to community care" (p. 372). Grimberg & Gummer

(2012) provide findings toward this aim with their study of a professional development program framed by CRP.

Differentiating the culture of science from school science, Grimberg & Gummer (2012) state, "The culture of science is defined by the attributes and paradigms of the scientific activity itself, but its practice echoes the social dynamic, place, and historical circumstances of the practitioners" (p. 15). There are numerous examples of how school science contradicts the culture of science and how that effects students: Aikenhead (2002) describes the alienation Aboriginal peoples experience as a result of assimilation into a foreign culture; that is Western science. Smith et al. (2022) traces the widespread, longstanding impact of colonialism around the globe as it contributes to the silencing of students' voices in science. Young et al. (2017) demonstrate that despite their positive disposition toward science, Black girls are uniquely marginalized in STEM classrooms; experiencing cultural discontinuity between home, school, and science content. For science curriculum to be accessible, students must cross cultural borders. However, non-mainstream students are disadvantaged when their home culture is not bridged to the culture of science.

Research Design Overview

I cover the design and methodology of the dissertation in depth in chapter three but provide an overarching introduction to the study here. The purpose of the study was to understand elementary teachers' experiences teaching culturally relevant science from the teachers' perspectives (Ladson-Billings, 1990; 1995a; 1995b; 2014, 2021). Trying to make sense of teachers' experiences, the research addressed two questions: (a) What does it mean for elementary teachers to teach science in culturally relevant ways? (b) How do teachers navigate school practices and policies to teach science in their elementary classrooms? To answer these questions, I conducted

two semi-structured interviews with the participants, seeking their experiences with teaching culturally relevant science. I collected information about their school contexts from available online sources (i.e. school websites). I conducted a narrative analysis (Reissman, 1993) of their stories using the Three Dimensional Narrative Space framework put forth by Clandinin & Connelly (2000). From there, I wrote and shared core narratives with the participants, taking them through multiple iterations before finalizing them as findings. From a critical theoretical standpoint, I analyzed the specific policies and practices the teachers navigated as they taught culturally relevant science. I offer a critique of those policies and practices that impeded teachers' culturally relevant science pedagogy.

Significance

Research literature using CRP as a framework is more robustly centered around disciplines other than science (i.e. literacy, social studies, or mathematics) or not discipline-specific (Brown-Jeffy & Cooper, 2011; Ladson-Billings, 1995b). This study fulfills the need to examine CRP in science education, a call put forth by researchers interested in providing science instruction that views students who are Black, Latinx, Indigenous, immigrant, and/or English language learners and their communities from a place of strength (i.e. Paris, 2021; Rodriguez, 2015; Seriki, 2018; Smith et al., 2022). While CRP has been taken up by science education researchers in contexts across K-16 education (Allen et al., 2017; Bettez, et al., 2011; Mensah, 2011) and with science teacher educators (Underwood & Mensah, 2018), the current body of work includes more studies at middle and secondary levels (i.e. Boutte et al., 2010; Johnson, 2011; Laughter & Adams, 2012; Morales-Doyle, 2017) than the elementary level. This study contributes to the growing literature on CRP in elementary education (i.e. Patchen & Cox-Petersen, 2008; Ullucci,

2011; Upadhyay et al., 2017). I focus on classroom implementation to contribute to the work taking place in schools and provide examples for teachers, science teacher educators, and policymakers to think about.

The timeliness of the study is significant; the effects of decisions made during and following COVID-19 school closures, the newly signed state education laws, and the recent shifts in district and school equity foci are all new considerations this study addresses. Policymakers, including those at the school and district level in position to write mandates and implement practices that adhere to policies will find the results of this study of use to them as they gain access to teachers' perceptions of how CRP science is enabled or inhibited by institutional norms. Others have documented challenges elementary educators face when teaching science from a social justice lens (i.e. Au, 2011; Braaten & Sheth, 2016; Roth, 2014; Trygstad, 2013). This study provides a critique of specific policies that impede students' access to culturally relevant learning. It is necessary to add to our understanding of seemingly well-intentioned practices taking place in schools.

Dissertation Outline

The dissertation is organized into five chapters. Chapter two, a review of the literature, presents research conducted in the interest of improving elementary science education from a social justice standpoint. Chapter three provides the details of the study's methodology, the rational for my approach, the research sample, information needed, the design of the research, data collection methods, data analysis and synthesis, and issues of ethics and trustworthiness. In chapter four, I present findings for each research question in narrative form, organized by participant. The second research question findings are presented in two parts, both focused on how teachers navigate practices and policies to teach culturally relevant science: First, narratives telling about

successful navigations of policies and second, narratives telling about unsuccessful attempts to navigate policies. Chapter five includes my interpretation of the findings for each research question from the CRP perspective as well as an interpretive critique of policies and practices; followed by implications for inservice teacher professional development, preservice teacher education, and policy. I include recommendations for future research and conclude with the limitations of the study.

Definitions

Agency- "…individuals or groups reflecting, acting, modifying, and giving significance…in purposeful ways, with the aim of empowering themselves and/or the conditions of their lives, students, and others" (Moore, 2007, p. 591).

Critical consciousness- "a broader sociopolitical consciousness that allows them to critique the cultural norms, values, mores, and institutions that produce and maintain social inequities" (Ladson-Billings, 1995, p. 161).

Culture- "shared and common beliefs, models for living, and practices by a group of people" (Muhammad, 2018, p. 45).

Cultural competence- "support students' understanding of their own history, culture, customs, and languages, and develop their fluency in the dominant culture" (Ladson-Billings, 2021, p. 4).

Culturally relevant pedagogy (CRP)- "a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes (Ladson-Billings, 2009, p. 20).

Social justice- "…exploring the social construction of unequal hierarchies, which result in a social group's differential access to power and privilege" (Lewis, 2001, p. 189).

2 REVIEW OF THE LITERATURE

In this chapter, I first share the steps I took to conduct my search and synthesize the literature. I discuss two overarching findings: The first is that my topics are relatively understudied, and the second is that researchers at times use CRP in ways that do not encompass the entirety of the theory. After that, I discuss the literature relevant to my topics organized into five sections:

1. Culturally Relevant Science Teaching in Elementary Classrooms
2. Social Justice Science Frameworks
3. Teachers' Conceptions of Social Justice Science
4. The Salience of Science Teacher Identity
5. Additional Factors Impacting Science Teaching

I conducted the review of literature using a combination of university library search tools, Google scholar, and reference lists to locate books and peer-reviewed journal articles related to the topics at hand: Elementary teachers' conceptions of CRP, and practices and policies that support and/or impede culturally relevant science teaching. I used the advanced search tool to filter results to those including my terms in the title and/or abstract. Journals such as *Cultural Studies in Education; Journal of Research in Science Teaching; Equity and Excellence in Education; Theory into Practice;* and *Pedagogy, Culture, and Society* also offered starting points. Then I read (and reread) related studies and created a quotation table to isolate the authors' operationalizations of their science teaching frameworks. The table also includes abstracts, the main components of each study (i.e. theoretical framework, research questions, methodology) and my thoughts about each. When searching for research on CRP in elementary science classrooms, I identified gaps in the literature.

First, few studies were available in the university library system when I entered *culturally relevant* and *elementary* and *science* as search terms to identify in the studies' abstracts. This yielded 144 results, which increased to 159 when I added the term *teachers*. Removing the term *elementary* brought the findings to 365. A search substituting *culturally sustaining pedagogy* for culturally relevant pedagogy produced 13 results, and adding *teachers* to that brought it to 12. Removing the term *elementary* increased results to 77. The differences in the number of results support the need for a focus on the elementary level. I utilized a variety of search terms and kept a running log of the kinds of results they produced as I conducted the review of literature. The term *social justice* in place of *culturally relevant* produced over 1,000 results, though fewer were available when I included the term *teacher*. A second conclusion I drew from these results was at times, authors conflate CRP with other asset-based frameworks, such as multicultural education (Banks, 2000; Nieto, 2004) and especially culturally responsive education (Gay, 2000). This is not necessarily a bad thing, as concepts grow and evolve in response to expanding research and diverse perspectives of researchers; and it is useful to have studies that provide in-depth analyses of individual dimensions to inform teacher development. However, taking into consideration the dimension that is most neglected, which is critical consciousness (or social transformation, critical agency, emancipatory pedagogy, etc.) becomes problematic when examining the breadth of research because as others argue, it is a missing component needed to address inequities in science education (Rodriguez, 2015).

One example of this conflation is Brown-Jeffy & Cooper's (2011) conceptual framework of CRP. While commendable for centering race and racism by layering CRP with critical race theory (CRT), the authors' framework lacks attention to the critical aspects of CRP in its own right. Rather than acknowledge the dimension of critical consciousness the teachers in Ladson-

Billings' (1995) studies exhibited and fostered in students, the authors attribute any critique to CRT. In actuality, the sociopolitical awareness of teachers and how they foster students' development of critical consciousness is what delineates Ladson-Billings' (1995) framework and those with comparable goals of social transformation or emancipatory characteristics from the other frameworks Brown-Jeffy & Cooper (2011) groups together under the umbrella term CRP. Smith et al. (2022) avoid the conflation pitfall in their argument while giving credence to the origins of what they call culturally adaptive pedagogies: Culturally relevant (Ladson-Billings, 1995), culturally responsive (Gay, 2002), culturally sustaining (Paris, 2012), and culturally sustaining/revitalizing (McCarty & Lee, 2014). I found that more research is needed that documents classroom practices of teachers who understand science as cultural and understand teaching science as more than an understanding of content, but a tool for improving their lives. In the next section, I share the extant literature that informed my study.

Culturally Relevant Science Teaching in Elementary Contexts

In this section, I briefly restate the need for a focus on elementary science, and then I share studies that utilized CRP in their studies specifically. After that, I extend my review to research that uses different terminology or theoretical groundings for aims that are similar to those of culturally relevant pedagogy. Recall the low number of studies available in elementary contexts as compared to those in middle, secondary, or preservice teacher education contexts. In the U.S., elementary-aged students are typically described as those in kindergarten through fifth grade, or aged five to ten years. Children in this developmental range matter as much as older youth and their prospective teachers: They are in the formative years of science identity development (Avraamidou, 2014), and research documents a racial gap in achievement as early as kin-

dergarten (Brown-Jeffy & Cooper, 2011). Young et al. (2017) analyzed the 2009 National Assessment of Educational Progress (NAEP) data, which reports 18% of white students scored at a level below basic, but 62% of fourth-grade Black students were below proficiency. Further, their analysis of fourth-grade Black girls' dispositions, parental involvement mechanisms, and opportunities to learn provided insight on aspects affording and/or constraining their development. They identified strengths in Black girls' understanding of life and physical science, and challenges in earth science. Further, while Black girls showed positive dispositions toward science, the survey data revealed a lack of engagement. Though their teachers were traditionally certified and possessed higher education degrees, most reported less than four hours of instructional time for science each week, and many reported a lack of resources and training to support science teaching. Finally, the 2018 survey of the National Academies of Science, Engineering and Medicine (NASEM) reported only 31% of elementary teachers surveyed felt very well prepared to teach science in general, and students most likely to be taught by teachers who feel unprepared are more likely to be those in high-poverty schools with historically underrepresented race and ethnicity groups. Research from a standpoint of cultural relevance or responsiveness contributes to improving the status of elementary science.

Of the studies I located, most were conceptual or theoretical in nature (i.e. Bettez et al., 2011; Brown-Jeffy & Cooper, 2011; Smith et al., 2022; Noel, 2016). A few focused on students (i.e. Bang & Medin, 2010; Carlone et al., 2021; Desautels et al., 2002; King & Pringle, 2019; Schenkel et al., 2019; Upadhyay et al., 2017), some on classrooms and/or teachers (i.e. Hagiwara et al., 2011; Maulucci, 2010) others on preservice teachers (i.e. Kimori & Ellingson, 2022; Mattheis et al., 2020; Mensah, 2011) or preservice teacher educators (Underwood & Mensah, 2018). In what follows, I present the studies that focus on classroom practices in their data collection

and analysis. Taken together, these studies point to the need for more research that documents elementary classroom practices that support students' learning, cultural competence, *and* critical consciousness in science.

One such study is Patchen & Cox-Peterson's (2008) case study of two white, female elementary teachers whose constructivist practices were analyzed to understand how the teachers met the needs of their native Spanish-speaking students. By analyzing interview and observation data from a framework consisting of constructivist teaching and CRP, the researchers present three categories of findings of constructivist teaching practices that may lead to CRP. The categories the authors identified were (a) authority, (b) achievement, and (c) affiliation. The authors explain a shift toward CRP that can potentially occur within each category as follows: Redistributing authority, supporting metacognitive development, and extending relationships beyond the classroom. Despite the constructivist practices observed in both classrooms, the researchers conclude CRP was out of reach as demonstrated by the lack of opportunities for students to direct or even truly construct their learning and a lack of asking students "why" or "how" in their teaching.

Another empirically driven study of CRP in elementary science is Lee's (2004) three-year study of six bilingual Hispanic fourth-grade teachers from a lens of Osborne's (1996) characterization of cultural congruence and Ladson-Billings' (1995) conception of CRP. According to Lee (2004), instructional congruence "maintains that effective subject area instruction should combine considerations of students' cultural and linguistic experiences with attention to the specific demands of academic disciplines" (p. 67). When congruence is present, students can appropriate science discourse and conduct science inquiry. The researchers collaborated with the teachers throughout ongoing professional development designed to use commonalities between

teachers and students' culture and language to teach science while promoting English language and literacy. Data included observations, individual and focus group interviews, field notes, teachers' feedback, and recordings of informal conversations; analyzed using qualitative methods. The researchers found the teachers' confidence and knowledge of science and science instruction improved over the course of the study. Further, their practices shifted from a focus on procedure in science to probing and extending student discourse by requiring students to elaborate, explain, and justify their answers. In addition, the teachers began teaching in both Spanish and English to promote science and English language learning. Finally, the teachers connected students' experiences at home to their science learning through connections to the foods they eat, the weather they experience, world maps, the birthplaces of the students and countries they visited, a mother taking a child's temperature. These were at times spontaneous, intuitive connections stemming from the teachers' shared language and culture with students. The researchers also found shifts in the teachers' beliefs that allowed them to implement more effective science instruction.

One such shift was the teachers' preconception that science is not connected to culture. Over time, the group became increasingly aware of the relevance of culture to science as they reflected on their own life histories and experiences with science instruction. While these findings are positive, and indeed the research points to successful outcomes for students based on the activities they were engaged in; the authors did not opt to analyze the practices they found instructionally congruent in terms of CRP despite having named it as their conceptual framework. Analysis of the dimension of critical consciousness, especially, was absent from the study though it was plausible to connect the teachers' realizations about the clash of their students' cultures to traditional school science to their own increased critical consciousness. To address the theory-to-

practice divide teachers like those in Lee's (2004) study experience, Brown et al. (2018) utilized cognitive apprenticeship alongside CRP in their study of elementary teachers' practices after participating in targeted professional development.

Extending the focus more broadly from science to science, technology, engineering, and mathematics (STEM); the researchers address three questions: (a) What do elementary teachers know about cultural relevancy in STEM teaching? (b) How do elementary teachers envision applying cultural relevancy in STEM teaching? (c) After participating in a professional development, what principles of cultural relevancy did teachers actually apply in their urban elementary classrooms? The researchers build on extant literature on culturally relevant *education* (CRE) which is a term offered by Aronson & Laughter (2016) to denote the grounding of Gay's (2002) culturally responsive teaching and Ladson-Billings' (1995) CRP together. Brown at al.'s (2018) analysis of interview and video data came from an all-African American male charter school serving students in kindergarten through fifth grade. After their professional development, teachers focused on racially specific phenomenon, and racially and culturally specific topics in their teaching and assessments. However, while the teachers were aware of CRE in STEM, they did not discuss teaching techniques that demonstrate an application of the theory.

As for demonstrating CRE in their teaching videos, the findings were dynamic across participants. Interestingly, it seems the application of CRE in the teachers' classrooms was stronger than their expressions about what CRE in STEM means. The teachers connected STEM topics to their students' lives, experiences, and cultures with topics such as melanin, fashion, and budgeting. Overall, these studies show the possibilities for teaching culturally relevant science with a variety of techniques, from a range of theoretical lenses, and for diverse groups of students. At the same time, the literature leaves room for additional studies addressing student

learning, cultural competence, *and* critical consciousness together. While studies that focus on one dimension (or a similar characteristic) are useful for informing our understanding of each, if teachers are to adopt culturally relevant practices and teacher educators are to support that goal; we need more studies that address all three dimensions. Given the relatively low number of studies on elementary science teaching from a CRP framework, I turn next to research that addresses goals that are shared with CRP, which I characterize as social justice science broadly.

Social Justice Science Frameworks

To reiterate, the phrase *social justice science* yielded the highest number of findings in my search. These studies are important for informing my research because, as Ladson-Billings (1995) states, the teachers may or may not identify their teaching as culturally relevant: It is a research term. However, they share a common set of beliefs about teaching that is reflected in these studies, and the goals of the research are similar to those of the aims of CRP. The range of possibilities for disrupting status quo science teaching as described in the frameworks included here are all included in my conception of the term *social justice science*. My purpose in including various frameworks is to be inclusive of the broad entry points I identified in the literature that work against forces and practices that marginalize students of color from science. To be clear, I heed Ridgeway's (2019) caution that "[t]he term social justice has been used to be a "catch all" phrase to encompass anything under the banner of "equity," which inadvertently has made it meaningless" (p. 285). For example, when examining socioscientific issues in science as an approach, I found it possible to utilize the framework, which claims empowerment through consideration of morals, virtue, and ethics embedded in science topics (Zeidler et al., 2004),

without a critical lens. Such use would preserve the status quo by examining issues without attention to power relations and thus the framework is not representative of social justice science in my envisage.

Though there are differences among them, the goals of these frameworks relate to teaching that seeks to interrupt the ways oppressive systems (i.e. white supremacy) functions in science education by privileging dominant epistemologies (i.e. white, Western ways of knowing) and marginalizing students from non-dominant identity groups. Research prioritizing *social justice science* (Cammarota & Romero, 2009; Moore, 2008) *justice-centered* or *justice-oriented science* (Davis & Schaeffer, 2019; Morales-Doyle, 2017; Tolbert, 2016), *socially just science* (Maulucci & Fann, 2016), *abolitionist science teaching* (Louis & King, 2022) points to the direction(s) science education needs to move (Mensah & Jackson, 2018). Research from these frameworks maintains the importance of knowledge and skills in the science, but goes beyond content knowledge and a singular way of doing science (i.e. the so-called scientific method) and in most instances, seeks opportunities for students to engage in science as a tool for transformation, socially and personally.

Social justice science frameworks are critical, implementing teaching practices that affirm students' racial, ethnic, gender and other identities *and* nurture a desire to use science to improve their own and others' surroundings as they are affected by oppressive forces by first naming those forces (Cammarota & Romero, 2009; Upadhyay, 2009). The working-class, Latinas/os high school students in Camarota & Romero's (2009) study engaged in participatory action research, selecting their research topics from poems they wrote expressing problems in their lives. Their involvement in conducting research led to personal changes such as positive identity development, empathy for others' struggles, and community activism.

These frameworks also involve creating equitable science classrooms, meaning all students have access to quality science instruction regardless of their multiple identities (Carlone et al., 2011; Moore, 2008; Morales-Doyle, 2017; Rodriguez, 2015). Students in two fourth grade classrooms in Carlone et al.'s (2010) showed understanding of science content and positive attitude toward science, but the African American and Latina girls expressed views of themselves as unlike the science people or smart science students in their classes. Their research suggests idea sharing in classrooms has consequences for the accessibility of what scientific knowledge means and who can be a scientist. Social justice science teaching also revolves around local understandings of "physical/spacial, social, political, and domain knowledge" (Davis & Shaeffer, 2019, p. 369). The fourth- and fifth-grade Black students in Davis & Shaeffer's (2019) ethnographic study engaged in a unit investigating water as a human right and the benefits of water justice as they learned science content related to water properties and its functions. Their analysis of students' meaning making showed they analyzed sociopolitical and ethical issues and made sense of them using their scientific understandings of water. Additional frameworks prioritize some or all of these same components around themes of social transformation, equity, funds of knowledge, power or a combination of these themes.

Scholars advocating for personally and *socially transforming science* teaching center the role of critiquing systems, policies, and practices of oppression such as whiteness. They argue the purpose of science education should be not only to teach in ways that go against oppressive systems but also in ways that produce actionable outcomes that make a difference in the lives of students and/or their communities (Bullock, 2017; Ridgeway, 2019). Brown (2017) used culturally responsive (Gay, 2010) and culturally relevant (Ladson-Billings, 1995a) pedagogies in combination with Giroux's (2011) critical theory to extrapolate a view of equitable science learning

that “emancipat[es] learners through instruction that offers social, political, and/or historical critique to challenge hegemonic systems” (p. 1146). This is related to the fostering of students’ critical science agency (CSA), which is influenced by Freire (1970).

Researchers interested in CSA propound to be scientifically literate is to “use the knowledge and practice of science in conjunction with various other forms of expertise to take action on critical issues in one’s life and society” (Schenkel et al, 2019, p. 310). It is the position that learning science involves a critical reading of one’s world and becoming an agent of change (Basu et al., 2009). Science educators need to recognize strengths in diversity, embrace a range of epistemologies, and teach from a stance that schools are sites of knowledge construction among all members rather than a place of the keeper of knowledge to be passed to students deemed worthy (Basu & Barton, 2010). Examples from these studies include girls who utilized engineering design processes to create sustainable products that addressed their local concerns: One group created an LED-lit *Woot Wall,* a light-up bulletin board that served to celebrate youth’s accomplishments in response to the low morale among students and lack of recognition peers received for things they valued, such as kindness. The second group of girls created *Bobbi The Trash Talker Recycling Bin* to provide positive reinforcement via a voice recording of the request, “please recycle” upon the push of a button. Powered by solar energy, a wheel also spun when the sun shone on the bin. A landfill at a student’s grandmother’s house was part of the impetus for this project.

Science education researchers have also taken up and extended Moll et al.’s (1992) notion of funds of knowledge to make explicit the ways that science, like other disciplines, is cultural (Young et al., 2017). Non-dominant cultural norms are assets to be brought into the class-

room; not mistakes to be corrected, gaps to be filled, or practices to wean children from in exchange for privileged ways of being. In a related vein of drawing on assets, Archer et al. (2015) put forth a conceptual device for understanding science capital in the tradition of Bourdieu's (1984) theory of practice. They elucidate that science capital, or the resources (economic, cultural, social and symbolic) someone possesses for forming a science identity and career aspirations is dependent on "who is possessing/deploying it and in what context (field)" (p. 6). They recommend attention to gender and class inequalities as an avenue for increasing diverse participation in STEM.

King & Nomikou (2018), building from Archer et al.'s (2015) notion, found that use of a professional development intervention from a science capital approach fostered teachers' critical agency. They recognize agency as "something that is achieved within the contingencies of the moment and in context, rather than something which is possessed and immutable" (p. 88) in being intentional not to separate an individual sense of agency from its co-constitutive social structures. Drawing on emancipatory pedagogy as put forth by Nouri & Sajjadi (2014), Swartz's (1996) notion of emancipatory pedagogy, and Love's (2019) theory of abolitionist teaching, Lois & King (2022) leveraged community cultural wealth (Yosso, 2005) from a CRT perspective. These "aspirational, familial, social, linguistic, resistant, and navigational" forms of capital (Lois & King, 2022, p. 210) were gained as teachers implemented pedagogy utilizing the Southern Poverty Law Center (2016) social justice standards comprised of identity, diversity, justice, and action domains. All four teachers took up abolitionist teaching by using critical readings, creating lessons valuing students' cultural capital, participating in discussion and reflection around their practice. I turn next to research that centers the teachers' conceptions of this kind of science teaching.

Teachers' Conceptions of Social Justice Science

The research I presented in the previous section is important for advancing scholarship toward the realization of social justice aims for science education, however practice has yet to reach such goals. Understanding what teachers' conceptions are as they work to implement research-based asset pedagogies and social justice science is vital to the betterment of students' experiences in the classroom. How/do they define equitable, justice-oriented science, or culturally relevant science? How/do their perspectives align and differ from researchers' conceptions of culturally relevant science? What are the teaching practices that contribute to this kind of teaching and learning? What types of activities will they prioritize in their science classrooms? The studies I discuss next, in conversation with the rest of the literature, reveal the context-specific pedagogical frameworks that teachers and their collaborators may find best-suited or adapt to fit their needs. Science content, social justice issues, and resulting projects and products cannot be easily laid out for others to follow.

Lee's (2001) investigation into the meaning that preservice early elementary teachers held about social justice showed a range of ideas. Related to my study is the view of social justice as its own content to be taught in social studies or literacy, but difficult to do in math or science. Elementary teachers are responsible for providing opportunities for students to form identities in all subject areas, regardless of their personal affinity for one over another or their training in each. In characterizing the potentially transformative curriculum Tobin (2002) wanted to provide students, he expressed:

> I wanted to enact a curriculum that the students would perceive as interesting, relevant to their lives, and useful. To the extent possible I wanted the students to have choices in what they would study and where they would study it. I predicted that they would enjoy

> doing science if the program was based on investigations, and I had a preference for the activities to involve real world problem solving. I wanted to focus on inquiry as a means to develop deep understandings of science subject matter (p. 128).

This expression of Tobin's intentions for his instruction provides a clear picture of the kinds of activities students could experience. It provides potential avenues a researcher in inquiry alongside this teacher could provide: Protocols for eliciting students' ideas and choices, connections with people doing the work in out-of-school spaces, resources for identifying and introducing specific problems to students, and support with implementing investigations. Other teachers express aims that resonate with social justice science perspectives another way. Carlone et al. (2010) studied 13 teachers who viewed science participation as empowering for students. They found that teachers also believed in inquiry-based learning, wanted every student to have a voice, every student to see their potential for becoming a scientist and use scientific knowledge in their everyday decision-making. They prioritized authentic forms of assessment in science, prompting students to participate in scientific discourse (e.g. making their thinking visible to others). Tobin's (2002) intentions include a dimension of real-world problem solving that the teachers in Carlone et al's (2010) research did not express when sharing the teachers' goals.

