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Teaching Science for Social Justice: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

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Teaching Science for Social Justice: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

By

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of the requirements for the degree of
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DEDICATION

This dissertation is dedicated to the teachers across the world who taught throughout the Covid -19 pandemic. Their hard work and support of students ensured we continue to educate the children of the future.

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The commitment to completing the doctoral process is a challenging one. The support, feedback and from my village and extended peers are the only reason I was able to complete this journey. When motivation waned, these individuals ensure I stayed the course. Therefore, I would like to express my sincere thanks and gratitude to those who assisted me entirely or partially throughout my journey. To my squad, Dr. Tara Nkrumah, Dr. Lenora Crabtree and my ASTE Bestie for life, Dr. Heather Lavender, you three have been there through my most difficult and joyous times without you I would not be done today.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Research on social justice continues to be conducted in urban, diverse schools, while independent schools are traditionally overlooked and absent from research in many disciplines, including science education. This embedded case study uses a critical pedagogical lens to examine this gap in the research literature by examining and describing what it looks like to teach science for social justice within a suburban independent school in the southeastern United States.

Research on social justice continues to be conducted in urban, diverse schools. In contrast, independent schools are traditionally overlooked and absent from research in many disciplines, including science education. This embedded case study uses a critical pedagogical lens to examine this gap in the research literature by examining and describing what it looks like to teach science for social justice within a suburban independent school in the southeastern United States.

Given the current social and political climate of the United States, justice-oriented science educators recognize the need to prepare students to grapple with multiple perspectives, engage in discourse, and learn to evaluate evidence that may conflict with their normative beliefs. Significant research in science education discusses a distributive

approach to social justice. However, research on student outcomes from subject areas that merge social justice tenants with science curriculum and teacher pedagogy is needed. Teaching for social justice combines critical science literacy and justice-centered science pedagogy for critical science agency.

The research questions are 1) How do independent school students understand science within a classroom using teaching science for social justice? 1a) In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? And. 1b) To what extent, if any, do critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?

The data sources accessed for this study included recorded and transcribed teacher and student interviews, participant artifacts, and classroom observations. Data were analyzed using coding techniques to derive patterns and themes, identifying commonalities from the cross-case analysis. Implications for how science teachers and science education researchers may use the information revealed in this study are discussed. This research concludes that teachers with a developed understanding of the intersection of social justice and science and the ability to develop critical science

curricula and teach from a justice-oriented lens may not guarantee the development of critical science agency students. This disconnect creates a gap between theory, practice, and student outcomes. Further, more support needs to be given to teachers as they develop justice to support the continued development of students' critical science agency as they matriculate in k-12 independent schools.

Given the current social and political climate of the United States, justice-oriented science educators recognize the need to prepare students to grapple with multiple perspectives, engage in discourse, and learn to evaluate evidence that may conflict with their normative beliefs. There is significant research in science education that discusses a distributive approach to social justice, but research is needed on student outcomes from subject areas that merge social justice tenants with science curriculum and teacher pedagogy. Teaching for social justice combines critical science literacy and justice-centered science pedagogy for critical science agency.

CHAPTER ONE: INTRODUCTION

As the population of the United States becomes increasingly diverse; educational disciplines should be moving towards more inclusive, culturally relevant, and socially just teaching practices. However, the American education system continues to mold younger generations into disconnected individuals from society (Morgan et al., 2016). Their construction of knowledge develops outside of historical, political, and social contexts and ignores the power and wealth structures of the same information we wish youth to learn (Kincheloe, 2004). Scholars like Rawls (1971, 2013) and Freire (1970, 2000) provide a foundation for educators to confront traditional views of education and move the focus toward more justice-related goals. Rawls questions the ability of individuals to challenge the injustices of society and imagine the solutions to those problems. Freire provides a critical perspective to similar questions and answers but situates these questions in an educational context, examining how these systems produce and reinforce systematic conditions of oppression.