In an action research project with students, Fusco's (2001) role as the teacher included setting an ambitious agenda, assisting with the division of labor for the project, maintaining broad objectives, and guiding purposeful products that students deemed important. To do this, Fusco (2001) had to respond to students' ideas daily and adjust instruction accordingly, resisting the urge to privilege positivistic science by allowing students to use epistemologies rooted in artistic forms and oral histories. Chiu et al. (2021) sought to understand how and why teachers

adapted a curriculum that was designed intentionally to be used in equitable engineering instruction by two 5th grade teachers. Teachers' main rationale for adapting the curriculum was in order to contextualize it for their students. First, they did this by connecting to the school by making evidence the connection between the curriculum's provided activities and the drainage problem on the field at their school. Second, they built upon school-based resources such as their knowledge of mathematics and science to connect their understandings to the curriculum. Last, they bridged to students' daily lives by eliciting their knowledge on related topics.

Three teachers in Haverly et al.'s (2020) study centered on equitable sense-making in their elementary science classrooms in terms of valuing student voice. These differences showcase the need to understand the teachers' perspectives for teaching science as part of analyzing the enactment of their social justice science teacher identity. Watts et al. (2003) remind readers, "[c]ritical consciousness can lead to different ideological outcomes; strictly speaking, there is no one set of conclusions that everyone should reach. Diversity precludes that. To press for equal outcomes turns the process of critical consciousness development into indoctrination" (p. 187). This reminder that striving to produce cookie-cutter teachers is not in the interest of CRP reiterates a point that brings me to the literature surrounding a social justice teacher identity. This specific identity consideration is needed due to the strategic navigating CRP often demands of teachers because school settings tend to contradict culturally responsive teaching. In addition to considering what culturally relevant teachers do, it is imperative to characterize who culturally relevant teachers are so that we can learn how to develop them.

The Salience of Science Teacher Identity

Literature using identity as a framework for studying science teacher development is influential to my research on teachers' culturally relevant science teaching because cultural responsiveness and criticality require teachers themselves possess a sociopolitical awareness (Villegas & Lucas, 2002), which is connected to who teachers are (Wallace et al., 2012). Further, it has been suggested that teachers with a strong science identity and a strong science teaching identity can facilitate students' development of a strong science identity, which enables them to reach goals of scientific literacy. This literature demonstrates that self-efficacy and agency are key to science teaching identity. Hagiwara et al.'s (2011) reflections demonstrate the connection between teacher identity and science teaching stating:

> By examining the classroom as a social space, we learn about the role and identities of three urban teachers and their middle school students, and examine the power bearing practices that are enacted upon based on the self-efficacy of the teachers. The power bearing practices of the teachers that inform the synergistic dynamics of students-teachers-science within the classroom ultimately enable and constrain students' self-efficacy and sense of agency to think scientifically and enact science (p. 1006).

What this quote demonstrates is the importance of who the teachers are because of the power relations that are shaped by multiple and intersecting identities, and in turn what self-efficacy the teachers possess, which then informs students' self-efficacy. Ritter at al. (2001) expand previous conceptions of self-efficacy that include teachers' beliefs about their science content knowledge, science teaching methods, responses to students' questions and impact on learning by including teachers' beliefs about their ability to teach equitable science. Ritter et al.'s (2001) expansion of self-efficacy to include equitable science adds teachers' beliefs about diversity and their ability

to effectively teach science to students of color, English language learners, children from low-income households, and girls.

Personal and social conditions are in concert as teachers develop teaching identities in multiple places over time. Science identities are socially constructed and depend on recognition from a knowledgeable other (Barton & Tan, 2010; Kier & Lee, 2017; Tugurian & Carrier, 2017). Understood narratively, identities are "stories to live by" (Clandinin & Connelly, 2000, p. 129). They are created as we construct stories about our past, present, and future (McAdams & McLean, 2013). In developing science teacher identity, such stories surround teachers' K-12 experiences of science, their science methods coursework, student teaching field experiences, classroom teaching, and cycles of reflection with attention to future directions. Maulucci & Fann (2016) state, "...teaching for social justice involves being able to evaluate teaching and learning situations, to imagine how they could be better… to develop and implement new plans, and to reflect on the relative success of those initiatives" (p. 112). This quote illustrates one kind of story that can be told over the course of time, resonating with the narrative view of identity.

Identity as a theoretical framework for studying teacher development has been useful in understanding issues of science teacher preparation (e.g. Luehmann, 2007; Avraamidou 2014; Mensah 2016). Additionally, Moore (2007) investigates the formation of an identity in which elementary preservice teachers (PSTs) view themselves as change agents. She states,

> agency is defined as individuals or groups reflecting, acting, modifying, and giving significance to the teaching of science in purposeful ways, with the aim of empowering and transforming themselves and/or the conditions of their lives, students and others. Thus agency is action-oriented; it is critical; it is the way that teachers use power, influence,

> and science to make decisions that affect positive social change in science classrooms. (Moore, 2008, p. 591)

Moore found teachers' critical *agency* integral to their identity as change agents, or in essence "social justice science teachers" (p. 608). The two were co-constructed. Only one out of 23 PSTs was classified by Moore to have been self-identified as a change agent outside the classroom. The PST who saw herself as this kind of teacher, interestingly, had a weaker teacher identity because she did not feel ready to teach yet. However, her view of her future work as a change agent included goals of social justice. She looked forward to driving change in the face of inequitable assessment, curricula, and policies; helping students navigate inequitable systems so they, too, can make changes in the world; and addressing diverse needs of students in dialogue with other educational stakeholders. Picower (2013), emphasizing the need for social justice-oriented teachers to first and foremost recognize that teaching is political, found preservice teachers who gained an awareness about the political nature of education shifted their stance from ethnocentric views to culturally relevant pedagogy. They were also more aware of systemic inequalities, saw strengths in students as opposed to deficits, and felt more connected after a yearlong professional development experience in a teacher residency.

Chen and Mensah (2018) conducted a collective case study to understand how PSTs identities shifted from coursework to student teaching placements; experiences, relationships and/or interactions that influenced their identities; and how their social justice science teacher ideals were challenged during student teaching placements. It was consistent that the positioning of the PSTs by cooperating teachers in their student teaching placements either provided or denied the PSTs of authentic teaching opportunities, shaping their science teacher identities. The school's low prioritization of science instruction conflicted with one PST's opportunity to teach

inquiry-based science lessons, as it was limited to a rotation in a station as part of a 45-minute segment each week. Another was limited to follow a scripted curriculum rather than the multi-cultural, inquiry-based science the PST was learning to design. In contrast, student teachers who were given time and space to practice the pedagogy they were learning in their coursework were positioned as teachers as opposed to learners, a recognition that affirmed a science teacher identity. To reiterate, the literature I reviewed in this section is related to my interest in teachers' conceptions of culturally relevant science and the ways they navigate policies and practices because the research emphasizes the importance of who teachers are and who they become. Aside from identity considerations, researchers have documented factors that impact teaching science at the school level, which I present next.

Additional Factors That Shape Science Teaching

Factors that impact science teaching in K-12 classroom settings in the U.S. include the teaching standards in each state, the compatibility of teaching and learning perspectives with those standards, and the practices in place within schools that hold teachers accountable to them. I share the research on these topics next.

Standards

Barton's (2002) analysis of 46 urban science education studies showed two main challenges to equity in science: (a) material resources and (b) policy and its enactment. Since UNESCO launched a commitment to "equalizing science learning experiences for all students" (p. 14), Barton (2002) reports on research that has asked questions about school, system, and community-based conditions impacting policy enactment and how/should the science education community understand the impact of policy. Her analysis found inadequate teaching conditions, distrust among decision-makers, a lack of understanding or shared mission, and a host of barriers

that persist even when professional development and an inquiry program are supported. Yet, there is a range of perspectives as to how and why policies restrict implementation. Today, the majority of U.S. states (45) have either adopted or based their version of K-12 standards on the NGSS. As mentioned in chapter one, the goals of the NGSS relate to high school graduates' understanding of scientific and technical information to engage in public discussions and enter careers of their choosing (NASEM, 2022). The NGSS lay out three dimensions necessary for science learning:

1. Crosscutting Concepts: Physical, Life, Earth, and Space science practices are understood in connection with Engineering Design. There are seven: Patterns; cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; and stability and change.
2. Science and Engineering Practices: Students engage in the actions or behaviors that scientists do to investigate the natural world and design and build systems. These deepen past conceptions of inquiry by requiring students to apply core ideas and crosscutting concepts. Detailed in a progression from K-12, there are eight practices: Asking questions (for science) and defining problems (for engineering); developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations (for science) and designing solutions (for engineering); engaging in argument from evidence; and obtaining, evaluating, and communicating information.
3. Disciplinary Core Ideas: Key ideas grouped into the domains of Physical, Life, Earth and Space Science and Engineering that serve to focus the K-12 curriculum. Core ideas meet two out of the following four criteria: The idea has broad importance

> across disciplines or a key organizing concept; it is a key tool for understanding a complex idea or solving problems; it is related to students' interests and experiences or connect to societal concerns requiring scientific or technical knowledge; and over multiple grades, the idea increases in depth and sophistication while being teachable or learnable (Achieve, 2013).

Bismack et al (2022) conducted a longitudinal case study of teachers from the time they spent two years in a practice-based teacher education program through their first two years teaching in elementary schools. I share this study because the program offered four courses in science teaching and learning, a higher number than the many teacher preparation programs which offer just one. The course titles are offered, though a description of the foci of each is not present in the study so whether the program prioritized diversity and/or equity in science is left unknown. However, their analysis of videos of teaching, lesson plans, teachers' reflections, interviews, and a program assessment yielded findings about their implementation that differ from previous studies in a positive way that shows with support, teachers can implement the NGSS practices. At the highest level of understanding, the participants knew the meaning and importance of constructing scientific explanations and arguments; and at the lowest level of understanding was the need to critique scientific explanations and arguments. Other studies have noted these same areas as difficulties for novice teachers (i.e. Arias, 2015).

The NGSS contain language that encourages multiple perspectives, centering the humanity of scientists, and encouraging students to form their own questions and arguments. These are worthwhile foci and an improvement from earlier standards that placed more emphasis on what topics to teach and recalling of facts. However, Rodriguez's (2015) critique from the lens of sociotransformative constructivism reports a discrepancy between the NGSS and frameworks for

social justice science described above that lies in how explicitly an equitable approach to science education should disrupt power imbalance in science. The NGSS utilizes broad conceptions of equity that ultimately allow for status quo teaching to persist (Rodriguez, 2015).

Brown (2017) drew on Giroux's (2011) conception of critical education in combination with Gay's (2010) culturally responsive and Ladson-Billings' (1995a) culturally relevant theories of teaching to examine the compatibility of an equitable teaching framework with the inquiry-based aims of the NGSS. Results of her metasynthesis of 52 empirical articles show that teachers can align these frameworks with certain attributes of inquiry detailed of NGSS. Those components include most frequently (a) Obtaining, Evaluating, and Communicating Information, (b) Constructing Explanations and Designing Solutions, and (c) Developing and Using Models. Brown (2017) also identified the three most common culturally responsive practices that were used in conjunction with the inquiry-based science practices: (a) Pedagogy, (b) Curriculum, and (c) Classroom Relationships.

It follows that teachers can potentially implement the standards in culturally relevant ways and create equitable science classrooms. One of the ways teachers do this is by shifting from backward planning with specific content mastery in mind to embracing the unfolding of scientific practice in response to each day's work, led by students (e.g. Buxton, 2010; Fusco, 2001; Tobin, 2002). Buxton's (2010) study demonstrated the power of a place-based social problem-solving science unit around water use around the world. The students were able to demonstrate science content knowledge typical of standardized tests while expanding their thinking about their local environment and expressions of their thinking. Sharing authority with students may necessitate adjusting the sequence of teaching particular standards, incorporating content that falls outside the requirements for the particular grade level, and designing assessments based

on the content students naturally came to learn because they needed to understand certain topics in order to solve the problem at hand. This means students in one classroom may study different topics than one another, and it follows that classrooms would have different content at different times within a grade level and from school to school. This work presents challenges and creates tension for teachers in the accountability climate of standardized tests.

Institutional Constraints

How/do teachers find opportunities for engaging students in activities that not only foster acquisition of knowledge and skills but also foster a sense of science identity, cultural competence, and critical consciousness as part of their science learning in the age of accountability? Upadhyay's (2005, 2006, 2009) studies reveal important understandings of teachers' enactment of empowering curriculum. Each teacher drew on her life history to inform her view of students from cultures different from *and* like her own. They all had to contend with the pressures of high stakes tests, but their interactions with students drove the direction of their teaching. They each had to balance positive and negative experiences with colleagues and students' families. In their commitment to centering students and their belief that science is connected to all parts of life, including other subject areas, the teachers were able to work around institutional constraints by integrating literacy and math with their science instruction.

One participant, Vera, for example, worked in a school environment was unkind to teachers with inadequate standardized test scores, and she saw passing the test as a form of empowerment for students because doing so provides opportunities. However, her desire to prepare students with conceptual understanding forced her to make the difficult decision to disregard district curriculum and goals. She was in conflict with her beliefs about learning and her obligations to

the school system. Vera's goal was to provide transformative experiences for her Hispanic students in stark contrast to the reading-focused science education she received that caused her to dislike science and believe it was not for her as a Mexican. Vera adapted the researcher-provided curriculum to include process skills in order to prepare for those questions on the tests.

Together, these studies reveal the salience of teacher positioning. Carlone et al. (2010) utilize the concept of "tempered outsiders" to portray how teachers in their study functioned simultaneously as insiders and outsiders in their schools. The teachers in the study knew the dangers of isolation from science their students faced as students of color and refused to take part in their exclusion from it. In their commitment to centering students and their belief that science is connected to all parts of life, including other subject areas, the teachers were able to work around institutional constraints (i.e. a schedule tightly-monitored by administrators, negativity from colleagues interested mainly in tested subject areas, parent preferences for students to pass tests rather than experience science practices) by integrating literacy and math with their science instruction.

At the same time, we can learn from teachers whose social justice aims were not realized, such as in the case of Rivera Maulucci's (2010) participant Tina, Mensah's (2022) participant, and Tobin's (2002) autoethnographic account of his own teaching. Tobin (2002) reveals how his deficit views, lack of understanding of his students' cultural and social experiences, and in-the-moment decisions to maintain control and order in the classroom constrained his implementation of his street science inquiry. Tobin's (2002) work reveals the contrast that occurred between writing about, speaking about, planning for, and preparing to teach using justice-oriented science pedagogy and enacting it in the classroom. He discusses his inability to connect science to stu-

dents' lives through a street science project that contrasts in outcome to Fusco's (2001) successful work with youth who reinvigorated an abandoned garden space in their neighborhood. The teacher in Maulucci's (2010) study, a white woman teaching Black and Latino/a students, would have quit teaching had it not been for the support of her colleagues in "understanding cultural, linguistic, and social difference as resources to be capitalized on in teaching" (p. 645). A white woman participating in Mensah's (2022) analysis of neoliberal ideology left the teaching profession altogether.

Teachers in the studies conducted from the CSA framework described above recognized students' ideas and assets, ensured a distribution of roles by holding students accountable to their groups' goals, paid attention to students' needs, and actually used their engineering solutions. Teachers without the insight to honor diverse students' funds of knowledge and utilize them in the classroom will struggle to implement social justice science. To this aim, Miller et al. (2018) argue for teachers to develop students' epistemic agency, meaning they are not expected to replicate the science practices of others' but to contribute to the shaping of knowledge production. Mensah (2022) reminds readers that *all* schools are projected to continue to increase in diversity of not only race but also additional identity markers, not just schools in urban centers. Teachers cannot simply choose to teach children they perceive are most like them. This points to the need for science teacher educators to prepare preservice teachers for a multitude of settings and cultures as part of becoming social justice science teachers. It is worth noting the scholarship on science teacher educators' conceptions of CRP and how to support preservice teachers toward social justice science teaching is relatively thin, according to Underwood & Mensah (2018), whose research showed four science teacher educators' conceptions of CRP were conflated with cultur-

ally responsive pedagogy (Gay, 2000). The authors recommend anti-racist professional development that addresses topics that would support science teachers' ability to model reflection processes with preservice teachers (i.e. the racial achievement gap, colorblindness, biases, and school racism).

Summary

Thanks to the studies I reviewed above, such as King & Nomikou's (2017) science capital intervention, and stories from community partnerships such as Lois & King's (2022), there are examples of specific supports we can consult as elementary teachers work to improve their science teaching practices. By this, I mean the strategic practices researchers taught preservice or in-service teachers in structured professional development settings and their discussion of the utility of those tools, activities, and lessons. The studies I have discussed led me to concur with Grimberg & Grummer (2013) who argue, "the individual's cultural, social, historical, and academic locations cannot be separated from the what (curriculum), how (pedagogy), why (policies), and by who (teachers)" (p. 1034). This speaks to the narrative design of the study. Rather than isolate any one component of the what, how, why, and who; I retain the complexity of science teaching by conducting my study from a three dimensional space of temporality, sociality, and place (Clandinin & Connelly, 2000), explained further in the next chapter.

3 METHODOLOGY

The purpose of the study was to understand elementary teachers' experiences teaching culturally relevant science from their perspectives. The need to understand teachers' experiences implementing science instruction that is effective, engaging, and socially impactful for all students stems from the following proposition: The state of Georgia is simultaneously increasing in diversity and establishing restrictive education policies (i.e. HB 1084, SB 1187). Both bills became laws in 2022, and research has yet to document its impact on elementary science education. Science is a human effort. Any attempts to restrict teachers' capacity or opportunity to respond to students' life experiences poses challenges that can be understood by hearing from teachers themselves since they are immediately translating policy to practice. Further, policies at the district and school level, as well as practices put in place to increase adherence to policies, are best understood by unearthing teachers' experiences in the classroom. Hence, I designed a qualitative methodology for studying teachers' experiences.

Understanding what it means to teach culturally relevant science from the teachers' point of view provides empirical data which could be used to first, contribute to the growing knowledge base about science education the elementary level; and second, critique institutional school policies and practices that create barriers to teaching culturally relevant science. A critique of institutional constraints could inform elementary teacher preparation programs about how teachers translate theory and policy into practice in the teachers' unique contexts at this critical point in time. The research addressed two questions: (a) What does it mean for elementary teachers to teach science in culturally relevant ways? (b) How do teachers navigate school practices and policies to teach science in their elementary classrooms? In this chapter, I describe the methodology of the study and discuss rational for my approach, the research sample, information

needed, the design of the research, data collection methods, data analysis and synthesis, and issues of ethics and trustworthiness. I conclude the chapter with a summary.

Rationale for Narrative Analysis

In this section, I provide a rationale for my use of narrative analysis. I provide the details of my procedure in an upcoming section. The data for my study were stories elicited through semi-structured interviews. Riessman (1993) defines narrative analysis as the study of the story itself, which reflects the analysis I conducted. Stories are one thing all of humanity has in common. The telling of experiences from first person accounts predates the written word. Stories are instrumental in passing along and preserving memories, traditions, and history. They evoke our emotions, enlighten us, educate us, foster reflection, and give us space to engage in hope for the future. They provide an outlet for solving problems, escaping our own reality, and experiencing modes of communication. From a research perspective, "narrative is the linguistic form suited for displaying human existence as situated action" (Polkinghorne, 1995, p. 5). The teachers in my study experience their teaching as situated action in their unique contexts, and that is why I chose to elicit their stories as the primary mode of inquiry.

The term *narrative*, in research, has taken on a life of its own, some arguing its origin in postmodern research with scholars such as Michel Foucault, Jacques Derrida, and Jean-Francois Lyotard (Taylor, 2014). According to Elbaz-Luwisch (2007), "Schwab was probable the first educational theorist to call for close attention to the lived experience of children and teachers in classrooms" in the 1950s (p. 358). Researchers have conceptualized narrative as a prosaic discourse, in which the text is the form of data to be analyzed (Riessman, 1993; Polkinghorne, 1995); an ontology (Clandinin & Connelly, 2000); and a theoretical tenet of critical race scholarship, in which counter-narratives serve to legitimize and prioritize the experiences of people of

color (Decuir & Dixson, 2004). While there is a tendency for social sciences to historically write off personal experiences as non-objective and thus unacceptable forms of data for making knowledge claims (Clandindin & Connelly, 2000), researchers across disciplines have taken strides in making it clear that not only are personal experiences viable objects of study, but they are invaluable for what they offer to increase the social relevance of research in general.

The ontological stance of my study is that people make meaning of experience narratively: They interpret events and actions through time, across place, within social milieus (Dewey, 1958). Riessman's (1993) use of narrative analysis focuses on first-person stories a researcher seeks to understand by way of a number of analytical frameworks. It is a necessary organizing principle for the information needed to answer my research questions surrounding elementary teachers' culturally relevant pedagogies and their contextual influences. Obtaining narratives to analyze involved participating in the creation of those narratives in my study because I gathered them via interviews. I became part of the social construction of the teachers' narratives as they told them in conversation with me. Next, I define the underpinnings of the design of my study to be clear about why, based on the theoretical framework and research questions, narrative analysis is appropriate for the study.

Through narrative analysis, I embrace an interpretivist paradigm, which maintains as Treagust et al., (2014) put it, "people construct their understanding based on their experiences, culture, and context" (p. 7). With an intent to provide the details of their lived experiences (Dewey, 1958), not to prove generalizability to other settings, I crafted a study that would allow me to interpret what the teachers in my study shared with me and provide an analysis that readers, too, will interpret for themselves. Further, understanding how teachers navigate their con-

texts in schools required a lens for analyzing power. Critical theorists share interpretivists' assertion that experiences shape people's truths, impressions, and values; but their focus on power dynamics and inequality sets them apart (Treagust et al., 2014). Certainly Paulo Freire's call for us to read the word and the world remains a touchstone for contemporary critical scholarship (see Green [2023] for a discussion of Freire in conversation with a selection of contemporary scholars). Anderson (1989) illustrates that criticalists' interpretations of social order gave rise to the critique of the school system for its role in reproducing inequity. Thus, in conjunction with the interpretivist paradigm, the research is also informed by critical theory.

Critical race, critical whiteness, intersectional, and postcolonial theories have been useful in exposing how white supremacy operates through policies, procedures, norms, and discourses in schools to ensure all students do not have opportunities to engage in culturally-affirming school experiences, let alone science that results in changes to their communities (e.g. Castagno, 2014; Collins & Bilge, 2020; Sojoyner, 2016; Lomawaima & McCarty, 2006; Vaught, 2011). A growing body of intersectional research shows how Black girls are precariously positioned to be excluded from science, more so than other marginalized groups (Mensah & Jackson, 2018; Young et al. 2017). For my study, viewing science learning as a civil right and teaching as inherently political made an understanding of power necessary. I sought to understand teachers' experiences from a critical lens in a way that connects to Carlone et al.'s (2010) stance that "institutional realities are so powerful because they authorize or sanction allowable practices and meanings" (p. 944). Examining challenges unique to elementary science educators, Mensah (2010) notes that social, institutional, and political agendas are not easily penetrable to teachers. Schools are power-wielding institutions organized in a hierarchy, with power relations resulting from individuals' positionalities (Tolbert at al., 2017).

An intersectional view of power is relational: Power is not something a group or individual holds while others do not. Rather, "people's lives and identities are generally shaped by many factors in diverse and mutually influencing ways. Race, class, gender, sexuality, age, disability, ethnicity, nation, and religion, among others, constitute interlocking, mutually constructing, or intersecting systems of power" (Collins & Bilge, 2020, p. 226). Collins and Bilge (2020) illustrate four domains of power, all of which are salient to making changes in education. They are: Structural, the arrangement and relations of a social institution such as an institution of higher education (IHE), school district, school, or classroom; cultural, that ideas and culture influence the organization of power relations; disciplinary, how rules and regulations are put to bear on people in discriminatory ways based on identity markers; and interpersonal, the ways individuals undergo the concurrence of these domains of power.

Critical theories shifted dominant discourses about *what* is studied and *how* in the name of social justice. In terms of how to conduct research, qualitative epistemologies were proffered as needed forms of representation and interpretation of social reality as early as Immanuel Kant's (1781) foundational model denoting researcher subjectivity as intrinsic to inquiry (Taylor, 2014). Bogdan & Biklen (2007) describe five characteristics of qualitative research that any given study will exhibit to some degree: It may be naturalistic, include descriptive data, center around processes over outcomes, include inductive data analysis, and/or emphasize a concern for meaning. While my study does not include the naturalistic characteristic because I did not seek observation as evidence for teachers' experiences, my study displayed the other four traits.

Qualitative research epistemologies allow for the study of beliefs, motivations, attitudes, behaviors, feelings, and meaning making. I designed my study's methodology to allow for an unearthing of teachers' realities from a constructivist standpoint. Constructivist epistemology

guides a breadth of methods that account for multiple realities due to the notion that individuals actively construct their realities through interactions with others (social constructivism) and according to their prior experiences (cognitive constructivism) (Patchen & Cox-Petersen, 2008). For an account of the epistemological roots of constructivism by way of Piagetian philosophy, see Staver (1986). To understand the ways the teachers in my study constructed their science teaching, I sought their stories. I crafted a methodology reflective of each of the perspectives I have mentioned thus far, which brings me to the justification for the narrative analysis utilized in this study.

Participant Selection Approach

Designing the study from an asset-based approach, I held two assumptions. First, culturally relevant science instruction *is* taking place in some schools. Second, teacher preparation programs and in-service professional development programming from organizations with commitments to social justice broadly would likely incorporate one or more culturally-affirming, asset-based, or otherwise transformative pedagogical stance in their offerings. To increase the likelihood of teachers' practices reflecting a justice-centered approach to teaching science, I identified prerequisite experiences I required participants to have. Conducting a purposeful sampling method, which Miles & Huberman (1994) call criterion sampling, I reached out to networks I knew were committed to social justice in mission and vision and had changed my teaching and/or research practices because of my involvement in them by increasing my sociopolitical consciousness and my capacity to facilitate students' development of the same.

The participants' professional development experiences also had to occur in the last five years because I was interested in hearing from educators who were receiving professional development that reflected the current climate in which teachers are working. The summer of 2020,

with its uprise in public displays of hatred toward Asian Americans amid misinformation about the Coronavirus and overdue global attention to violence against Black bodies committed by police, plus the rise of white supremacy groups emboldened by the Trump administration prompted more school districts and businesses than ever before to express their stance; in many places one of support for diversity, equity, and inclusion efforts. Thus, programs with no previous public social justice commitment crafted statements condemning racism and may have worked to change the scope of their work to better address inequity. Aware the change in equity work is certainly not a guarantee, my decision to limit professional development to no more than five years back was made under the assumption that the program would reflect our current times and a commitment to social justice.

At the same time, teacher education programs with social justice missions have existed long before this five-year period, and educators may well have attended reputable, effective programs before that. Despite this limiting of my selection, In other words, I included the participation in a social justice-leaning professional development program, but limited my scope to those of which I had insider knowledge rather than opening the invitation to any program that made the same claim. This way, I would reduce the number of teachers without a stance toward culturally relevant science teaching. At the same time, limiting the reach of my recruitment meant that I potentially missed the opportunity to interview teachers who are committed to culturally relevant science even though their teacher preparation and/or professional development came from somewhere else. I moved forward because the small sample size I sought for the study would still be possible within the constraints I set.

To determine the number of participants needed for my study, I examined studies with a similar scope and focus, as recommended by Onwuegbuzie & Leech (2007). My analysis

showed a range from one to 13 participants for studies utilizing narrative interview data. In keeping with the narrative tradition of relatively small sample sizes and no intent to generalize findings, I sought a minimum of five participants because the majority of studies had one to five participants. The maximum number of participants I identified was ten, and so I capped my sample size goal at ten to be able to conduct my analysis effectively as the sole researcher. Because the organizations provided me with a total of 558 teachers to contact, I moved forward with the restriction confident that I would meet my target sample size. I also drew contextual boundaries on my search according to my interest in CRP.

While preparing selection criteria, I prioritized the original purpose of CRP: To develop a theory of pedagogy that captured the commonalities of teachers who were successfully teaching students of color (Ladson-Billings, 1995). Thus, the teachers needed to work in schools that serve students of color. Ladson-Billings' (1995) framework has been embraced and utilized in education research and practice more commonly than other asset-based frameworks at this time. The perception that it has become common language is a reason I structured my codebook for the first interview around it instead of broadening my codebook to include characteristics from additional frameworks (i.e., Muhammad's [2020] culturally and historically responsive pedagogy). I posited CRP was likely a framework that teachers who participated in the programs I targeted would be familiar with, and thus more likely to implement teaching that is consistent with its tenets. The inclusion criteria I designed were:

1. Within the last five years from the time of data collection, the participants either earned teaching certification through an equity-centered teacher education program, whether bachelor's or master's level; or they have a record of attendance at one or more professional development sessions designed to support teachers in teaching for social justice,

whether the professional learning experience was science-specific (i.e. a conference focused on CRP).

2. The teacher was responsible for teaching science at the time of data collection.
3. The teacher was teaching in an elementary classroom (Grades K-5) at the time of data collection.
4. The school served students of color.

Recruitment Procedure

To recruit teachers, I emailed a study flyer (Appendix J) to the listserv of the past five graduating cohorts of students in a Bachelor of Science in early childhood and elementary education program and an urban accelerated certification and Master of Arts in elementary teaching program. I also sent the flyer to the past five years of attendees to a teacher residency's professional development programming. The college home to the certification programs and residency states its graduates will "improve the future for those who need it most" and they will "learn to work effectively within diverse classrooms," offering urban school setting preparation. Coursework includes Culture, Equity, and Responsive Pedagogy; and Science and Inquiry in Early Childhood Education among requirements. The Master of Arts program is an alternative route to teacher certification offered to preservice teachers who hold bachelor's degrees in other areas. Beliefs of the program include language around teachers' power, children's culture, respect for children's communities, and a respect for the children's home languages that shape a mission of developing empowered, equity-oriented teachers as change agents. The teacher residency program associated with the same college supports teachers for three years, beginning in the final year of their initial certification program. The residency's goals include supporting critically con-

scious, compassionate, skilled educators who prioritize deep joy and thriving; enacting transformative learning experiences. They work with practicing educators and leaders in addition to the three-year residency members. I also emailed the contacts in leadership positions in each of the programs to ask if they knew anyone who would fit the criteria and/or share the flyer, but that did not lead to any of my participants. In total, I sent the flyer to 558 teachers. Seven teachers expressed interest by filling out the Google form linked on the flyer: Three were from the teacher residency program, and four were from the bachelor's program. The form asked teachers to indicate the professional development they attended within the last five years from a drop-down menu of the programs I targeted. It also collected each teachers' name, place of work, grade level, and contact information.

One respondent was not included in the study because his professional development took place eight years prior to the five-year cut-off; and he taught grades K-8, so he was not a classroom teacher. Two teachers did not respond to my three attempts to schedule the first interview, so I moved forward with four participants from the email recruitment. I personally invited another teacher, Jake, who I met through doctoral coursework and fit the criteria as well. I initially included one teacher, Jason, who was uniquely positioned in the classroom as a special education co-teacher because he explained that he follows the same groups of students and co-teaches science with a general education teacher. Because he was involved in the planning and implementation of science instruction, I wanted to hear more. In total, I interviewed four teachers two times each: Their pseudonyms were Jake, Jason, Connie, Magenta. I interviewed Hannah only once. She ended her involvement in the study after the first interview due to time constraints. I excluded Jason from the final study because I was not able to code his stories for all three dimensions of CRP, and at times his talk contradicted the beliefs indicative of asset-based pedagogies.

About the Participants

The final three participants included in the study are Connie, who responded to the flyer sent via email to a listserv from her undergraduate teacher preparation program; Magenta, who received the flyer from prior attendance at professional development offered by the teacher residency; and Jake, who I recruited personally due to his fit with the criteria and current enrollment at the university. The following information was provided by the participants in their words. Connie is an African American, bisexual female in her first full year of teaching. She teaches fourth grade in a school serving grades Pre-K through five, serving over 800 students who are American Indian/Alaska Native, Asian, Black, Hispanic, White, or identify with two or more races. Jake is a Black, male, fifth grade teacher who is 27 years old, gay, and considers himself working class though he grew up in proximity to poverty through family. His school serves just under 400 students, who are American Indian/Alaska Native, Asian, Black, Hispanic, White, or two or more races. Magenta is a Christian, African American, heterosexual woman, wife, and mother in her eighth year of teaching. She teaches fourth grade at a charter school serving over 400 students who are American Indian/Alaska Native, Asian, Black, Hispanic, White, or two or more races.

Information Needed to Conduct the Study

I explored the two research questions introduced above to understand how teachers navigate school practices and policies to teach culturally relevant science. Table 1 shows the information needed for the study and its alignment to my research questions and theoretical framework. To answer my questions, I needed to obtain a picture of who the teachers are, their thoughts and stance toward teaching science, and information about their school context (i.e. signature programming, staffing model, vision and mission).

Table 1

Information Needed for the Study

Research Question	Information Needed	Data Collection	Theoretical Perspective
What does it mean for elementary teachers to teach science in culturally relevant ways?	Demographic Data Who are the participants? (i.e. age, gender, pronouns, race, ethnicity, grade level, school, number of students, daily schedule, prior teaching experience, degrees, certifications, endorsements) Who are the students? (i.e. school population demographics, grade levels served, school model, staff, etc.)	Personal Data Sheet (Appendix B) School Data Sheet (Appendix C)	Ladson-Billings (1995) CRP
What does it mean for elementary teachers to teach science in culturally relevant ways?	How do participants describe their science teaching? (i.e. What are their goals for students? How/do they describe student achievement, cultural competence, critical consciousness?) What are the participants' conceptions of knowledge, self and others? How do they describe social relations?	Interviews	Ladson-Billings (1995) CRP
How do teachers navigate school practices and policies to teach science in their elementary classrooms?	Institutional Context: School Level How do broader educational narratives unfold in their schools? How do participants describe the norms of the school? (i.e. addressing learning loss, early intervention, accountability) What structural barriers exist in the space? What affordances exist?	Texts from school websites: mission, vision, texts aimed to parents, handbooks Researcher memos Interviews	Critical theory (Freire, 1972)
How do teachers navigate school practices and policies to teach science in their elementary classrooms?	What practices or procedures are connected to federal, state and/or local policies?	Interviews School and district handbooks Education policies	Critical theory (Freire, 1972)

Research Design

I sought topical stories about teaching science in elementary classrooms, aiming for a total of two interviews as opposed to the greater number of interviews and additional forms of data indicative of a more in-depth story such as a life history. There is no singular, correct way to analyze narrative data. In fact, Kim (2016) recommends researchers flirt with their data and avoid working to fit their analysis into a procedural method so that researchers can consider multiple meanings and prospects. I heeded this recommendation throughout my study, resulting in a unique process that was iterative and non-linear. There were moments of tension from start to finish when I had to pause and clarify my decisions or return to the original transcripts and audio to reconsider my interpretation, a code I assigned. I conducted multiple iterations of my analysis before deciding I had considered all the possibilities and ensured consistency across participants. Still, I revisited decision-points in the research to verify subsequent steps were in keeping with those I took earlier.

I used email to schedule the initial semi-structured interviews with teachers, and after I met with each of them once, I uploaded AI-generated transcripts and audio and wrote memos to capture my interpretations of their science teaching. During the phase between the first and second interviews, I constantly moved back-and-forth and between audio, transcripts, memos, and the related literature. I designed the second interview protocol in response to the first interview. After the first interview, I was working to understand the teachers' conceptions of teaching science: What is important to them? How do they describe and define student engagement and success in science?

I produced multiple interpretations of many moments throughout the transcripts, so I sought to clarify those moments. One strategy was sending the transcripts to each participant and

asking for feedback, though no one opted to make any changes. Second, I designed the next interview to elicit more stories and to breach topics that were salient to my research questions that did not come up directly in the first interview. These included topics related to culture and social transformation. I wondered whether it reflected the researcher-participant relationship or the teachers' own understandings of science education. I consulted research using vignettes or case studies to elicit storytelling from participants during the second interview. After repeated listenings accompanied by annotating and coding, I worked to reduce my data and determine the core narratives.

Establishing core narratives was another iterative process involving several versions of stories I found using a Three Dimensional Narrative framework (Clandinin & Connely, 2000). I focused on moments of storytelling in each transcript and organized the stories by participant. Still, I returned to the transcripts to read surrounding text throughout my analysis and production of the final research text. Within those stories, I focused on different times, spaces, and social actors as I produced multiple versions of stories. I focused on classroom activity as a whole and incorporated time and sociality to provide richer description and detail surrounding the classroom incidents. To address my second research question around navigating policy, I asked questions of the stories: What affordances and/or constraints led to this classroom episode? What school practice or policy influenced the episode? State policy? Questioning the context of each story, I consulted school and district website documents and policy documents to inform my interpretation. Next, I wrote the core narratives for each research question and interpreted them from the lens of my theoretical framework. In the sections that follow, I provide detailed insight into my research process so that others may gauge the trustworthiness of my findings. The following list of steps

summarizes my process, and in upcoming sections I share more detail about the data collection tools, analysis, and synthesis.

1. I chose participants based on the criteria above and set up interview #1 over email.
2. I conducted audio-recorded, in-person, semi-structured interviews (Appendix D) with each participant in locations chosen by the participants (i.e. coffee shop or restaurant near their place of work).
3. I uploaded AI-generated interview transcripts to NVivo. During the first listen of the audio, I corrected the transcripts and paused for memo-writing and annotating. Then I sent the written files to the participants for review. Note: No participants asked me to change either of their transcripts.
4. On a second listening, I coded for storied talk.
5. On a third listening, I characterized the entire transcripts according to codebook one, a priori codes for CRP (Table 2).
6. I designed the protocol for the second interview and scheduled the second interviews over email. Hannah declined to continue in the study, citing a busy schedule.
7. I conducted the second audio-recorded, semi-structured, in-person interviews (Appendix E) in the same locations as the first.
8. I repeated steps 3-4. Then I isolated parts of both transcripts coded as storied talk and organized it into files by participant. (i.e. Connie's Storied Talk)
9. I analyzed storied data and arranged it into individual events, resulting in events that took place in the classroom, in the workplace, the place of a professional development experience, and elsewhere.

10. I analyzed events that took place in the classroom using a cross-coding analysis with the CRP codebook in conjunction with the Three-Dimensional Narrative (Clandinin & Connelly, 2000) framework. I revisited codes to confirm them, returning to transcripts as needed. These events informed the narratives developed for research question one.
11. I wrote narratives for participants whose classroom events included all three dimensions of CRP.
12. I returned to the storied talk data to code for constraints and affordances. I wrote memos to describe whether the story resulted in overcoming a constraint or not overcoming it, revisiting the original transcripts as needed.
13. I wrote memos to identify constraints and affordances stemming from practices or policies put in place at the school, district, state, and/or federal level. Those stories stemming from policy or practice are the core stories that make up the narratives I developed for research question two, following the same conceptual framework as the first: Three-Dimensional Narrative (Clandinin & Connelly, 2000) and CRP (Ladson-Billings, 1995a).
14. I wrote the narrative findings for research question two and sent them to participants for comment. No participants provided feedback for these narratives.
15. I returned to my narrative findings and considered several iterations of analysis, considering multiple organizational formats, consulting related literature, and returning to the findings to interpret in a cyclical nature.
16. I interpreted my findings from the theoretical framework consisting of CRP (Ladson-Billings, 1995a) and critical theory.

Data Collection

The main type of data I sought to analyze were stories I collected via interviews. To obtain interview data in storied form, I worked to create the circumstances for storytelling in conversational interviews. Riessman (2008) states that rather than use a particular technique to conduct interviews that encourage narrative accounts, researchers must loosen their control of the direction the conversation takes and instead ask questions that leave space for participants to talk for a lengthy amount of time in a form that is meaningful to them. The researcher should follow the participant's lead and explore "associations in meaning that might connect several stories" (Riessman, 2008, p. 24). Questions beginning with "tell me…" as opposed to "share your story…" can be more inviting to participants and remove the pressure to provide a story in an interview. Because the first interview was intended for a priori analysis centered around what participants perceived and envisioned for their science teaching, and my interest was in culturally relevant science teaching, the guide (Appendix D) contained focus questions that were predetermined. Preparing for a semi-structured interview, the questions were still intentionally open to allow me to follow the conversation according to the participants' lead. Per Riessman's (2008) recommendation, I practiced emotional attentiveness and engagement while listening to participants, allowing them to share in the ways they found meaningful.

After the first interview, I used the a priori coding results to design the second interview. I was able to code Connie, Jake and Magenta for all three dimensions of CRP (student learning, cultural competence, and critical consciousness), and they all provided insight about their beliefs that aligned with the aspect of the framework that indicates teachers' beliefs about teaching and learning (conception of self and others, social relations, and conception of knowledge). Table 2 includes the codebook and examples from Connie's first interview. I included Paris' (2012) conception of culturally sustaining pedagogy in the codebook because while aligned to Ladson-

Billings' (1995) CRP as a resource pedagogy, it differs in ways that I wanted to allow space for in my analysis.

Table 2

Codebook for Interview One

Code	Description	Examples- All from Connie (pseudonym)
Academic achievement	Characterizes talk about student learning and understanding of science content, participating in authentic science experiences	And the project at the end is really just to see how one like if they comprehended the information, and two letting that their curiosity show itself in what they learned.
Sociopolitical consciousness	Characterizes talk about the application of the content to problems in authentic contexts; recognize, understand, and critique social inequities of students' community and social worlds	I brought it back to... if you disrupt one part of a life of a food cy- food chain or a food web, what happens? And they know everything else falls out of balance. So they can make more conscious decisions in their everyday life as- as humans, not just as students, to make a better world in general but also not just be completely clueless about how our actions and how what we do affect everything around us.
Cultural competence	Characterizes talk about students' maintaining cultural integrity	They picked a waterfall in Venezuela. That's where he's from. So cause he's- and he's been there, he knows it, he's seen it. So I'm not saying, "We go to Kennesaw Mountain." He doesn't know what that is. …my student from Venezuela was also with my student from Colombia, and at the top of the waterfall they had a Venezuelan and Colombian flag…
Sustaining community cultural practices	Characterizes talk about maintaining students' linguistic or cultural practices or sharing across difference	one of my teachers had us make a non-negotiable list before we graduated…[including] things that you will never negotiate when it comes to your teaching. So like one of mine is like, every student's home language deserves to be shown in the classroom.
Conception of self and others	Characterizes beliefs about pedagogy, students, or community	…[l]etting them go. Not really saying, "Okay, now I want you to look at this part. This does this. Remember that. Now let's look at this part." Just letting them see it, and seeing what questions arise, seeing what connections arise and things like that.
Social relations	Characterizes the teachers' relationships with students or classroom facilitation	I want you to write down what you need to know. And then if you have questions, please write them down…. I'll try my best to have like little side notes with them. So I don't want to just say like, "that's not important," because it is important. It's a question they have.
Conception of knowledge	Characterizes how the teacher thinks about knowledge and assessment	And just saying, "What- how would you? Even if you don't know. What do you think? Cause then you might not know now but in 10 years, you'll think back to this like, "I had this thought. Now I know this. This is what I would do." "Okay!" And just being able to go along with life like that and it just ugh... I love it.

Paris (2012) posited that the term *relevant* inadequately captured a goal of cultural pluralism and held *sustaining* better encompasses the "valuing and maintenance of out multiethnic and multilingual society (p. 93). Thus, I coded talk for cultural competence separately from culturally sustaining practices.

I provided a vignette at the second interview containing an example of a science unit exemplifying the dimensions of CRP in science to provide opportunities for participants to share stories and discuss topics they had not breached or talked about in depth in the first interview. Nathan et al. (2010) utilized fictitious vignettes in a similar fashion in their study comparing teachers' decisions advising fictional students in engineering. I drew from the literature on elementary students' development of critical consciousness in science, wrote the vignette, and shared it with a critical friend for feedback before I used it with participants (Basu & Barton, 2010; Carlone et al., 2021; Maulucci & Sullivan, 2015; Roth & Desautels, 2002 Schenkel & Barton, 2020). To elicit participants' stories, I followed a semi-structure protocol (Appendix E) around the vignette. The vignette is included in Appendix F.

I asked participants to share what parts of the vignette felt in tune with their teaching, misaligned to the way they teach, and what aspirations the vignette inspired, if any. I probed to learn about the participants' experiences and what changes would need to happen for them to be able to accomplish any aspirations. Next, I explain how I transcribed the interviews.

Transcribing

First, I uploaded the AI-generated transcript from the Otter application I used to record the audio of each interview I conducted. I listened to the interview in regular time, pausing to correct the errors to create a verbatim transcript and to write memos. This helped me ward off technical threats to quality, as Poland (2003) puts it. I listened repeatedly until I was certain what

was on the transcript accurately represented what was said, keeping lengthy turns of text in tact. If I was unsure, I bracketed the text and wrote *unintelligible*. I captured interactions that were not spoken, such as sarcasm, a motion of air quoting, and laughter, all of which convey meaning differently than the written word by writing the action in parenthesis. I also wrote memos to capture impressions I got of the participants at the interview. One, for example, about Connie read: “Her voice is animated, she was smiling and talking excitedly. She even says throughout the interview and when we said goodbye that she loves talking about science and has a passion for it” (researcher memo, January 24, 2023).

While transcribing, I used punctuation that did not always indicate the dominant syntax in the English language, but to better represent how the participant spoke. An example of this incorrect syntax is the use of the comma to indicate when talk extends beyond a typical number of clauses. Instead, when participants paused their talk for a breath and started a new thought with a conjunction, I used a period to represent the natural pause and a capitalized conjunction to represent the new thought. Many times, participants recalled accounts of dialogue from their teaching, or talking to someone else.

When participants relayed conversations they had, I used commas and quotation marks to represent the dialogue, as seen in Connie's excerpt below. When they were sharing thoughts, I italicized their thinking. In both instances, participants may have used the word "like" to signal either dialogue or thinking, so the differentiation was necessary in the transcripts. When participants restarted sentences, cutting their prior string of thought short to revise it or start over, I represented that with a hyphen. This, as well as fictionalized dialogue an example of starting a new thought with a conjunction, appears in bold in the following excerpt from Connie's first interview:

> That is amazing- That- That's where they're- That's where their brain went, which is already amazing as it is. **But** I'll chime in and say, "Well remember you can't do that because..." and I'll- I won't- I try not to like, tell them why. (Interview #1, January 24, 2023)

Following Poland's (2003) recommendation, I only revised transcripts for the audience after I completed my analysis. I chose the interview quotations and moved them into my document appearing the same way they were transcribed. Later, I revisited them and revised them for clarity without changing the meaning. Next, I sent each corrected text transcript to the corresponding participant to provide an opportunity for them to read over the conversation and share any clarification or changes with me. No one opted to make any changes.

Data Management

I stored interview audio and transcripts on an external hard drive and protected any participant-identifying information by using pseudonyms of the participants' choice for their names and omitting the names of college or professional development affiliations, school districts, and schools. I uploaded the transcripts to a password protected NVivo software program and used the tool's coding and researcher memo capabilities for my analysis.

Qualitative Data Analysis

My coding process was two-tiered, including inductive and deductive schemas. The first interview was designed to elicit teachers' experiences teaching science and to identify teachers whose teaching experience and beliefs included conceptions of culture, the potential for students to engage in science to improve conditions around them, and prioritized science achievement in their classrooms. Because I was interested in how teachers navigate institutional affordances and constraints to teach with those priorities in mind, I used the first interview as a strategy for iden-

tifying those teachers by coding for CRP using the code book shown in Table 2, above. I included long stretches of talk in the coded references to keep the participants' responses intact, and my responses were included in those references. Knowing participants' definitions and understanding of CRP would differ from the language used in the literature and from my own understandings; I used broad inclusion criteria when I assigned codes to the transcripts. By using broad inclusion criteria, I mean I did not seek exact words or phrases (i.e. culture, sociopolitical, excellence, achievement) when I coded from the code book.

I drew upon previous research to inform my coding schema, revisiting the transcripts, literature, and audio in a cyclical nature to draw the bounds of the seven codes. I created annotations to explain why I coded references the way I did, and I recorded changes in my research log. For example:

> Revisiting Magenta's interviews- Her transcripts were already coded and I noticed a lot of "social relations" that I needed to change from that to "conception of self and others" because social relations have to do with the children, and I coded her talk about parents in that way. Talking about parents fits with conception of others because beliefs about community are within that. (Research log, June 12, 2023)

After coding each transcript, I revisited all the transcripts to compare the codes and search for and resolve discrepancies. Then I paused my analysis for several days and returned to the codes again to verify I agreed with my final analysis. During this phase, I allowed for multiple codes to overlap.

Overlap occurred many times between the two parts of CRP: The four beliefs and the three dimensions of instruction. This happened when Connie discussed her opinion of science and its purpose in the classroom as well as her role in that. She also expressed her conception of

knowledge and critical consciousness in the same reference. I included two categories within critical consciousness: Teachers' own critical perspectives and facilitating students' development of critical consciousness. According to Darling-Hammond (1995), the former is a prerequisite for the latter.

Coding for Storied Talk

Isolating storied talk from the full transcripts demanded reflexivity. As I reviewed the transcripts in the second phase of coding, I revisited the definition of *story* to ensure I included cultural differences that appear in storytelling. I was aware that I may not use the same structures in my speech, but I needed to recognize the participants' ways of sharing to avoid discounting a turn of talk erroneously. For example, Polkinghorne (1995) defines a story as "narratives that combine a succession of incidents into a unified episode" (p. 3). The expression of stories can be accomplished in many ways, so to include that variety, I used the term *storied talk* to indicate that the turns of talk may have multiple stories within them, and they do not all follow a predetermined or dominant structure (i.e. beginning, middle, and end in sequential order). Polkinghorne's (1995) definition provides a starting point for identifying storied talk, but it was important to include portions of talk that came at different points in an interview or across both interviews when participants revisited the same moment. This did not always happen sequentially. Further, as the researcher, I was part of the participants' storytelling.

The nature of semi-structured interviewing and the techniques I used to clarify participants' responses, probe for more details, and address my research questions meant that our conversations were shaped relationally. Therefore, the stories I elicited from the participants were shaped by the exchanges throughout our interviews. The participants and I started our research relationships with shared interests in elementary teaching and science education at minimum.

Things we knew about one another before embarking on the research would influence a level of comfort or openness talking about topics embedded in power dynamics such as race, sexuality, gender, and class. For example, Connie, Jake and I were aware of one another through involvement in programming offered by the university (policy courses and the teacher residency program) that are designed to confront social justice issues in education. Knowing this could have made participants feel at ease discussing such topics and sharing candidly. At the same time, my identity as a straight, white female with greater years of experience in the classroom could have caused participants to be less likely to share openly. Next I will discuss the references of storied talk so that readers can gain understanding of the differentiation I made between the stories included in the transcripts and the narratives in the final research text.

Table 3

Number of Coding References of Storied Talk

Participant	Transcript One	Transcript Two	Total
Connie	14	19	33
Jake	33	24	57
Magenta	20	14	34

Using the term *storied talk* also adds clarity to my methodology by differentiating between the talk I elicited from the participants during the interviews (storied talk), and the written findings, which I call *narratives*. As shown in Table 3 above, broken down by participant and interview, I analyzed a total of 124 references of storied talk. The coded references contained multiple paragraphs as opposed to a line-by-line or otherwise deductive way of coding. I share numerical representations of the stories to illustrate the distinction between participants' stories as individual pieces of data and the longer narratives I produced for the final research text.

Reisman (1993) advises researchers listen for participants' cues to establish a narrative from a longer transcript. I recognized entry and exit talk from my participants, but also found them referring to earlier moments to provide more details or make connections later in the same interview or in the second interview, meaning their stories were not told succinctly during a single conversation in ordered fashion. Connie often began a story with a simple, "So," or an opening line introducing what her story will show before she told it. To conclude, she tended to repeat the beginning of her story, or rephrase the subject of the narrative. Jake often opened with "I remember" or "One time." He tended to end his narratives succinctly stating, "So that's that." I included examples of entry and exit talk in Table 4.

Table 4

Entry and Exit Talk

Participant	Entry Talk	Exit Talk
Connie	They were very engaged as far as just like…	They get very engaged.
Jake	One time we…	So that's that.
Magenta	So, perfect example: We're on the water cycle right now.	Yeah, so that was a perfect example.

These signal phrases allowed me to delineate between participants' experiences and their talk *about* the state of science instruction in their schools or districts. This was necessary when, for example, participants would share their opinions about local legislation, or state testing emphasis on reading and math. While those stretches of talk provided valuable contextual information and

insight about how the teachers respond in their contexts, and why they made certain decisions, I did not include those portions of the transcripts in the coding for storied talk.

Another type of talk I contended with throughout the transcripts characterized the teachers' pedagogical beliefs. In the initial coding for storied talk, I kept those paragraphs intact. However, on subsequent analyses when I was working to develop core narratives, I did not include them. Those portions of talk boosted the credibility of the core narratives I crafted because they indicated what pedagogical belief formed the basis of the resulting classroom experience rather than if I were to have assumed. They also informed the teachers' alignment to the beliefs associated with CRP.

At times, teachers shared stories from their classrooms that resonated with culturally relevant instruction but stated that it took place during social studies or English language arts time in their schedules. Because the teachers were clear that the type of learning activities did not include scientific or STEM-related understanding, but rather focused on the writing and communicating of their ideas related to social justice issues, I did not include those stories in my analysis because the teachers did not identify those activities as integral to science.

Analyzing Storied Talk

I grounded my analysis of the storied talk within a Three-Dimensional Space Narrative Structure (Ollerenshaw & Creswell, 2002; Clandinin & Connelly, 2000), which is founded in Dewey's (1958) view of interaction. The structure defines three commonplaces of experience: Temporality (past, present, and future); sociality (personal interaction); and situation (environment or place). I utilized the commonplaces to make meaning of the teachers' experiences by, in short, "attend[ing] simultaneously backward and forward, inward and outward, with attention to

place(s)" (Clandinin, 2013, p. 39). The inward includes feelings, hopes, reactions, and moral dispositions; the outward includes environmental conditions. Avraamidou's (2013) study provided a helpful model for my procedure. Table 5 includes examples of my analysis procedure, codes, and quotes for each commonplace.

Table 5

Three-Dimensional Space Analysis

Dimension	Analysis procedure	Sample codes
Interaction	Storied talk was analyzed for experiences participants shared about interacting with other people	Instructional activity General planning for instruction
Temporality	Storied talk was analyzed for past, present, and future experiences	Experience in elementary school Experience in college
Situation	Storied talk was analyzed for situations in physical spaces	Experience in the workplace

Temporality was salient to the study. As the findings show, had I not attended to past experiences, I would not have drawn the same conclusions about the participants' pedagogies. Looking back provided clarity about the present: Policy changes over time, previous experiences in participants' teacher development programs, prior work experiences impacting teachers' decisions, and the residual effects of policies and practices in response to the COVID-19 pandemic were brought to the fore through the commonplace of temporality. Looking forward captured participants' recommendations for easing the constraints they faced. Sociality aided my analysis of the stories by providing space to attend to the personal interactions the participants shared. Their stories included administrators, parents, colleagues, professors, professional development facilitators, family members, and students. Place, too, was a necessary lens for the study.

The teachers all work in the state of Georgia, in the metro area of the same large city. Jake and Magenta currently work in the same school district, but in two different charter networks. They both have experience teaching in different schools prior to their current assignments as well. Connie works in the same district as a participant who was discontinued from the study having demonstrated a lack of CRP. Understanding federal policies are implemented by states, and state policies are implemented by school districts, this lens offered a dimension of complexity that is necessary to consider in the study of teachers' experiences. Further, as demonstrated by Jake's two workplace accounts, where children live drastically impacts the education they receive because the Tenth Amendment of the US constitution dictates state and local control of education policy. The phases of coding and analysis I have discussed thus far form the basis of the narratives I present in chapter four. Next, I share how those were crafted.

Crafting Narrative Findings

After moving from transcripts filtered through the theory of CRP (Ladson-Billings, 1995), reducing data to storied talk, and applying the lens of the Three-Dimensional Space Narrative Structure to those stories (Clandinin & Connelly, 2000), I began drafting my findings in narrative form. The narratives are representations of the participants' experiences as they recalled from their memories and conveyed to me during our interviews, presented as my subjective interpretation through the lenses I have described and from my unique point of view as a longtime educator and novice researcher.

To identify components of the narratives in response to the first research question, I isolated the events the participants' described that took place in their classrooms (as opposed to another space in the school, their teacher preparation program spaces, professional development locations, or elsewhere). From those portions of the transcripts, I identified the stories that I coded

originally using the CRP codebook. Those stories with codes for student learning, cultural competence, and/or sociopolitical consciousness were the portions of text that I focused on as the core narratives that respond to the question of what it means to the participants to teach science in culturally relevant ways.

I created an outline of each participant's stories by naming them with short topical phrases derived from the participants' words (i.e. checks for understanding, personal research projects, scientists made ice cream). Next, I rearranged those short stories in a way that would flow for readers. I then returned to the portions of the transcript coded for participants' conception of knowledge, self, others, and social relations to provide richer descriptions of the events that took place by including participants' thoughts and beliefs around their pedagogies. When a participant shared a story from another place or time (i.e. teacher preparation course), I included it as an anecdote in the narrative findings when it was explicitly tied to the classroom activity by the participant. This increased the depth of the findings and added to the richness of the narratives.

The process of crafting narrative findings for the second research question around navigating policies and practices was similar. During this phase of analyses, I moved between the files of storied talk and the literature to identify policies in place at the time of the story that was shared, which often explained or informed the school level practice. Thus, whereas the findings for research question one were restricted to classroom stories, the narratives for research question two take place inside and outside of the classroom (i.e. at a professional development session, in a meeting with administration). After several iterations of my organizing framework, I found that the participants' stories could be understood best in two categories: Surmountable constraints

and insurmountable constraints. Thus, the findings are organized into two parts and by participant within each part.

Trustworthiness

Quantitative or otherwise positivist criteria (i.e. validity, reliability, generalizability) are ill fit for assessing the rigor of this study. Still, qualitative research ignites a multifaceted debate about what constitutes a high level of trustworthiness of findings. Guba & Lincoln (2005) recommend researchers ask themselves, "Are these findings sufficiently authentic…that I (and research participants) may trust myself in acting on their implications? More to the point, would I feel sufficiently secure about these findings to construct social policy or legislation based on them?" (p. 205). I embedded techniques for this level of security from the onset of my study: Member checking, reflexivity, and a transparent methodology. I provide details for each of these techniques in what follows.

Member Checking

The extent to which I can justify my interpretation of participants' experiences informs the level of trust readers can put in the findings. I engaged in member checking during and after interviews, and upon completion of the narrative findings presented in chapter four. During the interviews, I engaged in member checking with each participant by asking if I was understanding correctly, pausing to share how I was interpreting what they were saying, and asking clarifying questions (see Appendix G). The following exchange with Jake took place toward the end of our second interview. In it, I confirm if my interpretation of a concern he was expressing about teaching white children about social justice issues was correct:

> Researcher: [Are you] questioning sort of, how do kids of different races engage with issues that are focused on race?

Jake: Mhmm. [nodding]

Researcher: If I could sum it up like that?

Jake: Yeah. Yeah. And really, white children-

Researcher: in particular.

Jake: in particular, mhmm. [nodding]

Researcher: Okay.

After I corrected the AI-generated transcripts, I sent them to the participants and invited them to elaborate, share more, clarify, or suggest changes. No participants opted to make any changes or additions to the transcripts. Finally, I sent the narrative findings to each participant as I completed them. One was met with great excitement at how I captured her "perfectly," (Connie, email exchange, July 16, 2023). Magenta and Jake offered no comment.

Reflexivity

"To be reflexive…not only contributes to producing knowledge that aids in understanding and gaining insight into the workings of our social world but also provides insight on how this knowledge is produced" (Pillow, 2003, p. 178). For this study, reflexivity conveys trustworthiness by showcasing my engagement in self-reflective practices. I acknowledge my role in the construction of the research problem, setting, and my findings. My awareness of my involvement throughout the research means that I understand that multiple interpretations of the data are possible. A tool I used for reflection throughout the research was a researcher journal. Set apart from my research memos and researcher log, I wrote reflectively about my involvement. Here is an example:

I think because of our connection in [a teacher residency] and her knowledge and background in science, there's a whole assumption that [the second interview vignette] is the

> best way to teach science, even though I never said anything about the quality of this provided unit. She automatically assumed that in my mind, this is what she's supposed to do. Or at least she believes in everything in that story that's as science should be taught. (Researcher journal, May 18, 2023)

That excerpt demonstrates a time in the research process when I documented a moment when I believed my involvement in a teacher residency the participant was involved with influenced our conversations. The next step to addressing this influence was to bring it to a critical friend to facilitate my reflection from a critical standpoint.

A critical friend is a partner in thought. Defined on a continuum of seven dimensions (i.e. relationship status, expertise, productivity), Stolle et al., (2018) identified vulnerability, reflection, and skepticism as three characteristics central to the effectiveness of critical friends. My critical friend was a former elementary teacher now working in diversity, inclusion, and equity (DEI) in the school district where two of the participants worked. At the time of our meetings, we were in similar phases of the dissertation process, and we were both utilizing critical friends throughout our research. We use similar theoretical frameworks and share familiarity with elementary education research. We differ from one another in racial and ethnic identity, our regional upbringing, and our work experiences prior to teaching, to name a few. This critical friend provided constructive, critical dialogue around my interpretations, questions, and concerns throughout the research. She acted as a sounding board, often listening or reading my interpretations and speaking or writing back to me about how she received them.

Ultimately, in the example provided here, I determined the relationship was not hindering the research but allowing me greater access to Magenta’s stories. Because we had a certain level of rapport prior to our interviews and our connection was through professional development

geared toward disrupting White supremacy in schools, she was able to speak freely knowing we shared a common recognition of how schools, by way of systemic racism, harm Black and Brown communities. At the conclusion of our final interview, she expressed a desire for more people to "come see" (Interview #2, March 23, 2023). She explained that policymakers, in particular, may be hesitant to do so because they could be faced with the reality of their policies in action and the need for change. Reflecting, bringing the issue to my critical friend, and reviewing Magenta's transcripts allowed me to make the determination that her stories provided insight to my research questions, and my interpretation was, as Wolcott (2009) puts it, "plausible, informative, or thought provoking, [thus] the research is regarded as worthwhile" (p. 47). Another tool for being reflexive throughout the study was my subjectivity statement, which I share next.

Subjectivity Statement

I was the "sciencey" one on the team everywhere I taught. That is part of my teaching identity, despite my position as an elementary teacher; therefore, generalist for 13 years. It is what Bradbury & Wilson (2020) have recognized as a "science teacher enthusiast," an identity that challenges dominant discourse that elementary teachers do not teach science because they lack the content knowledge and skills to teach it. Colleagues have recognized me this way across schools, grades, and teaching assignments from ESOL teacher to homeroom teacher to gifted specialist. I witnessed patterns upholding science education as property at the individual level ("science is messy"), the school level ("we teach it when those kids are pulled"), the district level, ("we adhere to a scripted curriculum") the state level ("we have a high college and career ready performance index") and federal level ("you are accountable for reading and math"). The pervasiveness of these systems of excuses working together to marginalize students from science drives my commitment to share stories of teachers who combat these narratives, not from the

lens of the science enthusiast, but of the social justice science teacher. Growing up in a rural borough, I know what it is like to believe you have limited options as a student, but teachers are in the position to ensure their students can picture themselves in science careers as much as they can in other disciplines.

My science teacher identity was not formed in me until my final year in my undergraduate teacher preparation program; it was the first time I learned science from a woman because despite the dominance of women in the teaching force, all of my math and science teachers growing up were men. A white female professor taught my science methods course, shifting my whole approach to general education to inquiry-based and science-focused. When I teach science methods, parts of her instruction flood back to me as I provide experiences for preservice teachers to engage in science, inquiry, and engineering during every session; and to reflect on the role of science in and out of school, as far back as they can remember.

Still, I have a critical appreciation of my teacher training program, which also influenced my lens for this study. A Professional Development School (PDS) model in the Northeast, it won plenty of awards and poised me to teach all five subjects confidently my first year of teaching and beyond. What it also did, however, was reproduce stereotypes and reinforce deficit-thinking about students from marginalized communities, all under the guise of preparing us rural White women to teach in "urban" schools—just in case! The message was loud and clear: *These* kids will need something different. The stories I was told served as warnings. They did not provide opportunities to recognize, analyze, understand, and resist oppressive structures in schools. I would have benefitted from hearing from teachers working in under-resourced schools with diverse student populations who were successful with CRP, not just tolerance of "all students."

I found after moving to the South and teaching in Title I and affluent schools alike, in urban and suburban contexts with diverse student bodies, that my teacher education program failed to help me understand the racist structures in place that allowed schools to treat children in ways that forced them to cope with their schooling as opposed to thrive from it. What compounds the effects of my lack of preparedness to teach for social justice is that I was constantly being handed leadership roles, being asked to deliver professional learning to my colleagues, even in my first-year teaching in a new state in a different region of the country. I am someone who grew up in a rural township with a population that remains 98.6% white as of the most recent available data. I was not someone who should have been providing professional learning in a school with majority Black and Latino/a student bodies. My students, their families, and colleagues, especially those I met and wrote alongside at the National Writing Project's Red Clay Summer Institute, helped me understand how racism was impacting our students, and I made the decision to flat out disregard policies in order to better provide students what I believed they deserved. I was not the perfect image of a social justice science teacher or the perfect culturally relevant generalist; I will always be developing no matter my role as an educator.

While my white racial identity allows me to relate to teachers of color differently than how I may gain access to white teachers' experiences, the relationships that were formed with the participants and our shared goals of culturally relevant science education served as a bridge. For too long, my identity as a social justice teacher was rooted in beliefs of equality, but no concrete actions were taken to address systemic inequity. I approach this work in resistance to the policies and practices that are used to keep science white, male, and elite.

Ethics

I took deliberate steps to minimize any potential harm to those involved in the study, respecting that participants put themselves in a vulnerable position by inviting me into their thinking, planning, teaching, and experiences. In narrative research, Clandinin (2013) explains, minimizing harm involves remaining "as wakeful as we can be to who we are in the inquiry space and to how our presence shapes spaces between us and participants" (p. 199). Further, it means listening to participants' stories nonjudgmentally, with care and attention to relational responsibilities negotiated by us throughout the inquiry. The study was designed to prioritize the participants' voices, experiences, and put their needs and desires before my own as a researcher. I emailed the informed consent form (Appendix H) to participants upon inviting them to join the study.

At each interview, I began with reconsenting orally and by obtaining participants' signatures on the consent form, reminding participants that they could withdraw at any time. Participants chose pseudonyms at the beginning of the study to ensure their confidentiality. I did not include any identifying information such as their name, address, phone number, e-mail address, name of school, school district, etc. in the transcripts. I did not finalize any research text without inviting the approval of the participants.

4 FINDINGS

Connie, Jake, and Magenta are three educators who stand up and make space for every part of every student they teach. They encourage, inspire, challenge and nurture children so each one knows without a doubt they can be, do and become anything. These three educators need no convincing that every student they meet can have a future as a chemist or a biologist, and they know there is no need to wait for high school to get started. What they do reflects what far more students deserve than is found in schools today. What they do is courageous as the education system is under constant surveillance and ridicule. What holds them back is not a mystery to these educators, and they are not complacent. Connie, Jake and Magenta recognize exactly when and how their students will be negatively impacted by legislation, district mandates, and school practices. Rather than succumb to the pressures of high stakes testing and throw their hands up in the face of a schedule that devalues science altogether, they resist.

In this chapter, I present findings in narrative form for each research question, organized by participant. The first research question, asking what it means for elementary teachers to teach science in culturally relevant ways, is answered through narrative retellings of Magenta, Connie, and Jake's classroom stories. The second research question, addressing how participants navigate policies and practices to teach science in their schools, is organized first into two parts and then by participant within each part. The first part exemplifies the participants' successes, and the second part depicts instances when teachers did not succeed in implementing some aspect of their pedagogies due to policy and practice constraints.

Research Question 1. What does it mean for elementary teachers to teach science in culturally relevant ways?

Imagine a noisy space, beats in the background, maybe indoors, maybe out. It is difficult to tell who the teacher is. The kids are the ones doing the teaching, standing in front of digital presentations they created, or arguing about theories. It is messy. There are liquids in various stages, posters, art supplies, exploding Cokes, large gatherings, and hollers of joy. That brief scene could well have taken place in Connie, Jake, or Magenta's classrooms. They share a view of science teaching that rejects an outdated approach where teachers hold all the knowledge or there is one set way to do an experiment. Even tests, in their classrooms, are not the sole or best determinant of assessing students' learning. Still, each teacher possesses unique strengths and experiences that come through in their stories. To further exemplify what it means for each teacher to teach science in culturally relevant ways, I present the following narratives of three teachers' instructional activities and the thinking they shared around them. I conclude with a summary of findings before moving onto the second research question.

Magenta

Magenta's passion for teaching is palpable as stories of kids doing authentic science roll off her tongue. When it came time to teach weather, she did not announce a page to turn to in a textbook. She took the class outside to observe the sky, feel the temperature, and collect measurements. Students made predictions, formed tentative claims, and engaged in scientific discourse with an increasing complexity of vocabulary and depth of questioning over time. When they were at home during the school closures for the COVID-19 pandemic, Magenta's scientists made ice cream in their kitchen laboratories using ingredients she sent to them in test tubes. She shared that when some attempts turned out more like Frosties than ice cream, they collaboratively made sense of their data to revise their procedures:

> And for those whose experiments failed, they were able to talk about messing up the procedure and how it skewed their data, like and they're using words like "skewing my data," and "I didn't get the results that I wanted," or "my hypothesis was incorrect because I thought this, but what really happened was this." They were able to actually own that without me having to do so much prompting. (Interview #1, January 18, 2023)

In Magenta's fourth-grade classroom, students *are* scientists. She tells them so every day, a practice that shows she recognizes their capability and potential in science. Magenta stated:

> I want them to see themselves as scientists and less of rappers, entertainers, Instagram models, whatever the media is putting in front of them. So getting away from that and seeing yourself as a scientist, at least in this classroom. (Interview #1, January 18, 2023).

She wants to be sure her students know they have options beyond what they consume on social media when they see people who look like them. Magenta uses technology to introduce her students to living, working scientists who break stereotypical images of who can be a scientist. She told her students when she introduced them to Dr. Kizzemekia Corbett, assistant professor of immunology and infectious diseases at Harvard who led scientists in the development of the COVID-19 vaccine:

> I'm like, look how young she is. She looks like she can be somebody Auntie. Like, she looks like somebody. Like, look at how she's wearing her hair. Look at the way she's wearing makeup. She's wearing nails, like she's not old. Like, you're not learning about anybody old. Some of y'all have been to Massachusetts before where she studied. (Interview #2, March 13, 2023)

When discussing STEM contributions, Magenta encourages students to define the relevance of the person in terms of how their work impacted the world. She recently introduced Garrett Morgan, inventor of a traffic light designed to warn drivers to stop with the addition of the yellow light. In class, she reminded her students:

> I'm like, "So being born, dying, and being married are not contributions to the world of science. So find something. Like dig deeper." And the things they pulled up about him were so, like a list of things, things that I had never even heard of that he did before. (Interview #2, March 12, 2023)

Magenta's students demonstrate their propensity toward science as they bring ideas to the classroom that arise outside of the school day as well.

One early morning, a student burst into the classroom excited to prove to his teacher that he figured out what she was teaching. She said about him:

> Teachers would write him off as being very aggressive and angry and easily triggered. Like he would fight anybody. But I remember that when I was teaching water cycle, he was paying attention, and he took interest in it because he liked to go outside. (Interview #1, January 18, 2023)

This student had been grappling with the idea that it can be raining at his home, but dry somewhere else. While eating her breakfast, Magenta listened while he shared his story about the research he continued at home. She affirmed his explanation of the material, and because Magenta maintains high standards for her students' scientific discourse, and she knows they will also be tested using scientific vocabulary, she then insisted he use it:

> I'm like, "Okay, well how does it work?" And he was so excited. So I'm giving him time to like, get it out while I take the next bite. And he's like, "Well, first you got the water

> and stuff and then when the sun come out and then it's heating up the water and then it start evaporating and stuff and then they get up there in the clouds and then the clouds be going like this," and I mean he wasn't using the vocabulary by far, but he was explaining the water cycle and I'm sitting there chewing [and nodding] like, "Mhmm, mhmm," and he- Like when he was done, he was like, "See, so I told you I know how that stuff work!" And I'm like, "But let's not call it that stuff. Let's call it the water cycle." And he was like "Yeah see, come on! Let's go outside. I'm gonna show you." (Interview #1, January 18, 2023)

She describes her teaching style like being on TMZ: Her classroom is relaxed, she is animated, and you may find her standing on a chair. Students do the most talking, as this story demonstrates.

Magenta prioritizes creating a safe space for students to talk about difficult topics and gives them time and space to figure out what they believe when they are uncertain in the process of learning something new. Rather than correct their misconceptions immediately, Magenta facilitates a scientific community of learners. She finds her students' conversations deep and beautiful. Magenta's students critiqued science models, for example. They noticed how texts tend to depict the solar system as though the planets are closely aligned, despite the reality of vast space between them; and how orbital paths are misrepresented. She explained:

> They're forming their own thoughts. It's not me saying, "We're teaching this and the government wants you to know this." That wasn't me. I would just simply say, "Hey, here's a problem." Or, "Have you ever thought about this?" And then go into the lesson. (Interview #1, January 18, 2023)

To encourage them to follow their own curiosities, Magenta created an ongoing assignment requiring students to share research projects based on current events in STEM.

One debate the students gravitated toward was flat Earth versus round Earth; ideas brought into the classroom by her students who had read from reputable resources like *National Geographic Kids*, *Doggo News*, and *NASA Kids* and became concerned about global warming. Magenta's goal was for students to understand the sources of evidence and claims each "side" makes and how they shape their arguments so that the students could draw their own conclusions. In other words: Do what scientists do. An abbreviated version of her telling is as follows:

> I remember we were talking about the greenhouse effect, and somebody mentioned global warming. And we were talking about scientific debates and how scientists…do a lot of research, but sometimes somebody's research can be undone if a fact is proven years later or whatever. And so they got into theories and global warming and how some scientists believe global warming is fake. And others believe that global warming is real. But then they got into the round Earth versus flat Earth theory, and do we live in the dome?... So [the point of the lesson was] it all depends on what that scientist believes. Are they a dome theory scientist or are they a flat Earth or you know, the-gases-can-escape type scientist? So it all depends on what you believe. And the students understood that as: We're talking about theory….And from there, from me posing that question, the kids are talking about all of the- anything that crosses their mind, and they- I created a safe space for them to ask questions and talk about it, and I never confirmed or denied what the truth is [in that moment]. (Interview #1, January 18, 2023)

This story exemplifies Magenta's willingness to follow her students' lead in the classroom and how she probed students to consider the tentative nature of science without dispelling misconceptions until students had time to consider various arguments.

Connie

Connie's eyes lit up, and a smile spread across her face the moment she began sharing the ways she teaches science in her 4th grade classroom. She told me time after time how much she loves science and thinking about teaching it. To her, it is an avenue for shaping a better world. Connie formed three non-negotiables for her teaching during her teacher preparation program: 1. Every student's home language deserves to be shown in the classroom. 2. Every kid has good ideas. 3. Everyone is a nerd! To Connie, that means finding what makes a child tick, that *something* they are curious about that can be leveraged in science. She said:

> They want to know, and the more that they know, the better the people they can be and the less just like, confused in general that they are. And we have so many problems on this planet that I feel like if people knew more, and if they understood more on a micro and macro level, that we would be better just as a species to handle them and to understand them, and other- understand other people. (Interview #2, March 20, 2023)

Honoring her commitments, she encourages her bilingual students to speak, read and write in Spanish.

Not knowing the language yet herself, Connie uses a bilingual dictionary app on her phone to bridge her understanding of what her students share in Spanish. She adapts her instruction, adjusting the pace and inserting time for multiple representations of the topic to support her bilingual students. Connie makes time to listen her students with genuine interest even on the most tightly scheduled days:

> [D]uring instruction if they have a connection to their life so many times they'll say, "I have a story about that." [I respond,] “alright, you have one minute. Tell me because we gotta keep going, but I do want to hear what you’re saying,” (Interview #2, March 20, 2023).

Connie has seen how students respond when they are not heard, and she knows the consequences firsthand. She shared:

> [W]hen they're always shut down and [told] like, "Well, we can't talk about that," like, "We don't have time. That doesn't have anything to do with what we're talking about.” Or "No, you don't know how to do this yet.”
>
> [Then] you're like, "Okay, well, I'm not going to ask anything then. I'm not gonna care anymore. I'm just gonna do what I'm supposed to do." And some students are really good at that. I was really good at it. Teacher said something, I wrote it down. I regurgitated it again for the project. And I did that every year until I got to college. It was a little different. But it was still- it was still like kind of the same, like the banking method kind of thing, and just like, put it in and take it out. *Can you take it out? Oh, you can't take it out? That means you're not good at this. That's what that means.* (Interview #2, March 20, 2023)

It is important for Connie to know her students deeply because it is from their stories that Connie derives her curriculum, explaining:

> And, like I said, just reiterating how important it is to understand your students’ lives and using that as a base point for their curiosity, and their connections definitely makes a dif-

> ference [as far as] their comprehension and their motivation to want to know more because if it's not- If they're not connected to it, some of them will just like, "I'm not gonna do this." (Interview #1, January 24, 2023)

While attending a competitive cup stacking meet to watch one of her students, Connie immediately noticed the intense focus the sport demands.

Back at school, she encouraged her student to draw on the focus he demonstrated doing something he cared greatly about when he had a difficult task in the classroom, acknowledging her student's strength and reminding him that he is capable. Connie also saw relevant connections to science in the experience points (XP points) that students earn while playing their video games. XP points are not gained by winning games or beating levels, but simply playing, thus gaining experience. She used this to help convey the ways scientists build on previous discoveries in a similar fashion, revising previously held knowledge claims as new knowledge is uncovered. She conveyed this bridge between experiments and video games:

> So teaching them, like when you're doing [experiments], it's your time to take time. Like it's gonna take a while. You're not gonna get results right then. You may even get- come up with nothing. So I tell them like, there's a Player One and a Player Two. Player one- every single time they try to beat like a level…[and] it was hard the first time and then they were like, "No I'm not gonna do it again and I'm just gonna stop." And then player two is like, "Well, this is hard but I'm gonna keep doing it, and keep doing it, and keep doing it." And player two gets more experience points, and they know what those are. (Interview #2, March 20, 2023)

The comparison between experimenting and gaining XP points in video games helped students understand that scientific discoveries are not necessarily linear. In addition to video games, Connie embraces her students' social media use with apps like TikTok and YouTube, even though she is not a big consumer of content through these in her personal life.

Connie finds that five minutes is more than enough time for her to ask her students to select a science topic so she can share a short clip with them that probes their curiosity or challenges their perspectives. From there, she puts her students into position as scientists, and herself as a guide. Connie poses real and imagined problems to her students as springboards for scientific discourse. She posed situations from the video game Minecraft where they have a task and a set list of materials; she asked students why there was frost on her car; and because her class loves extremes, she posed a dystopian scenario that required knowledge of barometric pressure for students to solve. Connie encourages students' questioning and problem-posing, and includes their concerns in her teaching:

> Most of my questions start coming from after recess. I'll focus on something that they asked me recently. So if we do the pollen thing. So if my kids come in from recess, and they're saying especially my throat hurts, it feels like it's itchy, my- I have a headache now, I'm sneezing all the time. So like asking, "Well, why do you why do you think your body's reacting like that after…being outside?" And give them a little time to think about it. If they need some prompting like, "What's changed from outside that wasn't there before? What things do you know?" …and then start from there. (Interview #2, March 20, 2023)

Connie also utilized technology with a simulator in which students could manipulate distance, gravitational force, and even the size of Earth, the sun, and the moon. From there, she gathered

students' questions and they worked together to categorize them and associate them with scientific vocabulary. When we spoke, she was planning where to go next with it, acknowledging, "You can't plan too far ahead" (Interview #2, March 20, 2023). This is because she elicits her students' responses to their learning before she plans her next steps.

One poster project Connie planned for her students was to choose a way to represent and demonstrate the water cycle as it occurs in nature. Her story exemplifies the way her students draw on their experiences outside of school to express their understanding:

> So I had two of my students very, very excited about it because they were gonna- they picked a waterfall in Venezuela. That's where he's from. So cause he's- and he's been there, he knows it, he's seen it. So I'm not saying, "We go to Kennesaw Mountain." He doesn't know what that is. (Interview #1, January 24, 2023)

Connie's students from Venezuela and Columbia were partners. Not only did they learn about their similarities being from neighboring South American countries, deciding to depict a waterfall in Venezuela on their poster, but they created space for their differences, celebrating by including both countries' flags in their artwork. Connie learned valuable information about her students as they orally presented their work. Seeing her students' projects on display, her colleagues asked if she would share the plans so they could also implement her project, and she did.

Jake

Jake was hesitant to join my study at first because he felt he did not teach science enough in his classroom. Reassuring him that I was also interested in hearing about the constraints he faced, he ended up deciding to share his experiences quite generously and with plenty of laughs over coffee. Jake views science education in the elementary classroom *as* a social justice issue because he understands the marginalization of people of color and women from STEM to be a

direct result, in part, of students' access to science experiences in their formative years. Jake described:

I could just see when I was teaching fifth grade, how these concepts connect to the year-long study that they do in middle school and then the year-long study that they do in high school. It just makes me more nervous. Like, if I don't teach this stuff accurately, and make them feel comfortable now, in day one of their seventh grade biology year then are they going to be uncomfortable and think that they're not good at science and then it's just gonna be like not pursuing higher course level sciences, like honors AP in high school, and then shy away from science-based degrees in higher ed.? (Interview #1, February 12, 2023)

This is something Jake recalls being taught explicitly in his teacher preparation program and is coming into realization about more and more by comparing his former and current school contexts. At one point in his past, he found himself not teaching science at all because of time constraints, despite being departmentalized and in charge of mathematics and science instruction in third grade. Jake shared the following memory that caused him to change that:

> …[T]he kids will go to these pep rallies and one time, a colleague was like, "You know, like when your teachers are teaching science…" and I was- and the kids looked at me, and I looked at them, and they looked at me, and it's just like, they were like, "Science?" We said you know, "Pollution!" which is a third grade standard. (laughs) So it was bad, but I bring all this up to say like, one of the things I think about was Dr. [professor from university], she was like, "Teaching science is a social justice issue." And I heard that and didn't really- and thought more about it as I became that teacher who just wasn't really teaching science, or who had to go with the flow. (Interview #1, February 12, 2023)

This story is important because it sheds light on an experience Jake had in his past that led him to secure access to science in a school where he perceived going with the flow meant putting it aside. Securing access is now a prerequisite for his teaching.

Jake maintains a standard of providing evidence when students communicate scientific thinking by probing them to consider empirical evidence, explaining:

> I like to ask a lot of why questions, and how do you know? And really keep asking them until kids provide an answer that answers it. They'll be like, "Why? Well, because I know." It's just like, how do you know? "Because I know," and then I'll keep going. So I do that. But then I think- I listen out for conjectures and we do a lot of like revision of like where we are. We are a constructivist school, and so they might start like observing a phenomenon and have immediate gut reactions about why they believe what they believe. However, when we do experiments, we then go back and re-assess. (Interview #2, March 11, 2023)

In the same vein, Jake's science methods professor taught him an "Activity Before Content" or ABC strategy that he is committed to, where students observe a phenomenon prior to teaching the scientific vocabulary so that they connect instructional material to what they have already seen. He uses technology to facilitate phenomena observations in his classroom when firsthand observation is not possible, but his preference is for students to gain hands-on experience. When students show interest in a particular topic, Jake supports their curiosity by providing time, space, and classroom materials. After building electrical circuits, for example, a handful of students asked if they could continue testing materials for conduction during recess. Another student worked alone:

> So they were working on that experiment and testing out which conductors…are good and then which are not. So they have like wood, cork, foil, all of that stuff. And one of my students asked, they were like, "Well, what else in here can we use as a conductor?" I said, kind of like this teacher [from the interview protocol], "Well, what do you think? How might you find that?" And so she ended up staying back in during recess and doing her own independent study. (Interview #2, March 11, 2023)

Jake gave her time to present her findings to the class later. He recorded videos of the students conducting their tests and talking about their findings and conjectures.

Students also use FlipGrid and Google Slides to create videos and presentations themselves. In one example that allowed students to connect science content to their own lives, students created presentations using similes for cells. They compared them to school, a favorite TV show, *Harry Potter*, and made other literary connections.

Summary of Findings for Research Question One

For Magenta and Connie, teaching science in culturally relevant ways means expressing scientific understanding in a way that makes sense to the child *and* using scientific vocabulary in the dominant version of English. For Jake, citing empirical evidence, revising previously held beliefs, and presenting findings are the norm. The narratives highlight the importance the teachers place on students' culture and identities: It is in Magenta's introductions to scientists who look and sound like her students, Connie's strategic use of students' home languages and out-of-school activities to explain science concepts, and Magenta and Jake's insistence that students of color especially understand STEM *is* an option for their futures. The teachers demonstrate their own critical consciousness, viewing science education as a means to a better future and a right

that they must secure in schools serving marginalized communities. Students in Connie and Magenta's classrooms were examining problems around them to varying degrees, some posed by the teachers and other brought up by the students. Jake shared less about facilitating students' critical consciousness, a finding that is expressed deeper in the findings for the second research question.

Research Question 2. How do teachers navigate school practices and policies to teach science in their elementary classrooms?

Few outside of education understand what it means to teach today. Many *in* education but outside of classrooms, too, could learn a great deal from what Connie, Jake, and Magenta share about what it takes to deliver the kind of instruction described above. They are not only skilled at facilitating learning, but in maneuvering their environments in ways that secure opportunities for their students. In the face of restricting education laws, one-size-fits-all district mandates, and interpersonal dynamics; these educators make an immeasurable number of decisions every moment of the day with their students at the center. The stories the teachers shared were ripe with successful attempts to adhere to policies *while* providing their classes with culturally relevant science (the what and why of their pedagogies). What may be less obvious from those retellings are the calculated ways participants managed to do so (the how). To share their moves, I present the teachers' narratives organized in two parts. In part one, I present moments when they stayed true to their pedagogies in the face of a contradiction that stemmed from a practice or policy. In part two, I shift to moments when the teachers were not able to teach in ways that were consistent with their pedagogies.

Part 1. Surmountable Constraints

Connie.

One of the constraints Connie contends with is being observed by leadership staff. Common in schools, the intent is assumably to support teachers in achieving the aims of the school's instructional program. At Connie's school, their current focus is implementing the IB PYP program, which is an inquiry-based framework that leaves room for students to determine the direction of their learning. However, on days when district personnel or IB staff come to observe her for programmatic aspects, Connie performs specific teaching strategies (i.e. referring to mass-produced posters on the wall, using specific terms). On these days, she explains to her students why things are different in her classroom. She is dressed differently, she is teaching differently and moving more quickly through content. She explains this to students knowing the differences in her teaching and pace will not work as well for them, and she wants them to understand why it is happening. When those other staff leave, she can circle back and repair the lesson using strategies that are more effective for her students. "Once they leave, I'll explain it again. I'll go over it a little more," she said (Interview #1, January 24, 2023).

At times, Connie's class is behind in comparison to the school-provided pacing guide, though the expectation is to maintain consistency in pacing among grade levels. She explained:

For the extra accommodations and the changes that I make, I don't usually involve the- my team or my AP because... it's something that we're not *not* supposed to do, but we're supposed to be doing something else or um we're supposed to be on another lesson by now. But they didn't understand, "Well, I had a train of questions that day that I couldn't just say no to. So yes, I'm a little bit behind." …They have a different perspective of how the classroom is going than my kids and I do. And balancing that has been a challenge. (Interview #1, January 24, 2023)

Connie explained to me that she is willing to take the heat from her administration if they take issue with her changes because she knows her kids best. She has also had to reject curriculum provided by her school to prioritize her students' interests and reflect their experiences. She relies on her students' natural curiosities aligning with the curriculum pacing guide she is bound to, hoping that they ask a question on the right topic at the right time so she can strategically incorporate it.

> And if the lucky times, and this happens, I think um probably like 30% of the time, where their- maybe 35- where their questions do align with our curriculum. And I'll say like, "We're gonna talk about that tomorrow." Right? "I'm like, we're gonna talk about that tomorrow. I'm so happy that you asked." (Interview #2, March 20, 2023)

Connie's relief mixed with excitement was audible. She strongly believes in students' innate curiosity and that the purpose of their education is to foster it toward making a difference in their lives and futures. Another aspect of prioritizing students' lives in her instruction involves making changes to district curriculum.

The practice of the school district is to provide teachers with ready-to-use assessment and instructional materials. When the school district provided a task designed to assess mastery of fourth-grade science content standards on the water cycle, Connie asked her class outright if they were interested in the project, and she was met with a resounding no. Instead, she pivoted to a group project that allowed students to express their understanding, described in the first research question finding above. Meeting the same assessment criteria by requiring students to explain a naturally occurring instance of the water cycle using scientific vocabulary, she loosened the restrictions on *how* students expressed that requirement. This reflects Connie's commitment to ensuring students apply science content standards to their lives.

At times, she substitutes a real-world example for a believable but fictional scenario. By coming up with a scenario, Connie is navigating the constraint that the provided curriculum, at times, lacks authentic application. She explained:

> One unit that I had trouble with doing some was simple machines just because, like, I think that was… very much like, *this is what this is*. *This is what it does*. *This is this*. But I would give them scenarios, like, "I'm a human in 6000 BC…it's really hard for me to carry these rocks up this hill to make my home. What thing can I make to make that work easier?" (Interview #1, January 24, 2023)

With the practice of providing curriculum comes the practice of dictating teachers' daily schedules down to the minute. Connie's school provides less time than she would like for science. To get around this, she incorporates student-driven research projects that students can return to whenever they find a spare moment. Connie shared:

> I have like personal little research projects that they can do in my room. …They just ask me what they want to do. I have books, they can go online, just like, you figure it out. You like, guide yourself. See what you have. Obviously they're not just like… I can present this and it'll get an A. And it doesn't need to. Like, I just want y'all to discover things and think about things. They love that. (Interview #1, January 24, 2023)

Another common practice with good intensions, assumably to alleviate the workload of planning for five subject areas as generalists, Connie's grade level team assigns a teacher to provide lesson plans for each subject based on the district curriculum guide and materials. Connie is not assigned to provide science plans for her team. She provides the reading plans. The sharing of lesson plans leads Connie to make adaptations for her students:

> The teacher who planned it, who, she has a lot less language learners in her class, a lot more gifted students, so she can go in depth a little more and a little quicker. And my kids they want to go in depth, but it just takes them a lot longer. So…I've been making like guided notes for if we don't finish a slide…."So you gotta go home, answer this." Like, "Fill in the blank for this. What do you think about this?" And still trying to include the inquiry into, "What do you think is going to happen if you do this, this, and that?" And that also comes with some um like, discrepancies of if they'll do their homework when they go home or what kind of environment they're going to when they go home. Do they have Wi Fi when they're going home? Um. And me trying to make those accommodations as quickly as possible and as much as possible while still trying to influence- not influence but encourage that inquiry and just matching them where they are because my kids lookin' at TikTok 24/7. So I'm going to try and find a science TikTok video that explains this and this. (Interview #2, March 20, 2023)

Notably, Connie does not lower the expectations for her students. She adjusts to provide opportunities for the students to think as deeply as the class with students who are enrolled in the gifted and talented program at her school.

Jake

Jake compared his old school to his current school when he shared his experiences. In his previous school, as illustrated in his narrative above, there were times when Jake followed the norms of the school and neglected to teach science. Jake perceives this practice, namely the overemphasis of reading and math, to stem from the accountability era policies in place. The school was a designated a turnaround school, one of 59 elementary schools in the state in the spring of

2019. According to Georgia HB 338, to make the turnaround list, the school had a three-year average of 57.0 or below on the College and Career Ready Performance Index (CCRPI) (Government's Office of Student Achievement, 2019). He shared:

> Like, we had kids who needed [Early Intervention Program (EIP) services], but because of the schedule, they were getting pulled for reading EIP during the science block. So the year where I was actually able to really start getting better at teaching it and had like a little bit more time or just made the time, half of my class was in the back doing reading stuff and they were like, "Well, they can read science articles," and I was just like, it's not the same. But you know, I guess it is what it is, and their argument was, their reading is more important. Like reading instruction takes priority over the science. (Interview #1, February 12, 2023)

Once he recommitted to his students' right to science, Jake secured opportunities for them to engage in it. Drawing from his teacher preparation program, he started then and continues to use strategies like "speedy science" to sneak science into the day, meaning he incorporates brief demonstrations or quick experiments.

> One thing for sure is I accepted that time constraint, and really went back to what was, what I learned in Dr. [undergraduate university professor's] class about speedy science lessons. So I was just like, just plan for 20 minutes. And see if you can integrate some of this stuff, that way you can steal time from other subjects. So, accepting the schedule one, integrating two. So like, I just realized if you put a book with anything you can get away with calling it reading. (laughs) So, it'd be like, a three-minute read aloud…now I can take about 20 minutes from reading and then 20 from reading plus the 20 from science is now 40. (Interview #1, February 12, 2023)

In his current school, Jake's teaching team also works together to secure access to science by providing grade-level experiences. As a practice, teaching as a grade level team activity came up quite frequently when I talked with Jake.

In one instance, the fifth graders gathered outside to observe a demonstration of the physical change that occurs when Mentos candies are dropped into a two-liter bottle of soda. Met with screaming, cheering and fascination from the students, Jake recalled debriefing back in his classroom later when the excitement subsided. In keeping with the constructivist-driven vision of this school, he gave students an opportunity to revise previously held notions about chemical and physical changes.

At his previous school, material resources were scarce. "Georgia is one of only eight states in the US that does not provide additional funding specifically to educate students living in poverty" (Owens, 2022, p. 7). Jake worked with the science specialist at his school to create projects on the Donor's Choose website, which sources funding from the public to secure materials. The specialist was also a resource for Jake in terms of his professional development for teaching science:

> I'm not a scientist, and I'm not super big on science, and so I just like accept that and just make whatever [I] can with it, and I would ask colleagues, too. We're, like, we have a STEM teacher at the lab, and so I would just ask her. (Interview #1, February 12, 2023)

Jake also shared he had very little professional development dedicated to science at both schools where he worked. He gained confidence teaching science by using prepared slideshows that included content information because they helped him learn information prior to introducing the topics to students.

Magenta

The bulk of Magenta's stories about navigating constraints successfully are, unfortunately, from a time before she stopped bringing science to life in the ways she did with her students in the past. On a positive note, it is because her current workplace has little restrictions on what Magenta can do. Material resources are readily available, and science is built into the daily schedule and prioritized as it is a certified STEAM school. There are two teachers in each classroom, and they designate which subjects each teacher is responsible for planning and teaching. Her class was nicknamed "The Class of Privilege" because of her colleagues' perception that they were able to do things that other classes could not. Magenta put it this way:

> Her wife is an author. And she has like celebrity friends, and they would come talk to our kids and make guest appearances and different authors of books that the class were reading, they would like appear like, "Hey!" And so the kids would like, "Oh my gosh, I'm reading your book and you're the author," and like, making connections like, I see you. I'm reading- you know. …The thing was our class was "The Privileged Class" so I feel like we were able to get away with more, if that makes sense, because we had people who supported either me, her, or the both of us. (Interview #2, March 13, 2023).

One activity that Magenta recalls getting away with was called "On This Day in Marginalized History." Students chose different days on the calendar and used Google to identify a fact that happened on that date involving someone who was Black, Latinx, Indigenous, Asian, or part of the LGBTQ+ community. For Magenta, the times when she did her best science teaching are distinctively set in her not-so-distant past. Her focus when we talked was often about her current workplace experiences and the differences between how she used to teach, how she would like to

teach, and why those versions of her teaching are not coming to life today. This brings me to the second part of findings for this question: Insurmountable constraints.

Part 2. Insurmountable Constraints

Connie

Connie has participated in mandatory trainings to implement the IB PYP program throughout the year. Concurrently, her school district holds regular data meetings where they bring teachers from neighboring schools together to examine their standardized test scores in literacy and math. They also provide regular professional development for teachers around literacy and math instruction. Science is largely absent from these meetings and/or trainings, however Connie sees connections between the way she teaches science and what she sees in the trainings for the IB PYP program. Connie said the IB focus for this year is eliciting student questions and using them to guide lessons. She described the action cycle component of IB as reflective of critical consciousness. During the second interview, after reading the story about a science unit incorporating all three dimensions of CRP, Connie explained the connections between a successful IB unit and the vignette used in the interview. She concluded:

> So then you can go on from that [student reflection on who can be in STEM and how communities can be improved through STEM]: Well, what other ways can you work and study to improve your community? Why did communities need improvement? What communities don't need improvement? What communities do? Stuff like that, and you can just go on and that takes a lot of time, which in those 180 days.... So right now, in my head, it doesn't seem feasible, and I would love to be proven wrong. (Interview #2, March 20, 2023)

She is stalled, however, as a second-year teacher striving to meet the demands of the IB model within the constraints of her school.

The support for math and literacy curriculum implementation is more frequent than the support for IB in terms of professional development and instructional coaching. Second, the chosen curriculum resources are not explicitly aligned to the IB PYP program. IB PYP programs do not provide scripted or daily lesson plans like the math and literacy resources do. Rather, they provide approaches to teaching that are "deliberately broad, designed to give teachers the flexibility to choose specific strategies to employ that best reflect their own particular contexts and the needs of their students" (International Baccalaureate, 2019, p. 6). She said:

> And the professional development that I went to for IB- I loved it so so much and at the end of the day I, like I told my IB coordinator it was so frustrating because I know we can't do this. (Interview #2, March 20, 2023)

Connie may not see this as feasible because the context of the IB training she received was so different from where she works:

> They showed us a school in Japan-an international school that was, had been working on it for like I think at least five years. And they emphasized, like, every single staff member was working hard on this for a long time to get where they are. …And it's just so restricted, I feel…. When I step away from, what [the teacher assigned to planning for science for the grade level] planned, it's a hit or miss. Sometimes. Because either I didn't prepare enough for it because of just time and materials and lack of knowing like, okay, well this is my first year, how do I kind of like, guide them through this? Or it's like, okay, they really, really like this. (Interview #2, March 20, 2023)

When she talked more with the IB coordinator at her school, Connie was met with validation coupled with encouragement to attempt what she can. Parts of the second interview vignette included inviting outside stakeholders into the classroom.

On that topic Connie responded, “See I wish I knew more about my community and knew more like people like the local college or the scientists” (Interview #2, March 20, 2023). At times, she has seen her school connect with the community: When the family member of a prominent school board member was shot and killed, there was a brief but loud expression against gun violence. She saw school staff come together in support of the family in many ways, “So I know we can do it,” she said (Interview #2, Marcy 20, 2023). However, when anyone who visits the classrooms comes through, Connie’s students become quiet and reserved; she believes they get scared. Their visits are part of a practice of brief observations and walk-throughs of schools and classrooms rather than opportunities to hear students’ ideas, which Connie would prefer.

Jake

Where Jake teaches currently, grade level teams to teach the same thing as one another at the same time, though the teachers may create their own timeframes and lessons. During the 2021-2022 school year, the team moved their science instruction to the beginning of the year. Their rationale was: With the uncertainty of the Covid-19 pandemic, it was possible they would experience another school closure. They wanted to secure access to science materials for experiments in case they would be sent home without notice to prepare again. This meant the science standards were addressed as early in the year as possible, so once they covered all the content, they stopped teaching science. This cease of science instruction in response to pandemic-era policies meant that students had all but forgotten taking part in science instruction in that year. That

spring, parents of a child whose end-of-grade science test score was below the level of proficiency had a conference with Jake. The child is in the gifted program at the school, so they were surprised by her score. Jake explained:

> So I was just, you know, telling them… we kind of anticipated some different scores just because we front loaded so much. We did try and do some review, but I think it might have been a little bit more beneficial to just teach that stuff closer to [the test]. (Interview #2, March 11, 2023)

When planning as a team for the 2022-2023 school year, the team decided to shift their science content nearer to the end-of-grade test to avoid the lower science scores they saw when they taught it all at the beginning of the year.

> And so that's what we're doing here. We've taught a couple of concepts. …We're just doing the units closer to the um- closer to, to the Milestones [end-of-grade test]. …We'll be here this week. We're finishing up social studies content. We'll go on a week-long break and then when we come back, it'll really be a lot of science content that we'll have to get to: Magnetism, electricity, landforms, microorganisms, physical and chemical change. So it will be like science, science bootcamp, science university. (Interview #2, March 11, 2023)

Jake made a comparison between his previous school and his current school when he talked about instructional decisions specifically related to breadth versus depth. Here he explains:

> And so, [my current school is] predominantly white, there's a higher level of affluence, and then there is two teachers to every single classroom. …One of the things that we try to stick to is depth over breadth. So we have a little bit more- We have more autonomy to spend time on one topic, as opposed to covering a ton of different topics just to be

> through. …This school that I'm at now is very different than the school that I was at... before I came here, where the demographics were very different. (Interview #1, February 12, 2023)

Even with the autonomy Jake recognized, the team's decisions were based on state testing. Team decision-making came up often in Jake's thinking around the vignette of a culturally relevant science unit I shared during the second interview.

As Jake took in the segment of the unit where students met scientists of diverse backgrounds, including the racial identities of the students in the class, he paused to imagine something similar with his own students. He shared the response he received from some of his students recently while preparing for a singing performance in honor of Women's History Month:

> So we were like, "The girls are going to be in the middle and the boys are going to be on the side. And it's- We're gonna you know, highlight the girls," and the [White] boys have apparently been in the bathroom revolting, like, "We feel like we're being treated badly because of our ancestors." … And I had a White, girl student who said, "I don't want to make the boys feel bad." (Interview #2, March 11, 2023)

The connection Jake made to the interview vignette and what happened around Women's History Month surrounded his White, male students' perspective of learning about diverse contributions to the world of science. He said:

> And so, when we do that, and they get to see the diversity, what's the interpretation? Is it like, *Oh, they're trying to efface us?* Or is it like, *Okay, well, you know, scientists can look like anybody*. Is it either/or or both/and, you know? I don't know. (Interview #2, March 11, 2023)

Jake discussed the difference between incorporating scientific issues surrounding marginalized communities in terms of the relevance for students of color versus students who are White. He sees the relevance and application for his Black and Brown children, but for White students, he wondered if over-emphasizing racial disparities would be interpreted as a Black teacher just wanting to talk about Black things. Because of the team-teaching practices at his school, Jake also voiced a concern surrounding interpersonal dynamics because teachers have different preferences for how they plan and prepare to teach.

Magenta

Recall the moment I presented earlier when Magenta's class engaged in an exploration of theories about Earth and global warming, topics Magenta's students brought into the classroom (i.e. flat versus dome). What I am about to share is a defining moment for Magenta that directly caused her to stop the On This Day assignment, end theoretical discussions in her classroom, and even change the way she used to connect science content to students' lives. This moment reveals the practices of Magenta's leadership staff in response to a complaint from a group of her students' parents. Some parents called Magenta's administrator directly and accused her of teaching junk science after their children came home with thoughts on the theories of Earth's surface. Without a conversation among them, Magenta's administration expressed to her that *they* understood what she was doing because they knew her as an educator and trusted her judgment. In the end, Magenta's administration advised her to stick to the curriculum provided to appease the parents. They required her to write and submit her lesson plans, including the questions she planned to ask the students, to the gifted coordinator and principal to be approved prior to teaching. "Don't take it to heart," they told her, "They're just being parents." Magenta said:

> I felt like that was stifling my genius…. I felt like I couldn't really be myself as a teacher anymore because I have people who don't know what my teaching style is like, people who won't come to my classroom to observe, people who don't know anything about me teaching-wise trying to govern or like have a say so in what I'm doing… And part of me was like, *I just want to be free. I want to be able to cultivate these wonderful conversations*…. These are fourth graders, and we're talking about scientific theory. So the kids who are genuinely interested in that conversation, we had to stop it. …And so I'm like, "I'm sorry, guys. We can't talk about it." I had to completely just shut it down. Yeah, so it took me a while to like recuperate and jump back. (Interview #1, January 18, 2023)

Magenta was in the second year of looping with her class, having taught the same students the entire previous school year in addition to this one, and so she believed she had established positive rapport with families and expected to be supported. Here, Magenta compares her old lesson openings with what she does now because of what happened:

> I would just simply say, "Hey, here's a problem." Or, "Have you ever thought about this?" And then go into the lesson. Like so I looked at it- It's like attention grabber type thing. Or like uh, you know, in lesson plans, they call it something like attention grabber or like a brain jogger or something, like something to get their mind going. I stopped doing that altogether. I no longer do that in my science instruction. I go straight into learning target, objective, essential question. …I no longer do that. Period. No more current events. No more research. No more. (Interview #1, January 18, 2023)

Magenta reflected on her past association with privilege at the school, and this rule to attain approval of her lesson plans prior to teaching that was imposed on her individually. Parents had not complained about a display featuring historical contributions of people in the LGBTQ+

community, or the project requiring students to research events to learn about marginalization. “Like, who gets away with what? And who doesn’t?” she wondered (Interview #2, March 13, 2023). Magenta found it was possible to incorporate more conscious-raising activity in her classroom when her co-teacher worked there. Now, every teacher on her team is new to the building. Her class was on their third teacher in a now departmentalized format when we talked in March.

At that time, Magenta, too, was exploring strategies for leaving the school. The revolving door of teachers put additional responsibilities in Magenta’s hands as the only steady member of the grade level team, and thus the acting grade level chair, a position for which the school requires an application process. Magenta, while preparing for her maternity leave, found herself abruptly mentoring a student teacher, advising all the new teachers on grading policies and policies for supervising students on others’ breaks, and how to format lesson plans. “Just the basic things to keep our day going,” she said. (Interview #2, March 13, 2023). All of this points to a gap in support for teachers from the moment they are hired at the school, according to Magenta. She recommends the following changes:

> I would also like to see my school have an actual onboarding specialist. …When anybody gets hired, whether it's a long-term sub, short-term sub, or new teacher, and you weren't here during summer orientation- “As your onboarding specialist, I'm going to be your mentor [for] how to be successful during this year. So that way, if you have a question about lesson plans, you come to me. Questions about Infinite Campus, putting in grades, taking attendance: That's my job. How to respond to angry parent emails. Come to me. Let's formulate this email together. How to set up your classroom. Come to me. Classroom materials. Come to me.” Like you need an actual onboarding specialist position, somebody who can set you up for success to keep you here. Because my philosophy that

> developed over my teaching span was, teachers stay when they are supported, equipped to do the job, and compensated fairly. (Interview #2, March 13, 2023)

Magenta recalls her first year at the school and the impact that not having a mentoring program had on her, even though it was her third year in the profession. The assistant principal filled the role in many ways, but as the testing coordinator for the school, support waned when the testing seasons arrived. There is a procedure in place at the school, where leadership staff elicit teachers' input.

Magenta, who passionately expresses the ways that supporting teachers in the way she suggested above would allow them to implement culturally relevant science, has been advocating for a science support position through the proper channels in the school network for some time. She interviewed for the newly created position to no avail. In Magenta's conception of the role, issues deemed controversial or sensitive (i.e., those that foster critical consciousness) would be included in the classroom because teachers would have the support from the school in shaping their instruction. Then, if parents misunderstood the instruction, a support role would facilitate dialogue among stakeholders and teachers.

Summary of Findings for Research Question Two

The participants in this study shared stories the shed light on practices and policies they could navigate successfully to incorporate culturally relevant science, and those which ultimately were not overcome. Constraints included the perceived misalignment between the school's programming and the curriculum resources, pacing, and assessments; a lack of time designated to science in the daily schedule; the practice of teachers sharing planning responsibilities by subject; pressure to overemphasize reading and mathematics due to testing accountability; lack of

material resources; and little to no professional development in science. The participants' strategies for teaching meaningful science lessons included reteaching and repairing lessons after administrative observations, relying on luck to follow students' lines of inquiry, redesigning materials provided by the school district, situating content in fictional scenarios, creating space for independent research, sending classwork home, implementing quick science activities, integrating science into other subject areas, team-teaching science with the whole grade level, obtaining materials through grant-writing, collaborating with a STEM specialist and co-teaching in a classroom with a respected reputation.

When it came to policies and practices the teachers were not successful in overcoming, they included a lack of support for implementing a school model that, in Connie's eyes, allows for the authentic application of science content. However, it is incompatible with the provided lesson plans and observable behaviors of teachers the district uses to evaluate teachers. For Jake, the autonomy his grade level team was given to arrange the teaching sequence of science topics at his current school revolved around the end-of-grade testing results. He found it difficult to see the relevance of racialized experiences from his White, male students' perspective. Finally, for Magenta, the handling of a parent complaint shut down several of her core instructional practices when she was abruptly advised to stick to the book and required to turn in lesson plans for approval before teaching. On top of that, at Magenta's school, a lack of mentoring for new teachers added responsibilities to her workload, shifting her focus from providing her best instruction to assisting her new grade level teammates. Finally, the participants made recommendations for addressing the constraints they experienced.

5 DISCUSSION

This study addressed two questions: First, what does it mean for elementary teachers to teach science in culturally relevant ways? Second, how do teachers navigate school practices and policies to teach science in their elementary classrooms? In this chapter I discuss my interpretation and implications of the study, recommendations for future research, and limitations. This research serves as a resource for other teachers who strive to teach science in affirming ways that students connect with: The teachers in this study did not succumb to an anti-science atmosphere, and though it can feel isolating to go against the grain, this study serves as a reminder that there are educators in our elementary schools who are making space for memorable science experiences.

It is my intent for administrators and those who support teachers at the school level (e.g., instructional coaches) to use these findings in conjunction with other research on the contextual influences on elementary science (e.g., Banilower et al., 2007 Mensah, 2011; Sandholtz et al., 2019; Upadhyay, 2009) to make better decisions, informed by teachers, about the practices in their schools. Additionally, elementary teacher educators can draw on the findings to better prepare teachers for not only the reality this study revealed but also to push for changing restrictive school environments in advocacy work. Researchers should continue building on the body of work that informs the teaching of non-dominant science cultures and practices and consider the potential of vignettes. As used in my second interview protocol, they offer a springboard for story-eliciting, and more teachers' stories are needed. Policymakers must incorporate teachers' recommendations into their decision-making as their insight to the consequences of education policies alongside their students is invaluable. Finally, I express the limitations of the study, including sample size and data sources.

Interpretation of Findings

Connie, Jake, and Magenta's stories beg a host of questions about the way things are done in their schools and others like theirs: Why, if the mission is to foster STEM literacy, are we structuring teaching in silos of reading, math, social studies, writing, and science? Why must we sequence content around tests instead of students' curiosity? Why do teachers feel the need to hide their actions when they act in the interest of the learners in front of them? Why are individual teachers propping up science instruction for a whole grade level? Why must children express their learning first and foremost by traditional testing measures? I could go on, but what is important to take away from these stories is these teachers have ideas and concrete recommendations that would allow them to teach science for social justice. I offer a critique of the practices and policies that hindered teachers' CRP science to "raise serious questions about the role of schools in the social and cultural reproduction of social classes, gender roles, and racial and ethnic prejudice" (Anderson, 1989, p. 251). My analysis found the following policy-created constraints: (a) state policies including GA HB 1084, HB 1187, and the Georgia Standards of Excellence; (b) district-mandated school programming; (c) COVID-19 response; (d) school-level norms around co-teaching, collaborative planning, and professional development.

Teaching Science Has No Grey Area

Going through motions, complacently teaching a lesson designed by someone else, or passively turning to science resources without an eye for how every student would internalize that instruction does not count as teaching science for the teachers in this study. Connie, Magenta, and Jake at times had to be less than their ideal teacher selves, and they do not count those instances as teaching science. There is no grey area for them. Science must represent the kids, it must be useful for them, it must excite them, it must be authentic, and if it is not one of those

things; it is not teaching science. The temporal dimension of my analysis captured the teachers' ways of being when they talked about what is or is not consistent with the kind of science teachers they consider themselves to be. It was evident that their science teacher identity changed based on the influences in their schools that either afforded or constrained their science teaching. Their science teaching took place in certain times, places, and interactions when they were able to be a certain kind of teacher, embodying what Moore (2008) calls a social justice science teacher identity. Understanding that the teachers believed teaching for cultural relevance to be subject to change is important because it underscores the influence of context on their ability to stay true to their pedagogical beliefs and thus provide instruction that best serves their students. When they could not, they were not teaching science as they define it. In all, when examining the changing nature of teaching science, it is possible to identify the supports the teachers need to prevent science from slipping away or waning in rigor or relevance.

The tentativeness of Jake's pedagogy was rooted in his perception of what was possible within the bounds of standardized testing. Whether a grade had an end-of-year accountability mandate or not determined the level of depth with which he perceived he was able to cover content. Jake said this about both schools where he taught. Though he concluded his current school would provide support, material resources, and time for him to teach CRP science, Jake hesitated to bring up issues of marginalization in the classroom with white students because he is Black. He viewed a focus on inequalities as more relevant when he taught Black students, and expressed concern for white, male students' perspectives as learners of race and gender inequality. This is connected to Jake's beliefs about critical consciousness, which I discuss more in a later section. Connie, Jake, and Magenta expressed beliefs about being members of the community where they teach, which they recognize is necessary for teaching science. However, whether they felt they

were *acting* as community members varied. Connie specifically wished she was more involved with the community outside of her school. She believes community involvement is possible and important, but as a novice educator she has yet to find ways to make community improvements an outcome of student learning. Further, it took a tragedy for Connie's school to come together around a common issue (gun violence). While it shows care to speak out against gun violence in the wake of tragedy, asset-based pedagogies maintain communities are sources of knowledge, joy, and pride that should also be valued by school staff and board members (Love, 2019; Moll et al., 1992).

Magenta believed she was part of the greater school community, trusted by parents of students she taught for multiple years. However, when the parents complained about her and caused her administrators to require her to submit lesson plans for approval before she taught, she shut down and no longer felt that way. When that happened, her CRP science instruction ceased. Still, Magenta attended school sporting events, and she was there when one parent apologized to her for what happened. Magenta thanked the parent but did not open up about the impact the turn of events had on her. Connie and Magenta's stories indicate there are missed opportunities for school leaders to pave the way for trusting relationships and reciprocity among families and teachers.

Science is a Path Forward

While previous research has found teachers lack sociocultural consciousness (Allen, et al., 2017; Johnson, 2011), that is not the case for Magenta, Jake, or Connie. On the contrary, the teachers in this study were aware not only of how science as a discipline is worthy of teaching, but of how their students' racial identity, home income, and housing status would make them more vulnerable to receiving an education without attention to science at all or with instruction

inconsistent with their lived experiences. Wallace & Brand (2012), too, found understanding racial inequities to be a prerequisite for sociocultural awareness. Further, all three participants understood how mandates in response to standardized test score discrepancies directly impacted their students in ways that those from historically higher-scoring schools would not experience (Brown et al., 2022; Darling-Hammond, 2010; Dunac & Demir, 2013; Robinson & Simonton, 2019; Vaught, 2011). Last, Connie, Jake, and Magenta saw the potential for students to use science learning to create needed changes in their lives.

The participants' classroom activities demonstrate, albeit infrequently, some opportunities for students to cultivate their critical consciousness. Connie pulling back the curtain on the changes to her instruction on days her administrators visited her class was an invitation for students to critique the practices of their own educational system. She also described constantly connecting science content to the impact of the decisions humans make in their daily lives. The way Magenta followed her students' lead as they interrogated theories of Earth's surface they heard about outside the classroom gave students time and space to engage in argumentation about a topic that mattered to them. Jake discussed some related aspects, such as (a) his adaptation of teaching materials to reflect humans' impact on the environment more directly and (b) his desire to implement transdisciplinary instruction including mechanisms impacting historically marginalized identity groups. However, Jake did not ultimately share stories that directly included facilitating students' critical consciousness.

I posit the teachers' lack of stories about students' critical consciousness did not stem solely from their own knowledge or beliefs; but rather their circumstances created by practices and policies in their schools. Critical race, critical whiteness, intersectional, and postcolonial theories have been useful in exposing how white supremacy operates through policies, procedures,

norms, and discourses in schools to ensure all students do not have opportunities to engage in culturally-affirming school experiences in general, let alone through science instruction that results in changes to their communities (e.g. Castagno, 2014; Collins & Bilge, 2020; Sojoyner, 2016; Lomawaima & McCarty, 2006; Vaught, 2011). A growing body of intersectional research shows how Black girls are precariously positioned for exclusion from science, more so than other marginalized groups (Mensah & Jackson, 2018; Young et al. 2017). This is not to say that teachers who *are* able to implement CRP science consistently over long periods of time are not subjected to similar constraints as the participants in my study.

However, as demonstrated in my review of literature, the majority of empirical evidence of elementary teachers successfully facilitating students' critical consciousness development in science comes either from school-university partnerships where teachers have the backup of the researcher (Carlone et al., 2010; Rivera Maulucci, 2010; Sandholtz, 2019; Valenzuela, 1999) or they are set in out-of-school settings. This study adds to the literature by amplifying the stories of teachers who are working in schools in conditions without that form of system backup (Pollock et al., 2022) and who recommend staffing, professional development and curriculum changes that are needed. It demonstrates that despite the evidence of the positive outcomes for students, CRP science has yet to become a priority. I name and critique the specific policies and practices that worked against the teachers in this study next.

Policies and Practices

My analysis lifted a persistent concern among proponents of asset-based pedagogy, which is the lack of opportunities for students to develop critical consciousness. Given the onslaught of attacks on critical race theory and classroom censorship laws in the education policy

sphere now, I maintain certain policies work to dampen students' opportunities to develop critical consciousness by precise design. At the institutional level, it appears in the schools where Connie, Jake, and Magenta worked were acting less deliberately against their students' right to a quality science education and more so out of ignorance or a lack of even attempting to understand the way their practices unfolded with these teachers. The teachers exercised their agency (Holland et al., 1998), adjusting and responding to students to center their learning and reflect their lives outside of school. The data in this study points to the following policy impacts on teachers' critical consciousness facilitation: Georgia's HB 1084 and HB 1178, schoolwide programming, COVID-19 response, school-level practices around co-teaching and collaborative teaching, and in-service teacher professional development.

State Law

Teachers concluding sociopolitical conscious-raising activities are impossible could feasibly be viewed as victories for advocates of state laws that serve to limit what they can do, read, and say in the classroom. Two laws relevant to the participants' experiences passed in Georgia in 2022: HB 1084, the Protect Students First Act; and HB 1187, the Parents' Bill of Rights. HB 1084 is a law prohibiting discrimination based on race that requires Local Boards of Education to resolve complaints filed by parents, students at age of majority, or employees within a five-day review period.

Consider Jake's personal hesitation about how white boys would respond to too much focus on marginalized groups. Jake's school, a charter, has one of the more explicit and strategic equity missions of the three participants, found on the school's website. Jake also believed he would be supported by his administration if he were to teach students about social justice issues in science. He referred to the CRP science vignette I showed him as the ideal, and he recognized

the theoretical underpinnings from his teacher preparation coursework. Yet, without a model in his school or one that reflects the racial diversity in his current classroom, Jake was concerned students would view him as the Black teacher bringing up Black issues. He did not see the relevance for white students. In addition to the need for professional development around the necessity for all students to develop critical consciousness, not just students of color; Jake's concern signals a perception that he is at risk in his environment.

It is apparent Jake may not feel safe being a Black teacher fostering students' critical consciousness at his school. It is also problematic if Jake is the only teacher at this school engaging students in sociopolitical consciousness-raising activities. The CRP-driven teachers in Carlone et al.'s (2010) study received negative treatment from colleagues who did not share their teaching philosophy and prioritized test preparation in math and reading knowing their bonuses were at stake. Teachers in Upadhyay's (2005, 2006, 2009) studies, too, had negative experiences with colleagues and with students' families. On the other hand, Magenta named the freedom she enjoyed fostering students' critical consciousness when she described the privilege assigned to her and her co-teacher; the safety for her ended when parents jumped to conclusions about her teaching and her administration failed to provide the necessary school leader backup (Pollock et al., 2022).

Georgia's HB 1187, the Parents' Bill of Rights, is supported by those who contend the use of critical race theory and social emotional learning indoctrinates children into believing they are inherently racist, wanting to express non-conforming gender and sexuality, and threaten their rights as parents to have a say in their children's education (Foran, 2022). They claim the Supreme Court has not sufficiently protected their rights. Though no cases have been through the courts yet, Magenta's story shows us that even without lodging a formal complaint under HB

1187 and undergoing a review process, parents can leverage their power and influence what takes place in school. The Moms for Liberty, for example, states they are a 501c non-profit whose mission is "to organize, educate, and empower parents to defend their parental rights at all levels of government" with a goal to host chapters that serve as watchdogs over every school district in the United States (Moms for Liberty, 2023). Georgia has four chapters. One of their publications is a how-to for combatting critical race theory in your child's school district. Magenta's story is one that ends not only in her deciding to teach at the surface level but in her leaving the classroom altogether in search of a position where she can support classroom teachers in the very ways she was not supported. It can be said that both sides of the argument find common ground in their interest in children's' well-being; but mandating silence around race, accurate history, and student-driven inquiry which does not shy away from so-called divisive topics is not beneficial for all children. It stalls every child's development of sociopolitical consciousness, a civil rights issue itself (Tate, 2001).

Schoolwide Programming

District-mandated schoolwide programming was salient to all three teachers' science teaching. Connie and Jake's schools are IB programs, and Magenta's is a STEM school. All three participants indicated alignment between their school model and quality science instruction; but not in the delivery, which they gauged by their professional development experiences and school level practices (i.e. team planning, co-teaching). The implementation of IB and STEM models from the professional development to the curriculum resources to the school schedules supported their teaching unevenly. Again, critical consciousness was most pushed aside, but cultural competence in science was also restricted.

Both IB and STEM programs are inquiry-driven, but without an embedded framework of cultural relevance used at the point of implementation, the school models are insufficient for institutionalizing the cultural competence and critical consciousness. Georgia's Standards of Excellence, which incorporate the NGSS, are aligned explicitly in the curriculum resources where Jake, Magenta and Connie work. It seems Rodriguez (2015) was correct in stating "Unless we take prompt and more direct transformative action, the only ones to benefit from the NGSS will be publishing companies…" (p. 1032). While equity and diversity are addressed directly in the case studies of the standards, professional development in the Georgia districts where the participants worked did not include an examination of those case studies that they could recall.

Equity is a foundational tenet of the missions in the school districts where the participants in this study work. Also, Magenta is involved with a university-based teacher residency program that held a three-day convening focused on CRP that included science-specific sessions over two days. The same residency works with teachers in the school where Jake currently teaches, though Jake is not directly involved in the professional development offerings. Connie perceived her professional development offered by staff from IB, not her district, to align with her priorities for teaching science even though it was delivered from an IB lens. Connie's local curriculum resources restricted her to the point where she and her instructional coach *both* understood she was incapable of implementing the aspects of IB that most supported students' critical consciousness. This research shows even when the programming of a school is compatible with the teachers' pedagogies; the implementation is hindered by procedures and practices at the school, though well-intentioned they may be. Adopting a program does not guarantee science will be taught in

culturally relevant ways, but it is positive that each of the participants found connections and recognized what would need to change for them to stay truer to authentic science even through the IB or STEM frameworks.

School-Level Practices

Collaborative planning, co-teaching, and grade-level decision-making in general served as supports for Magenta and constraints for Jake and Connie. Simply serving on a grade level team with shared decision-making, assigned responsibilities for planning each subject, and even co-teaching responsibilities did not equate to support for their science teaching. Research supports that teachers find agency in interactions, thus working with colleagues can be an avenue for improving science (Maulucci et al., 2015; Rivera Maulucci, 2010). Magenta's story showed how co-teaching served as a support for fostering critical consciousness in the past, but she lost that form of backup (Pollock et al., 2022) when her teaching team changed as teachers left the grade level and school.

Magenta was put into a position to lead new teammates in skills and procedures. As discussed, she halted any facilitation of critical consciousness after the incident with parents, meaning her new team of teachers was left without a teacher-leader in that dimension. Jake sought assistance from the STEM specialist in the past, though his focus was more on securing students' access to science in general, not criticality or cultural competence. All three teachers spoke of departmentalized planning even though each of their school models embraces transdisciplinary learning.

Jake did not describe culturally relevant science plans, ideas, or lessons coming from his current teaching team. On the contrary, they focused their decision-making on standardized science test scores. Connie was not in charge of the science lesson plans for her team, so she

worked to modify what her colleague provided, which made it difficult for her to receive and edit in time to use with students in culturally relevant ways. Given the research showing how rare it is to see critical consciousness being developed in students through science in elementary school classrooms, it is not surprising that Jake, Connie, and Magenta were at times the sole teachers on their grade levels with the knowledge and desire to implement it.

Inservice Teacher Professional Development. Overall, none of the participants articulated a strong, positive connection between teaching science and the professional development at their schools. While this study did not collect data directly from professional development materials or observations, the teachers' perceptions of their experiences translate directly into their practice, and their stories reflect that. Lee & Buston (2010) offer an explanation for what the data from this study shows, which is that professional development for teachers traditionally does not include cultural considerations alongside other foci (i.e. content knowledge, curriculum adaptation, inquiry-based instruction) (Brown & Crippen, 2016). The teachers struggled to recollect a science-specific professional development experience offered at their schools at all. Elementary teachers historically have had to seek science professional development outside their school districts (NASEM, 2018). Given the adoption of inquiry-based teaching models like IB and STEM, and their potential to support scientific inquiry, it makes perfect sense to bolster the science-specific professional development in schools.

COVID-19 Response

Connie and Jake's narratives show how the residual effects of the COVID-19 pandemic closures, virtual instruction, and reopening are at work today in ways that maintain pre-COVID inequities by continuing to overemphasize standardized testing, thus impacting the quality of sci-

ence instruction in the elementary classroom. Azevedo et al. (2022) report the available evidence, mostly from wealthy countries, regarding the impact of school closures during COVID-19 indicates "low and unequal effectiveness of remote learning" (p. 434). In the three schools where the participants worked during the closures, each school followed unique scheduling for returning to school.

Connie expressed frustration at the way her school district neglected to adapt learning goals for students after the pandemic caused them to miss school, as not all students had consistent access to virtual learning during the closures. Her school district holds data meetings during which her school's test scores are compared to those of the neighboring school; but Connie shared differences in the number of language learners, students in low-income households, and those without access to internet or electronic devices. Azevedo et al. (2022) describe successful initiatives in Kenya, Ghana, Zambia, India, and Brazil, where instruction was targeted by learning level rather than grade or age in response to differing learning levels upon returning to school. It seems from Connie's point of view, the interventions at her school are insufficient for addressing the inequalities that existed prior to the pandemic, which have worsened student learning loss for those same groups of students (Azevedo et al., 2022).

Jake's teaching team rearranged their science content in the 2021-2022 school year in response to the school closures, causing that year's group of students to gain exposure to science they would typically see in a full school year back-to-back at the start of the year. Recall his story about low science test scores that year, which Jake's team then attributed to the length of time between teaching and testing rather than examining the quality of instruction that may have led to a lack of retention. Rose & Martin's (2005) finding from a survey of 38 teachers about

their concerns around high-stakes testing in science rings true: “Teaching to the test will dominate the teaching of science in their elementary schools” (p. 351). The following school year, Jake’s team taught science in a similar back-to-back fashion, only this time in the weeks immediately leading up to testing. “Science university” as Jake called it, is reflective of the kind of rapid science instruction that covers breadth over depth and does little to foster students’ critical thinking or student-driven inquiry. It is possible the school leadership team was unaware of the teachers’ plan to save science instruction for the springtime, or they agreed with the strategy because they, like Connie’s school, emphasize and promote test scores as their priority. However, instructional coaches would have been wise to support the teachers in using the IB model of instruction from a culturally relevant lens so that students had the opportunity to engage in authentic, agentic science experiences instead.

Implications

> In reflecting on stories as meaning over stories as fact, what we see as important is that the stories themselves become a piece of history, a lens through which to interpret which features of that context have significance for the author, and in what ways and through what connections [Personal Narratives Group, 1989] (Barton, 2003, p. 8).

Rightfully securing their place in history, this study found three elementary science teachers persisting and plateauing unevenly in their efforts to teach justice-oriented science depending on the time, space, and social interactions; all influenced by policy and school-level practices. Practitioners should note how the teachers manipulated their schedules, revised provided curriculum, and provided opportunities for students to express criticality as inspiration for navigating the constraints in their own schools. Teacher leadership and instructional support staff should focus on the restricting aspects of practices the teachers shared and work to arrange their professional

development, school schedules, and community involvement in ways that allow a clear path for culturally relevant science, driven by not only what the teachers in this study have recommended, but also by seeking recommendations from the teachers in their schools. Policymakers, understanding what teachers recommend toward this aim, should de-emphasize singular determinants of student learning and secure opportunities for teachers to implement varied forms of assessment. I discuss these implications in the sections that follow.

Inservice Teacher Professional Development

These stories resonated with me as a sixteen-year elementary educator who, like Connie, Magenta, and Jake, often felt the kind of support I was offered was misaligned to what my students or I could use. The supports were the same for everyone; yet the teachers in this study show one size does not fit all. The supports Magenta described are different from what Connie requested; they are seven years apart in experience. There is no doubt these teachers have solid knowledge about strong science teaching and further, they are able to identify goals for themselves. Instead, yearly goals are often identified and even quantified by leadership teams who then use observation tools to identify areas of growth and subsequent professional learning experiences. I do not believe observation checklists or rubrics are inherently bad; however, flexibility and diversity in what it looks like and sounds like to teach should be part of an evaluators' expertise. I propose a change in inservice teacher professional development and support that prioritizes students' access to culturally and linguistically affirming instruction before all else, followed by an examination of the school model chosen to support equitable science opportunities, and then time and support for adapting curriculum resources to support critical consciousness through interdisciplinary study.

Time and attention to identifying sociopolitical issues related to the science content the teachers are responsible for teaching at their grade level would serve Jake and Connie, who indicated a need in that area. Dunac & Demir (2017) proposed a model for teacher preparation integrating critical race theory and culturally relevant pedagogy with pedagogical knowledge, context knowledge about students and school, and subject matter knowledge. It is a digestible framing such as theirs that could support teachers in their efforts to organize their thinking and planning across theory and practice.

This shift in professional development points to a need for teacher leaders, administrators, district leaders, and those in classroom support positions to have a deep understanding of the justice-oriented, culturally relevant, culturally sustaining, etc. pedagogies I referred to in the review of literature. Since it is not the norm, those in leadership positions will also likely need professional development around these ideas. A collaborative learning setting such as a professional learning community (PLC) could facilitate ongoing learning for staff in any position in the school district. It is important for all school staff to share in the mission of educating students from an equity viewpoint to secure that right for students. This also means making it clear to teachers that curricular resources are not provided to them with the expectation that they follow them like a script.

Rather, they can be rearranged, augmented, and used in ways that best serve students. School leaders must not continue to create conditions where students are forced to secure experiences with science during their recess or other free time. It should be part of their time at school by design. Jake and Connie's students took it upon themselves to secure time in their school day when they could engage in science. Jake's students chose science during recess; Connie's worked in any spare time on personal research projects. She also sent home any science work

students were unable to complete during the school day. The intention on the teachers' parts were good, of course. They were agreeing to allow students to give up their free time or put in more time at home because they were restricted by the schedule the leadership at the school created. As Barton (2003) found, science for transformation is part of youth culture, and her students, like Jake and Connie's, insisted on participating in science. Knowing this, school leaders have a responsibility to provide and ensure access to science so that the onus is not on the student and his or her ability to convince the teacher to allow for science engagement during alternative times.

Preservice Teacher Education

Elementary preservice teachers have much to learn about the art and science of teaching reading, writing, math, science, and social studies in a relatively short amount of time. Programs should continue to include preparing them for work in diverse classrooms with embedded (not stand-alone) asset-based pedagogies including but not limited to CRP. Programs should incorporate learning about education policies. They should learn how to recognize practices that inhibit teaching that resonates with diverse groups of students so that they can respond accordingly, as the teachers in this study and others show is possible. Graduating from teacher education programs with explicitly social justice-oriented, equity-focused missions, or even those directly using asset-based pedagogies at the university level does not guarantee graduates will be equipped to incorporate CRP in *science*. They should have opportunities to foster their sociopolitical awareness of science issues in particular and be exposed to diverse ways of knowing, doing and using science. Preservice teachers should also engage in conversations about identity and relational power dynamics so that they know the importance of critical consciousness for everyone, not only marginalized groups; thus for all teachers, not only teachers of color to teach. This is a

tall order for teacher preparation programs alone; school-university partnerships should be used as a bridge to continue learning in both spaces and support a common goal.

Policy

Leach (1980) states, “In educational planning contradictions are often recognized between the designs of national planners and the perceived interests of individuals who are the raw materials of planners’ schemes” (p. 186). Policymakers and supporters of education laws that genuinely serve to foster equity need to hear stories from teachers who strive to do the same but have insider knowledge about how legislation effects their ability to teach. Georgia’s HB 1084 and HB 1178 are not unique to Georgia. They are reflective of a national campaign to uphold current structural inequalities benefitting dominant groups (López & Sleeter, 2023; López et al., 2021). The verbiage on Georgia’s laws is replicated from classroom censorship policies supported by organizations of parents (and others) seeking more control over what their children learn in school based on their own values. To counteract these efforts, encourage those in power not to support such legislation, and invite outsiders to education into the conversation in the spirit of knowing better to do better, teachers’ stories need to be heard.

Recommendations for Future Research

Teachers and those in positions to mandate curriculum, dictate schedules, and provide professional development to teachers need tools and resources to strengthen the use of empowering teaching frameworks. My study indicates a need for research addressing effective professional development for in-service teachers, studies on elementary classroom implementation of culturally relevant science, and studies on effective practices of school leadership supporting implementation. I proffer vignettes as a tool for professional development; call for the expansion of

the literature on culturally relevant science with attention to cultural ways of knowing and application of critical consciousness through science learning; and increased understanding of teachers' development of sociopolitical consciousness.

Vignette as a Professional Development Tool for CRP Science

Effective methodologies are needed to understand how professional development translates into classroom teaching. Bernabeo et al. (2013) found vignettes stimulated reflection when they used vignettes to discuss professional ambiguity. It would be worthwhile to study the use of vignettes as a professional development tool for culturally relevant science pedagogy in the elementary classroom. Researchers have utilized case studies in this manner in other fields, but it is less common for educators to experience professional development using science teaching narratives. A memo written while analyzing my second interview with Jake stated, "He's imagining and storytelling a unit based on the [vignette I provided]. He has mentally imagined a new narrative for his teaching, and though it's hypothetical, he's trying it out" (Researcher memo, May 16, 2023). It was an exciting moment to witness Jake coming to terms with a science unit that anchored students' development of critical consciousness and what that would entail in his school. I saw the potential for vignettes to provide a picture of what is possible for teachers to use to plan for their own practice similar to the normal conversations heard around schools and teacher learning communities. When a teacher asks, "How did you do it?" they are met with stories.

Studies on Culturally Relevant Science Approaches in Classroom Settings

Gloria Ladson-Billings' latest publication, *Culturally Relevant Pedagogy: Asking a Different Question* is a "greatest hits volume" of her work (Ladson-Billings, 2021, p. vii). Part two of the book is called "Culturally Relevant Pedagogy in Specific Subject Areas" (p. v). Notably, science education did not earn a space in the 30-year retrospective book. Other researchers have

expressed that science education has been late to utilize CRP; and in consideration of the dearth of examples teachers have access to, it is imperative that researchers continue to document success and challenges. Connie and Jake both expressed a desire to have more examples of CRP science. It would be especially useful to document precisely how teachers receive mandated curriculum within a school model and shape it into culturally relevant science experiences for students. It would be helpful to also document the leadership and administrative decision-making and practices in place at the school level as they work to support all students in learning science that is reflective of their experiences and serves to improve their surroundings. To the same aim, I suggest increased attention to the dimension of cultural relevance in science. The overwhelming presence of dominant ways of knowing, doing and using science serves to maintain the status quo (Dunac & Demir, 2017).

Studies on Developing Sociopolitical Consciousness in Teachers

Research points to the influence of race, class, gender, sexual orientation, and their intersections on teachers' sociopolitical consciousness and how it informs their work with students. An inquiry into how each of the teachers' experiences throughout life as a bisexual, Black woman; a gay, Black man; and a straight, African American woman informed their teaching was beyond the scope of this research study, but it would help to inform teacher education. Additional research informing our understanding of the influence of experiences teachers have prior to entering the classroom could shed light on what teacher preparation programs could be doing to foster teachers' sociopolitical consciousness. It could also inform inservice teacher professional development.

Limitations

A limitation of this study is the relatively small sample size of three, even for narrative research. As stated earlier, I sought up to ten participants; but was unable to secure as many who exhibited the beliefs and dimensions of CRP as outlined by Ladson-Billings (1995a) after the first interview within the timeframe indicated on my IRB application. Additional sampling techniques, such as referrals or snowball sampling, may have increased the number. Seeking teachers across elementary grade levels, in additional districts in Georgia, with varying years of experience, and from varying identity groups would have provided additional information about policies and how they are implemented as well.

Second, I was able to code for the beliefs and dimensions of CRP across two interviews, however Ladson-Billings (1995a) stated teachers "demonstrated their commitment to these conceptions of self and others in a consistent and deliberate manner" (p. 30). While my analysis through the Three-Dimensional Narrative Space (Clandinin & Connelly, 2000) allowed me to consider the teachers' past, present, and future teaching episodes, additional interviews would allow for a longer timeframe for understanding how plans did or did not come to fruition. Jake's "science university" for example, was coming up soon at his school, and it is left unknown whether he was able to teach so many science concepts in deliberately culturally relevant ways.

Third, while two interviews were appropriate for our topical conversations around science instruction, answering the first research question about what it means to teachers to teach science in culturally relevant ways; observations would have allowed me to uncover richer descriptions of the teachers' pedagogies. Rather than solely relying on the teachers' recollection, I would have additional data to present to them and ask about in our interviews to unearth more (i.e. material on the classroom walls, students' materials and resources, conversations participants had with students, facilitation protocols). To be clear, I would not seek observational data

to validate or otherwise affirm what teachers shared; I believe their stories are valid representations of their experiences. Rather, observations would provide me with points to probe for further information and richer descriptions of their contexts.

Conclusion and Reflection

The teachers in this study expressed changes necessary for providing young children access to the kind of science learning that has a positive impact on their lives. It is apparent that school-level decisions and the policies that shape them are determinants for teachers' capacity to implement the science instruction this study sought to understand. In essence, the key takeaways from the study point us in the direction of liberatory education. For students, that is honoring their identities while nurturing their capacity to shape our future society, including not only the potential for careers in STEM but also engagement in scientific discourse to make decisions about their health, livelihoods, environment, and people around them. Truly allowing students to engage with topics they care about, follow their curiosity, and conduct investigations using a diverse range of methods and inventive ways requires a shift away from telling teachers exactly how to perform the art and science of educating children. It also requires a shift away from prescribed teaching standards and pacing, dominant ways of doing science, and controlling what can and cannot be discussed in public school classrooms.

Teachers need preparation and professional development that is culturally relevant to them so they, too, feel what it is like to be heard, valued, and respected as capable doers and users of science. Only then are they likely to design similar learning experiences for their students. Thus, educators and staff support in positions outside of the classroom have a duty and responsibility to listen to the teachers they support if they are invested in liberatory education. Uniting these shifts is a need to understand cultural ways of knowing and diverse ways of doing science.

Keeping this at the foundation of what science educators and science teacher educators do should lead to programming that supports the goals described throughout this study.

This study informed my commitments as a STEM instructional coach in an elementary school, a researcher, and a teacher educator. I will apply the insights the participants in the study shared with me to the practices I put in place where I work, supporting their goals rather than dictating what they do. I commit my future research to the advancement of liberatory education and amplification of teacher and student voices. Finally, I commit to providing preservice teacher education that is responsive to the preservice teachers I have the privilege of teaching.

REFERENCES

Achieve Inc. (2013). The next generation science standards. Retrieved March 2014. http://www.nextgenscience.org.

Aguilar, E. (2020). Coaching for equity: Conversations that change practice. John Wiley & Sons.

Aikenhead, G. (2002). Whose Scientific Knowledge? The Colonizer and the Colonized. *Counterpoints, 210,* 151–166.

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. https://doi.org/10.1002/tea.21122

Aronson, B., & Meyers, L. (2020). Critical race theory and the teacher education curriculum: Challenging understandings of racism, whiteness, and white supremacy. *Whiteness and Education*, 1–26. https://doi.org/10.1080/23793406.2020.1812109

Au, W. (2011). Teaching under the new Taylorism: High-stakes testing and the standardization of the 21st century curriculum. *Journal of Curriculum Studies*, *43*(1), 25–45. https://doi.org/10.1080/00220272.2010.521261

Avraamidou, L. (2013). Prospective elementary teachers' science teaching orientations and experiences that impacted their development. *International Journal of Science Education*, *35*(10), 1698–1724. https://doi.org/10.1080/09500693.2012.708945

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145–179. https://doi.org/10.1080/03057267.2014.937171

Avraamidou, L. (2016). Studying Science Teacher Identity. In: Avraamidou, L. (Ed) *Studying Science Teacher Identity: New Directions in Mathematics and Science Education.* SensePublishers, Rotterdam.

Azevedo, J.P., de Hoyos, R., Saavedra, J. (2022). The unequal impacts of COVID-19 on student learning in Reimers, F. M. (ed). *Primary and secondary education during Covid-19: Disruptions to educational opportunity during a pandemic* (pp. 421-460). Springer. https://doi.org/10.1007/978-3-030-81500-4

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. https://doi.org/10.1002/sce.20392

Barton, A. C. (2002). Urban science education studies: A commitment to equity, social justice and a sense of place. *Studies in Science Education*, *38*(1), 1–37. https://doi.org/10.1080/03057260208560186

Barton, A.C, Tan, E., & Birmingham, D. J. (2020). Rethinking High-Leverage Practices in Justice-Oriented Ways. *Journal of Teacher Education*, *71*(4), 477–494. https://doi.org/10.1177/0022487119900209

Barton, A. C. & Tan, E. (2010) *We be burnin'!* Agency, identity, and science learning. *Journal of the Learning Sciences*, *19*(2), 187-229, DOI: 10.1080/10508400903530044

Basu, S. J., & Barton, A. C. (2010). A researcher-student-teacher model for democratic science pedagogy: Connections to community, shared authority, and critical science agency. *Equity & Excellence in Education*, *43*(1), 72–87. https://doi.org/10.1080/10665680903489379

Basu, S. J., Calabrese Barton, A., Clairmont, N., & Locke, D. (2009). Developing a framework for critical science agency through case study in a conceptual physics context. *Cultural Studies of Science Education*, *4*(2), 345–371. https://doi.org/10.1007/s11422-008-9135-8

Beck, J. S. (2020). Investigating the third space: A new agenda for teacher education research. *Journal of Teacher Education*, *71*(4), 379–391. https://doi.org/10.1177/0022487118787497

Bell, L.A. (2019). *Storytelling for social justice: Connecting narrative and the arts in antiracist teaching* (2nd ed.). Routledge. https://doi.org/10.4324/9781315101040

Bernabeo, E. C., Holmboe, E. S., Ross, K., Chesluk, B., & Ginsburg, S. (2013). The utility of vignettes to stimulate reflection on professionalism: Theory and practice. *Advances in Health Sciences Education*, *18*(3), 463–484. https://doi.org/10.1007/s10459-012-9384-x

Berry, T. R. & Cook, E. J. (2019). Critical race perspectives on narrative research in education. In DeCuir-Gunby, J. T., Chapman, T.K., & Schutz, P. A. (Eds.) *Understanding critical race methods and methodologies* (pp. 86-96).

Berry, B. (2013). Good schools and teachers for all students: Dispelling myths, facing evidence, and pursuing the right strategies. *Closing the opportunity gap: What America must do to give every child an even chance*, 181-192.

Blank, R. K. (2013). Science instructional time Is declining in elementary schools: What are the implications for student achievement and closing the gap? *Science Education*, *97*(6), 830–847. https://doi.org/10.1002/sce.21078

Bloomberg, L. D. (2019). Completing your qualitative dissertation: A road map from beginning to end. SAGE Publications.

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste*. Cambridge, MA: Harvard University Press.

Braaten, M. (2019). Persistence of the two-worlds pitfall: Learning to teach within and across settings. *Science Education, 103*(1), 61–91. https://doi.org/10.1002/sce.21460

Braaten, M., & Sheth, M. (2017). Tensions teaching science for equity: Lessons learned from the case of Ms. Dawson. *Science Education, 101*(1), 134–164. https://doi.org/10.1002/sce.21254

Bradbury, L. U., & Wilson, R. E. (2020). Questioning the prevailing narrative about elementary science teachers: An analysis of the experiences of science teacher enthusiasts. *Science Education, 104*(3), 421–445. https://doi.org/10.1002/sce.21574

Brayboy, B. M. J. & Chin, J. (2019). A match made in heaven: Tribal critical race theory and critical Indigenous research methodologies. In *Critical Race Research Methods and Methodologies: Lessons From the Field*. Routledge.

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching, 54*(9), 1143–1173. https://doi.org/10.1002/tea.21401

Brown, B. A., Boda, P., Lemmi, C., & Monroe, X. (2019). Moving Culturally Relevant Pedagogy From Theory to Practice: Exploring Teachers' Application of Culturally Relevant Education in Science and Mathematics. *Urban Education, 54*(6), 775–803. https://doi.org/10.1177/0042085918794802

Bullock, C. (2017). Only STEM cans save us? Examining race, place, and STEM education as property. *Educational Studies*, *53*(6), 628–641. https://doi.org/10.1080/00131946.2017.1369082

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. https://doi.org/10.1080/10665680903408932

Cammarota, J., & Romero, A. F. (2009). A social justice epistemology and pedagogy for Latina/o students: Transforming public education with participatory action research. *New Directions for Youth Development*, *2009*(123), 53. https://doi.org/10.1002/yd.314

Carlone, H. B., Haun-Frank, J., & Kimmel, S. C. (2010). Tempered radicals: Elementary teachers' narratives of teaching science within and against prevailing meanings of schooling. *Cultural Studies of Science Education*, *5*(4), 941–965. https://doi.org/10.1007/s11422-010-9282-6

Carlone, H. B., Haun-Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge- and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching*, *48*(5), 459–485. https://doi.org/10.1002/tea.20413

Carlone, H. B., Haun-Frank, J., & Kimmel, S. C. (2010). Tempered radicals: Elementary teachers' narratives of teaching science within and against prevailing meanings of schooling. *Cultural Studies of Science Education*, *5*(4), 941–965. https://doi.org/10.1007/s11422-010-9282-6

Carrier, S. J., Whitehead, A. N., Minogue, J., & Corsi-Kimble, B. S. (2020). Novice elementary teachers' developing visions of effective science teaching. *Research in Science Education*, *50*(4), 1521–1545. https://doi.org/10.1007/s11165-018-9742-7

Castagno, A. E. (2014). Educated in Whiteness: Good Intentions and Diversity in Schools. University of Minnesota Press.

Chang, A., Martin, R., & Marrapodi, E. (2020, August 16). Summer Of Racial Reckoning. *NPR*. https://www.npr.org/2020/08/16/902179773/summer-of-racial-reckoning-the-match-lit

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

Clandinin, D. J. (2013). *Engaging in narrative inquiry.* Left Coast Press.

Clandinin, D.J., & Connelly, F.M. (2000). *Narrative inquiry: Experience and story in qualitative research*. San Francisco, CA: Jossey-Bass.

Clandinin, J., & Rosiek, J. (2007). Mapping a landscape of narrative inquiry: Borderland spaces and tensions. In *Handbook of narrative inquiry: Mapping a methodology* (pp. 35–76). Sage Publications.

Cochran-Smith, M., Piazza, P., & Power, C. (2013). The politics of accountability: Assessing teacher education in the United States. *The Educational Forum*, *77*(1), 6–27. https://doi.org/10.1080/00131725.2013.739015

Collins, P.H., & Bilge, S. (2020). *Intersectionality*. John Wiley & Sons.

Connelly, F. M., & Clandinin, D.J. (1990). Stories of experience and narrative inquiry. Educational Researcher, 19(5), 2-14.

Cooks, L. (2003). Pedagogy, performance, and positionality: Teaching about whiteness in interracial communication. *Communication Education*, *52*(3–4), 245–257. https://doi.org/10.1080/0363452032000156226

Cooks, L. (2003). Pedagogy, performance, and positionality: Teaching about whiteness in interracial communication. *Communication Education*, *52*(3–4), 245–257. https://doi.org/10.1080/0363452032000156226

Critical Race Theory Ban States (n.d.). World Population Review. Retrieved July 11, 2023, from https://worldpopulationreview.com/state-rankings/critical-race-theory-ban-states

Cross, S. B., Bavazit, N., & Dunn, A. H. (2019). Whiteness as a dissonant state: Exploring one white male student teacher's experiences in urban contexts. *Journal of Teacher Education, 70*(4), 306-318.

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

Darling-Hammond, L. (2006). Securing the right to learn: Policy and practice for powerful teaching and learning. *Educational Researcher*, *35*(7), 13–24.

Darling-Hammond, L. (2022). Breaking the legacy of teacher shortages. *Educational Leadership*, *80*(2), 14–20.

Davis, N. R., & Schaeffer, J. (2019). Troubling troubled waters in elementary science education: Politics, ethics & black children's conceptions of water [justice] in the era of Flint. *Cognition and Instruction*, *37*(3), 367–389. https://doi.org/10.1080/07370008.2019.1624548

DeBoer, G. (1991). *A History of Ideas in Science Education*. Teachers College Press.

Dewey, J. (1958). *Experience and nature,* New York: Dover.

DeCuir, J. T., & Dixson, A. D. (2004). “So When it comes out, they aren’t that surprised that it is there”: Using critical race theory as a tool of analysis of race and racism in education. *Educational Researcher*, *33*(5), 26–31. https://doi.org/10.3102/0013189X033005026

DeCuir-Gunby, J. T., Chapman, T.K., & Schutz, P. A. (Eds.). (2019). *Understanding critical race methods and methodologies*. Routledge.

Delgado, R. & Stefancic, J. (2012). *Critical race theory: An introduction*. New York: New York University Press.

Dunac, P. S., & Demir, K. (2017). Negotiating White science in a racially and ethnically diverse United States. *Educational Review*, *69*(1), 25–50. https://doi.org/10.1080/00131911.2016.1150255

Dixson, A. D., & Rousseau Anderson, C. (2018). Where are We? Critical Race Theory in Education 20 Years Later. *Peabody Journal of Education*, *93*(1), 121–131. https://doi.org/10.1080/0161956X.2017.1403194

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal*, *33*(2), 261–295. https://doi.org/10.2307/1163285

Elbaz-Luwisch, F. (2007). *Handbook of Narrative Inquiry: Mapping a Methodology*. SAGE Publications, Inc. https://doi.org/10.4135/9781452226552

Feiman-Nemser, S., & Buchmann, M. (1985). Pitfalls of experience in teacher preparation. *Teachers College Record*, *87*(1), 53–65. https://doi.org/10.1177/016146818508700107

Ferguson, D., & Dunlop, C. (2021). Uncovering stories of resilience among successful African American women in STEM. *Cultural Studies of Science Education*. https://doi.org/10.1007/s11422-020-10006-8

Foran, S. R. (2022). Parents' Rights or Parents' Wrongs?: The Political Weaponization of Parental Rights to Control Public Education. *Wisconsin Law Review*, *2022*, 1513.

Freire, P. (1970). Pedagogy of the oppressed. New York: Herder and Herder.

Fusco, D. (2001). Creating relevant science through urban planning and gardening. *Journal of Research in Science Teaching*, *38*(8), 860–877. https://doi.org/10.1002/tea.1036

GA HB377 | 2021-2022 | Regular Session. (2021, March 31). *LegiScan*. Retrieved May 09, 2022, from https://legiscan.com/GA/bill/HB377/2021

Gay, G. (2002). Preparing for Culturally Responsive Teaching. *Journal of Teacher Education, 53*(2), 106–116. https://doi.org/10.1177/0022487102053002003

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99 – 125.

Geelan, D. R. (1997). Weaving narrative nets to capture school science classrooms. *Research in Science Education, 27*(4), 553-563.

Giroux, H. A. (2011). On critical pedagogy. New York, NY: The Continuum International Publishing Group.

Green, C. (2023). *Freire and critical theorists*. Bloomsbury Publishing Plc.

Grimberg, B. I., & Gummer, E. (2013). Teaching science from cultural points of intersection. *Journal of Research in Science Teaching*, *50*(1), 12–32. https://doi.org/10.1002/tea.21066

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic Controversies, Contradictions, and Emerging Confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 191–215). Sage Publications Ltd.

Governor's Office of Student Achievement. (2019). *Turnaround Eligible Schools List*. https://gosa.georgia.gov/accountability/turnaround-eligible-schools-list

Gutiérrez, K. D., Baquedano-López, P., & Tejeda, C. (1999). Rethinking diversity: Hybridity and hybrid language practices in the third space. *Mind, Culture, and Activity*, *6*(4), 286–303. https://doi.org/10.1080/10749039909524733

Haverly, C., Calabrese Barton, A., Schwarz, C. V., & Braaten, M. (2020). "Making Space": How novice teachers create opportunities for equitable sense-making in elementary science. *Journal of Teacher Education*, *71*(1), 63–79. https://doi.org/10.1177/0022487118800706

Holland, D., Lachicotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds.* Cambridge, MA: Harvard University Press.

International Baccalaureate. (2019) *What is an IB Education?* https://www.ibo.org/globalassets/new-structure/about-the-ib/pdfs/what-is-an-ib-education-en.pdf

Johnson-Agbakwu, C., Ali, N., Oxford, C. M., Wingo, S., Manin, E., & Coonrod, D. V. (2022). Racism, COVID-19, and Health Inequity in the USA: A Call to Action. *Journal of Racial and Ethnic Health Disparities*, *9*(1), 52–58. https://doi.org/10.1007/s40615-020-00928-y

Kavanagh, S. S., & Danielson, K. A. (2020). Practicing justice, justifying practice: Toward critical practice teacher education. *American Educational Research Journal*, *57*(1), 69–105. https://doi.org/10.3102/0002831219848691

Kier, M. & Lee, T. (2017). Exploring the role of identity in elementary preservice teachers who plan to specialize in science teaching. *Teaching and Teacher Education*. *61*, 199-210. http://dx.doi.org/10.1016/j.tate.2016.10.016

Kelly, L. B., Angeles-Wann, V., Wann-angeles, J., & Jimenez-Silva, M. (2019). STEA2M camp at the orchard: A community cultural wealth approach. *NABE Journal of Research and Practice*, *9*(3–4), 143–154.

Kim, J. H. (2016). Narrative data analysis and interpretation: Flirting with data. *Understanding narrative inquiry: The crafting and analysis of stories as research*, 185-224.

King, H., & Nomikou, E. (2018). Fostering critical teacher agency: The impact of a science capital pedagogical approach. *Pedagogy, Culture & Society*, *26*(1), 87–103. https://doi.org/10.1080/14681366.2017.1353539

King, H., Nomikou, E., Archer, L., & Regan, E. (2015). Teachers' understanding and operationalisation of 'science capital.' *International Journal of Science Education*, *37*(18), 2987–3014. https://doi.org/10.1080/09500693.2015.1119331

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. https://doi.org/10.1080/02607476.2016.1215550

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. *Theory Into Practice*, *34*(3), 159–165. https://doi.org/10.1080/00405849509543675

Ladson-Billings, G. (2013). Critical race theory-What it is not! In *Handbook of Critical Race Theory in Education* (1st ed., pp. 34–47). Routledge.

Ladson-Billings, G., & Tate, W. F. (1995). Toward a critical race theory of education. *Teachers college record*, *97*(1), 47.

Levine-Rasky, C. (2019). Creative nonfiction and narrative inquiry. *Qualitative Research Journal*, *19*(3), 355–367. https://doi.org/10.1108/QRJ-03-2019-0030

Lewis, J. B. (2001) Social justice, social studies, and social foundations, *The Social Studies*, *92*(5), 189-192, DOI: 10.1080/00377990109604001

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. *Theory Into Practice, 34*(3), 159–165. https://doi.org/10.1080/00405849509543675

Ladson-Billings, G. (1995). Toward a Critical Race Theory of Education. *Teacher's College Record, 97*(1), 47–68.

Ladson-Billings, G. (1998). Just what is critical race theory and what's it doing in a nice field like education? *International Journal of Qualitative Studies in Education, 11*(1), 7–24. https://doi.org/10.1080/714858243

Ladson-Billings, G. (2013). Critical race theory-What it is not! In *Handbook of Critical Race Theory in Education* (1st ed., pp. 34–47). Routledge.

Ladson-Billings, G. (2014). Culturally Relevant Pedagogy 2.0: A.k.a. the Remix. *Harvard Educational Review, 84*(1), 74–84. https://doi.org/10.17763/haer.84.1.p2rj131485484751

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.

Learning Policy Institute. (October 3, 2018). *Understanding teacher shortages: 2018 update*. Learning Policy Institute: Research. Action. Impact. https://learningpolicyinstitute.org/product/understanding-teacher-shortages-interactive

Lois, V., & King, N. (2022). Emancipating STEM education through abolitionist teaching: A research-practice partnership to support virtual microteaching experiences. *Journal of Science Teacher Education, 33*(2), 206–226.

Lomawaima, K. T., & McCarty, T. L. (2006). To remain an Indian: Lessons in democracy from a century of Native American education. Teachers College Press.

Lee, O. (2004). Teacher change in beliefs and practices in science and literacy instruction with English language learners. *Journal of Research in Science Teaching*, 41, 65 – 93.

Lee, Y. A. (2011). What does teaching for social justice mean to teacher candidates? *The Professional Educator, 35*(2), 21.

Love, B. (2019). We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom. Beacon Press.

Madison, D. S. (2012). Introduction to Critical Ethnography: Theory & Method. In *Critical Ethnography: Method, Ethics, and Performance* (2nd ed., pp. 1–17). SAGE.

Matias, C. E. (2013). Check yo'self before you wreck yo'self and our kids: Counterstories from culturally responsive white teachers? . . . To culturally responsive white teachers! *Interdisciplinary Journal of Teaching and Learning 3*(2), 68-81.

Marco-Bujosa, L. M., McNeill, K. L., & Friedman, A. A. (2020). Becoming an urban science teacher: How beginning teachers negotiate contradictory school contexts. *Journal of Research in Science Teaching*, *57*(1), 3–32. https://doi.org/10.1002/tea.21583

Maulucci, M. S. R. (2010). Resisting the marginalization of science in an urban school: Coactivating social, cultural, material, and strategic resources. *Journal of Research in Science Teaching*, *47*(7), 840–860. https://doi.org/10.1002/tea.20381

Maulucci, M. S. R. (2010). Navigating role forces and the aesthetic|authentic caring dialectic: A novice urban science teacher's developmental trajectory. *Cultural Studies of Science Education*, *5*(3), 625–647. https://doi.org/10.1007/s11422-009-9221-6

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

Maulucci, M. S. R., Brotman, J. S., & Fain, S. S. (2015). Fostering structurally transformative teacher agency through science professional development. *Journal of Research in Science Teaching*, *52*(4), 545–559. https://doi.org/10.1002/tea.21222

McAdams, D., & McLean, K. (2013). Narrative identity. *Current Directions in Psychological Science*, *22*, 233–238. https://doi.org/10.1177/0963721413475622

McCarthy, C., Fitchett, P., Lambert, R., & Boyle, L. (2020). Stress vulnerability in the first year of teaching. *Teaching Education*, *31*(4), 424–443.

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

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

Mensah, F. M. (2022). Educating Klaren: Neoliberal ideology in teacher education impacting candidate preparation and the teaching of science to Black students. *Cultural Studies of Science Education*, *17*(1), 9–29. https://doi.org/10.1007/s11422-022-10111-w

Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *Journal of Research in Science Teaching*, *55*(7), 1053–1075. https://doi.org/10.1002/tea.21459

Milner, H. R. (2012). Beyond a Test Score: Explaining Opportunity Gaps in Educational Practice. *Journal of Black Studies*, *43*(6), 693–718. https://doi.org/10.1177/0021934712442539

Milner, H. R., & Laughter, J. C. (2015). But good intentions are not enough: Preparing teachers to center race and poverty. *The Urban Review*, *47*(2), 341-363.

Moll, L., Amanti, K., Neff, D., & Gonzalez. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice*, *31*(2), 132–141.

Moore, F. M. (2008). Agency, identity, and social justice education: Preservice teachers' thoughts on becoming agents of change in urban elementary science classrooms. *Research in Science Education*, *38*(5), 589–610. https://doi.org/10.1007/s11165-007-9065-6

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

Morgan, H. (2022). Resisting the movement to ban critical race theory from schools. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *95*(1), 35–41.

Mueller, M. (2008). Ecojustice as ecological literacy is much more than being "green!" A philosophical review of Chet Bowers' transforming environmental education: Making the cultural and environmental commons the focus of educational reform—implications for commons education. Educational Studies, 44(2), 155–166.

Nathan, M. J., Tran, N. A., Atwood, A. K., Prevost, A., & Phelps, L. A. (2010). Beliefs and Expectations about Engineering Preparation Exhibited by High School STEM Teachers. *Journal of Engineering Education*, *99*(4), 409–426. https://doi.org/10.1002/j.2168-9830.2010.tb01071.x

National Academies of Sciences, Engineering, and Medicine. (2015). *Science Teachers Learning: Enhancing Opportunities, Creating Supportive Con- texts*. Committee on Strength-

ening 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: The National Academies Press.

National Research Council. (2012). A framework for K-12 science education: Practices, cross-cutting concepts, and core ideas. Washington, DC: National Academy Press.

Nishi, N. W., Matias, C. E., Montoya, R., & Sarcedo, G. L. (2016). Whiteness FAQ: Responses and Tools for Confronting College Classroom Questions. *Journal of Critical Thought and Praxis, 5*(1), 6430768. https://doi.org/10.31274/jctp-180810-55

Nouri, A., & Sajjadi, S. M. (2014). Emancipatory pedagogy in practice: Aims, principles and curriculum orientation. The International Journal of Critical Pedagogy, 5(2), 76–87. http://partner shipsjournal.org/index.php/ijcp/article/view/228

Ollerenshaw, J. A., & Creswell, J. W. (2002). Narrative Research: A Comparison of Two Restorying Data Analysis Approaches. *Qualitative Inquiry*, *8*(3), 329–347. https://doi.org/10.1177/10778004008003008

Paris, D. (2021). Culturally sustaining pedagogies and our futures. *The Educational Forum*, *85*(4), 364–376.

Patchen, T., & Cox-Petersen, A. (2008). Constructing cultural relevance in science: A case study of two elementary teachers. *Science Education, 92*(6), 994–1014. https://doi.org/10.1002/sce.20282

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

Picower, B. (2009). The unexamined Whiteness of teaching: How White teachers maintain and enact dominant racial ideologies. *Race Ethnicity and Education, 12*(2), 197–215. https://doi.org/10.1080/13613320902995475

Pillow, W. (2003). Confession, catharsis, or cure? Rethinking the uses of reflexivity as methodological power in qualitative research. *International Journal of Qualitative Studies in Education, 16*(2), 175–196. https://doi.org/10.1080/0951839032000060635

Plumley, C. L. (2019). 2018 NSSME+: Status of elementary school science. Chapel Hill, NC: Horizon Research, Inc.

Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. International Journal of Qualitative Studies in Education (QSE), 8(1), 5–23. https://doi.org/10.1080/0951839950080103

Pollock, M., Kendall, R., Reece, E., Lopez, D., & Yoshisato, M. (2022). Keeping the freedom to include: Teachers navigating "pushback" and marshalling "backup" to keep inclusion on the agenda. *Journal for Leadership, Equity, and Research, 8*(1), 87-114.

Riessman, C. A. (1993). *Narrative analysis*. Newbury Park, CA: Sage.

Ridgeway, M. L. (2019). Against the grain: Science education researchers and social justice agendas. *Cultural Studies of Science Education*, *14*(2), 283–292. https://doi.org/10.1007/s11422-019-09939-6

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

Rivera Maulucci, M. S., & Kassidy, F. (2016). Teaching for social justice in science education. In Avraamidou, L. (Ed.) *Studying Science Teacher Identity* (pp. 111–128).

Robbins, K., & Cipollone, K. (2023). The Real Learning Loss: A Lost Opportunity to Reimagine Schooling. *Educational Studies*, *59*(2), 184–205. https://doi.org/10.1080/00131946.2023.2169695

Rodriguez, A. J. (2010). Exposing the impact of opp(reg)ressive policies on teacher development and on student learning. *Cultural Studies of Science Education*, *5*(4), 923-940.

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

Rodriguez, A., & Magill, K. R. (2016). *Diversity, Neoliberalism and Teacher Education*. *12*(3), 18.

Rodriguez, A. J. (2019). Expanding and enacting transformative meanings of equity, diversity and social justice in science education. *Cultural Studies of Science Education*, *13*, 265–281.

Roth, W.-M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, *88*(2), 263–291. https://doi.org/10.1002/sce.10113

Roth, K. (2014). Elementary science teaching. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science teaching* (Vol. 2, pp. 167–186). New York, NY: Routledge.

Roth, W.-M. & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, *88*(2), 263–291. https://doi.org/10.1002/sce.10113

Russell, T. & Martin, A. (2014). Learning to teach science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science teaching* (Vol. 2, pp. 567–586). New York, NY: Routledge.

Ryder, J., Lidar, M., Lundqvist, E., & Östman, L. (2018). Expressions of agency within complex policy structures: Science teachers' experiences of education policy reforms in Sweden. *International Journal of Science Education*, *40*(5), 538–563. https://doi.org/10.1080/09500693.2018.1435921

Sandholtz, J. H., Ringstaff, C., & Matlen, B. (2019). Coping with constraints: Longitudinal case studies of early elementary science instruction after professional development. *Journal of Educational Change*, *20*(2), 221–248. https://doi.org/10.1007/s10833-019-09338-2

Saka, Y., Southerland, S. A., & Brooks, J. S. (2009). Becoming a member of a school community while working toward science education reform: Teacher induction from a cultural historical activity theory (CHAT) perspective. *Science Education*, *93*(6), 996–1025. https://doi.org/10.1002/sce.20342

Schenkel, K., Calabrese Barton, A., Tan, E., Nazar, C. R., & Flores, M. D. G. D. (2019). Framing equity through a closer examination of critical science agency. *Cultural Studies of Science Education*, *14*(2), 309–325. https://doi.org/10.1007/s11422-019-09914-1

Sleeter, C. E. (2001). Preparing teachers for culturally diverse schools: Research and the overwhelming presence of whiteness. *Journal of Teacher Education*, *52*(2), 94–106. https://doi.org/10.1177/0022487101052002002

Southern Poverty Law Center. (2016). The social justice standards: A framework for anti-bias education. https://www.tolerance.org/frameworks/social-justice-standards

Sojoyner, D. M. (2016). First strike: Educational enclosures in Black Los Angeles. University of Minnesota Press.

Swartz, E. (1996). Emancipatory Pedagogy: A postcritical response to standard school. Journal of Curriculum Studies, 28(4), 397–418. https://doi.org/10.1080/0022027980280402

Tate, W. (2001). Science education as a civil right: Urban schools and opportunity-to-learn considerations. *Journal of Research in Science Teaching*, *38*(9), 1015–1028. https://doi.org/10.1002/tea.1045

Tanner, S. J. (2020). Playing with whiteness: Toward a second wave of critical whiteness pedagogy. *Teaching Education*, *31*(2), 230–244. https://doi.org/10.1080/10476210.2018.1532988

Taylor, P. C. (2014). Contemporary qualitative research: Toward an integral research perspective. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science teaching* (Vol. 2, pp. 38–56). New York, NY: Routledge.

Tobin, K. (2002). Beyond the Bold Rhetoric of Reform: (Re)Learning to Teach Science Appropriately. *Counterpoints*, *210*, 125–150.

Tolbert, S., Schindel, A., & Rodriguez, A. J. (2018). Relevance and relational responsibility in justice-oriented science education research. *Science Education*, *102*(4), 796–819. https://doi.org/10.1002/sce.21446

Tolbert, S., Snook, N., Knox, C., & Udoinwang, I. (2016). Promoting youth empowerment and social change in/through school science. *Journal for Activist Science and Technology Education*, *7*(1), Article 1. https://jps.library.utoronto.ca/index.php/jaste/article/view/26827

Tolbert, S., Schindel, A., & Rodriguez, A. J. (2018). Relevance and relational responsibility in justice-oriented science education research. *Science Education*, *102*(4), 796–819. https://doi.org/10.1002/sce.21446

Treagust, D. F., Won, M., Duit, R. (2014). Paradigms in science education research. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science teaching* (Vol. 2, pp. 3–17). New York, NY: Routledge.

Ullucci, K. (2011). Culturally relevant teaching: Lessons from elementary classrooms. *Action in Teacher Education, 33*(4), 389–405. https://doi.org/10.1080/01626620.2011.620528

Underwood, J. B., & Mensah, F. M. (2018). An Investigation of Science Teacher Educators' Perceptions of Culturally Relevant Pedagogy. *Journal of Science Teacher Education*, *29*(1), 46–64. https://doi.org/10.1080/1046560X.2017.1423457

Upadhyay, B. R. (2005). Practicing reform-based science curriculum in an urban classroom: A Hispanic elementary school teacher's thinking and decisions. *School Science and Mathematics, 105*(6), 1–9. https://doi.org/10.1111/j.1949-8594.2005.tb18127.x

Upadhyay, B. R. (2006). Using students' lived experiences in an urban science classroom: An elementary school teacher's thinking. *Science Education, 90*(1), 94–110. https://doi.org/10.1002/sce.20095

Upadhyay, B. R. (2009). Teaching science for empowerment in an urban classroom: A case study of a Hmong teacher. *Equity & Excellence in Education, 42*(2), 217–232. https://doi.org/10.1080/10665680902779366

Upadhyay, B., Maruyama, G., & Albrecht, N. (2017). Taking an active stance: How urban elementary students connect sociocultural experiences in learning science. *International Journal of Science Education, 39*(18), 2528-2547. https://doi.org/10.1080/09500693.2017.1392645

Vaught, S. E. (2011). Racism, Public Schooling, and the Entrenchment of White Supremacy: A Critical Race Ethnography. State University of New York.

Walls, L. (2016). Awakening a dialogue: A critical race theory analysis of U. S. nature of science research from 1967 to 2013. *Journal of Research in Science Teaching, 53*(10), 1546–1570. https://doi.org/10.1002/tea.21266

Watts, R. J., Williams, N. C., & Jagers, R. J. (2003). Sociopolitical Development. *American Journal of Community Psychology, 31*(1–2), 185–194. https://doi.org/10.1023/A:1023091024140

Woodbridge, K., Schellenberg, M. (October, 2021). *Situating self in a system of racism: Critical whiteness praxis of an elementary teacher educator.* Critical Race Studies in Education Association, virtual.

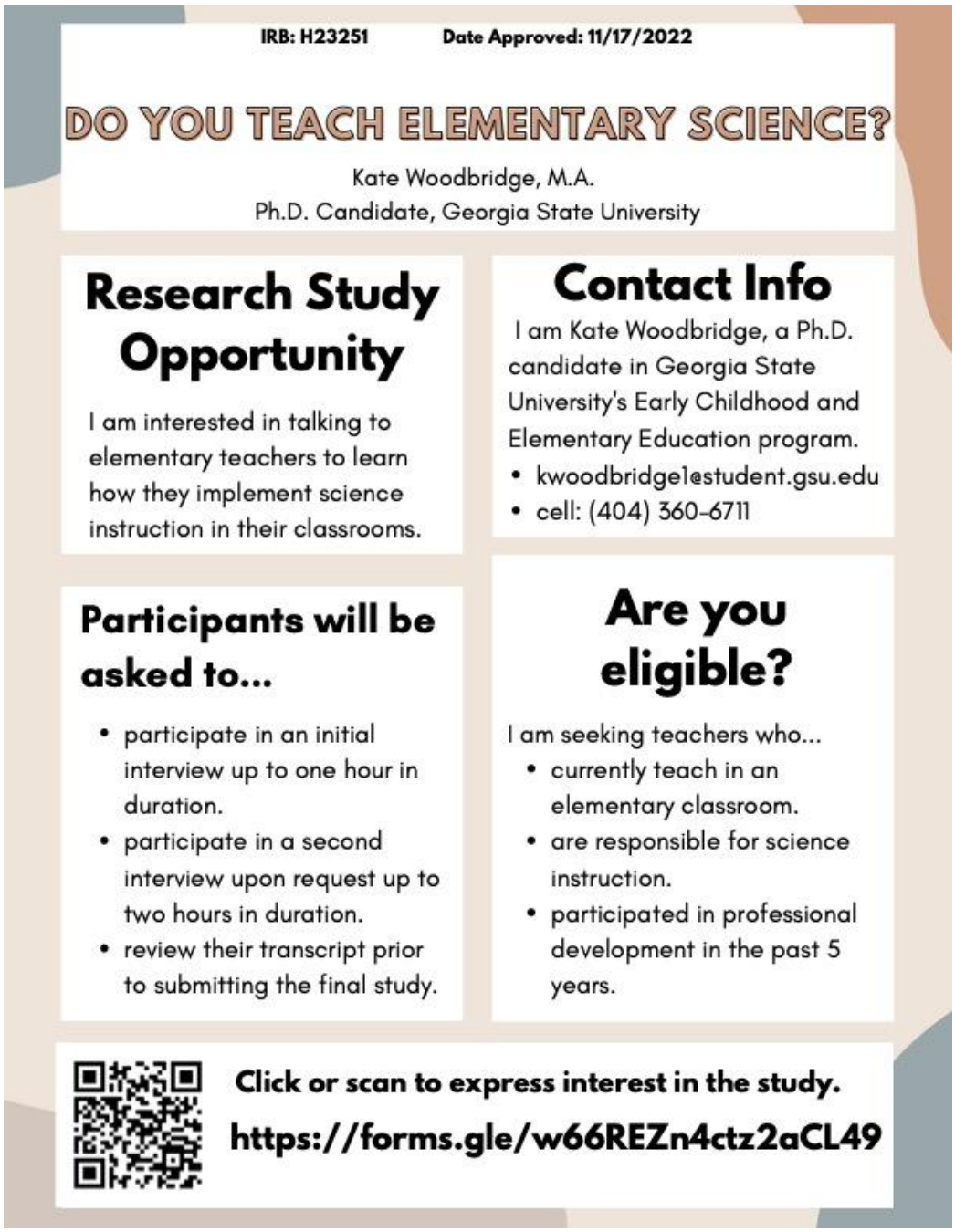
Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, *89*(3), 357–377. https://doi.org/10.1002/sce.20048

Zembylas, M. (2006). Science education as emancipatory: The case of Roy Bhaskar's philosophy of meta-reality. *Educational Philosophy and Theory, 38*(5), 665-676. http://doi.org/10.1111/j.1469-5812.2006.00218.x

APPENDICES

Appendix A

Study Flyer



Appendix B

Personal Data Sheet

About You

Name

Pronouns

Preferred method of communication

Contact information

Pseudonym

Identities

About Your Work

Grade

School

Number of Students

Class Data (numbers or percentages)

Gender

Free/reduced lunch

Racial makeup

Language

Prior Teaching Experience

Appendix C

School Data Sheet

Name of School

Participant(s) at this school

Pseudonym

Grade Levels Served

Number of Students

Title 1 Status

Race/Ethnicity

Languages

Charter Status

Appendix D

Guide to Participant Interview #1

Part 1. Consent

Thank you for your willingness to speak with me about your science teaching. I want to let you know I'm using a service to record and transcribe our conversation today, and your name and any identifying information will be replaced with the pseudonym you chose. Do I have your consent to record? [If not, stop recording.] Thank you, and will you please sign the consent form before we begin?

This interview is designed to help me think about teaching science in from your perspective. I appreciate you taking the time to talk to me, and if at any point you want to stop the interview or stop recording, we will do that.

Part 2. Focus: Teachers' Descriptions of Science Teaching Practices

1. Will you describe the way you teach science? (What does it look like? What are the prerequisites for quality units, lessons, or activities?)
2. What's the reasoning behind teaching science in the particular way you teach it?
3. Tell me about a science lesson or unit where students were really engaged. (What was the lesson about? How did you facilitate? How did they respond? Do you believe this exemplifies your teaching?)
4. Tell me about a lesson you taught that you think students were able to relate to science and the ways it's being taught. (Why did you select this?)
    a. What curricular resources do you use?
    b. How are you able to create activities and learning goals to make the curriculum come alive for students?
5. Is there anything else you think is important to know about your students or science in your classroom?

Part 3. Focus: Constraints Teachers Face

1. Tell me about a time when you had to compromise what you wanted to do or how you wanted to teach science. (How did you respond to ___?)
    a. Tell me about anything that makes teaching science in the ways you've described more difficult.
2. Is there anything else you think is important to know about what makes it difficult to teach science in the ways you've described?
3. What advice/strategies can you offer to teachers who want to teach science in elementary school?

Appendix E

Guide to Participant Interview Two

Part 1. Reconsent
Thank you for talking with me again today. I want to let you know I'm using a service to record and transcribe our conversation today, and your name and any identifying information will be replaced with the pseudonym you chose. Do I have your consent to record? [If not, stop recording.] Thank you, and will you please sign the consent form before we begin?

This interview is designed to help me think about teaching science in from your perspective. I appreciate you taking the time to talk to me, and if at any point you want to stop the interview or stop recording, we will do that.

This interview is a bit different from our first one. This time, I brought a story about a science unit to use a tool for us to talk about your teaching. You can read it once through and I'll ask you about what aligns and/or misaligns with your teaching, and then we'll revisit the story and talk about aspirations and constraints.

Prompts:
First read
What parts feel in tune with your teaching?
What parts feel misaligned or counter to your teaching?

Second read
What parts excite you or make you aspire to teach in a certain way?
What would have to change in your current role for you to be able to ____?

As appropriate
What connections and/or disconnections did this bring up from your own experiences? (teacher training program, professional development, school experiences, out-of-school experiences)

Reflection on Process
How did it feel to read this story and think about your teaching?
If you were to write a story like this for your dream science teaching with no restraints, what would that sound like?
How did it feel to come up with your own story?

Appendix F

Interview Two Science Unit Vignette

Every afternoon in the warmer months, a class of elementary students returned for indoor learning time sweating and desperate to get cool. One such day, a group of students approached their teacher, asking why the playground had to be so hot. The teacher returned the question, and students began a heated discussion. Their wide-ranging arguments included anything from differences in their body temperatures, to where they were during most of their time outside, to the temperature that day, to the lack of cloud coverage, to the absence of shade.

The teacher captured the students' ideas and asked a new question: How can we stay cooler during recess? Suggestions flowed: Move recess to an earlier time in the day, build a roof over the playscape, take off jackets, send out robots with fans, cover the blacktop with white sheets, drink something cold, and so on. The teacher made plans to move forward with a unit unifying the topics of energy and heat-related health risks. The issue of study was the disproportionate impact in low-income communities and neighborhoods with majority Black residents resulting from policies that created segregation in housing and development. Using the students' conjectures about what causes heat, the teacher designed science content assessments.

Students designed and conducted experiments and demonstrations supported by resources collected by the teacher: Books, videos, articles, local tree ordinances, and playground blueprints. They worked in teams and questioned each other's methods. Students engaged in small and large group discussion protocols for communicating evidence for their claims and using sound reasoning to connect them. The teacher invited a group of scientists to talk about their work using an online service that connects classrooms to scientists. The teacher included scientists with the same racial identity as the students and from a range of fields related to the questions students posed. In all, they met Indigenous, Black, Latinx, Asian, and White scientists. In addition to sharing their scientific thinking, the panel shed light on their experiences with marginalization in the STEM field holding one or more identities of bilingual, gender non-conforming, people of color, women, or members of the LGBTQ+ community.

A researcher from a local college visited the class to share findings about her ongoing study that shows how hot neighborhoods around the city are throughout the day. Local county commissioners and structural engineers visited to answer questions about the government's response and plans to mitigate heat risks in the state. Students engaged in perspective-taking protocols to inform their stances on the issues they were studying. Responding to their designs and models, caregivers and community members collaborated with groups of students on construction, cost, materials, and cycles of revision in their home languages and in English.

The teacher recorded the students' processes and decisions in preparation for presenting immediate changes to school administration: building a shade pergola, creating a weather station, and installing their stationary bicycle-powered fan invention. They presented longer-term plans to the school board, such as planting trees that would grow to provide shade and installing water fountains outside. Each team worked collectively on certain aspects and brought individual contributions to the work as needed, such as creating a presentation about their proposed solutions using

technology. She documented students' understanding about each team's related science content and engineering practices throughout the unit with observation, portfolio, quiz, and performance rubric data. At the end of the unit, students responded to statements that showed increased competence and agency in STEM: "My ancestors, community, and I do science. Work in STEM can improve my community." Most importantly, their playground was better protected from heat and the school board committed to conducting playground analyses of the heat risks at all of the schools in the district.

Appendix G

Member Checking During Interviews

J: Yeah-
R: Okay.
J: Especially after that conversation that I had yesterday with that student. It's like, what is the extent to which you believe some of the things- the points that you're raising here, not necessarily that they're right or wrong, it's just like, from a researcher's perspective, like here's just what the data says. So like, when I- If I were to include that part, which I think it's relevant, am I gonna have kids tuning out or becoming resentful because they're like, what does this have to do with me? And like, it's- They're not being reflected in the curriculum the same way in which it would meet that objective for a black student, so. Yeah.

1:05:39
R: [Are you] questioning sort of, how do kids of different races engage with issues that are focused on race?
J: Mhmm.
R: If I could sum it up like that?
J: Yeah. Yeah.

1:05:52
J: And really, white children-
R: In particular.
J: in particular, mhmm.
R: Okay.

Appendix H

Research Consent Form

Georgia State University
Department of Early Childhood and Elementary Education

Part 1. Research Description
Principal Researcher: Kate Woodbridge
Research Title: Culturally Relevant Science in the Elementary Classroom

You are invited to participate in a research study that explores your teaching experience. Your participation in the study requires two interviews during which you will be asked questions about your views of yourself as a science teacher and your experiences in your school. The duration of the interviews will be up to two hours. With your permission, interviews will be audiotaped and transcribed, the purpose thereof being to capture and maintain an accurate record of the discussion. Your name will not be used at all. On all transcripts and data collected you will be referred to only by way of pseudonym. Lastly, it will be important that the research text produced as a result of the study accurately represents your story. I will ask you to read texts as they are produced and before finalizing them to gather your feedback and make revisions.

This study will be conducted by the researcher, Kate Woodbridge, a doctoral candidate at Georgia State University. Interviews and conversations will be undertaken at a time and location that is mutually suitable.

Risks and Benefits
This research will hopefully contribute to understanding teachers' experiences teaching science, so the potential benefit is the improvement of elementary teacher education.

Data Storage to Protect Confidentiality
Under no circumstances will you be identified by name in the course of this research study or in any publication thereof. Every effort will be made that all information provided by you will be treated as strictly confidential. All data will be coded and securely stored and will be used for professional purposes only.

How the Results Will be Used
This research study is to be submitted in partial fulfillment of requirements for the degree of Doctor of Philosophy at Georgia State University, Atlanta, Georgia. The results of this study will be published as a dissertation. In addition, information may be used for educational purposes in professional presentation(s) and/or educational publication(s).

Part 2: Participant's Rights

Investigator's Verification of Explanation

I, _____ (researcher), certify that I have carefully explained the purpose and nature of this research to _____ (participant's name). He/she/they had the opportunity to discuss it with me in detail. I have answered all his/her/their questions and he/she/they provided the affirmative agreement (i.e., assent) to participate in this research.

Investigator's signature: _____ Date ____/____/____