If students are ignorant of these salient structures, then they will likely lack the critical competency to use what they learn in school in their every day and adult lives. Critical literacy provides the means for students to participate in a democratic society in

just ways by critiquing their position in the world (Calabrese Barton & Upadhyay, 2010). Without an awareness of critical literacy, students unintentionally perpetuate dominant ideologies and are not equipped to challenge the status quo (Rezende et al., 2020). Therefore, the desired outcome of this critical justice-centered approach is that students become aware of injustices, feel empowered to use their agency to address those injustices, and, ultimately, choose to act by participating in social movements (Swalwell, 2013).

When learning is placed within realistic contexts, learners begin to recognize systems of power and oppression that enhance their ability to become empowered learners that make informed decisions. In contrast, however, current education policy focuses on adhering to standards and scripted curriculums that decontextualize facts that are then measured with standardized testing (Giroux, 2019). This positivist adoption of knowing privileges one objective truth, the dominant one, which further moves learning away from inclusive practices and student empowerment (Aikenhead, 2006; Rezende et al., 2020; Zeidler et al., 2016). This is especially prevalent within the science classroom. Research has directed much attention to investigating teaching methods and not the social, political and cultural issues that are intrinsic to curriculum and additionally impact students' social practices (Rezende et al., 2020). This narrow

focus on teaching methods pushes science education towards hegemonic practices (Hodson, 2011; Rezende et al., 2020; Zeidler et al., 2016). Additionally, with an over reliance on standards-based learning, science education has missed an opportunity to develop critical thinking for social practices and scientific knowledge for everyday life (Hodson, 2011).

While some members of society have begun to embrace the idea of multiculturalism at least socially, education continues to preserve inequitable policies and pedagogical practices. The mythical belief that we are living in a "post-racial society" where success can be achieved by hard work continues to stifle policy growth that could address the inequities of a system that should create opportunity for all children. Brown vs. Board of Education passed in 1954, is often cited as a hallmark of the era of educational desegregation (Alexander, 2020; Smedley & Smedley, 2011). However, today's public schools are becoming more segregated, and it is not difficult to identify instances of contemporary Jim Crow Laws (Alexander, 2020). Privileged families are enrolling their children in predominantly white, suburban, private and charter schools that lack multiculturalism in faculty, students and curriculum (Frankenberg et al., 2010). The performance results of these racially segregated schools suggest a disparity of wealth and poverty, indicating that children of color within

modern-day segregated schools are less successful in their adult lives. Issues such as unequal access to healthy food and elevated post-traumatic stress disorder in children which are caused by local community violence, for instance, have been linked to inequitable school outcomes and environmental racism (Akom, 2011; Mohai et al., 2011).

In order to address these inequities, some teachers have turned to teaching for social justice (Calabrese Barton & Upadhyay, 2010). Social justice pedagogies "improve the learning and life opportunities of typically underserved students while equipping and empowering them to work for a more socially just society themselves" (Chubbuck & Zembylas, 2008, p. 285). Some scholars refer to the term social justice pedagogy as teaching for social justice. This area of research centers learning in a social, political, and historical context that challenges hegemony and creates a democratic classroom that privileges students' voices. It further provides opportunities to take responsible action (Moje, 2007; Swalwell, 2011). Social justice pedagogy should "… offer possibilities for transformation, not only of the learner but also of the social and political contexts in which learning and other social action take place" (Moje, 2007, p. 4).

Swalwell's (2011) work explores who is served by teaching for social justice in elite schools. She posits that, given the political and social context of our educational

system, it is logical for progressive scholars and researchers to devote their time and energy toward empowering teachers of marginalized students to increase their ability to think critically and combat hegemonic ideologies. While empirical studies continue to broaden the focus of science education for marginalized students, independent schools can benefit from the development of social justice practices in all disciplines. Thus, an equally deserving area of need is communities of privilege or elite schools "… where nothing is perceived as broken, curriculum is rarely questioned, and injustice is something that is perceived as something that happens 'over there'" (p. 12). While empirical studies continue to broaden the focus of science education for students of color, privileged groups still need their own form of antiracist and counter-hegemonic scientific teaching and learning. Without this expanse of focus, pockets of dominant communities will continue to circumvent the development of a more critical perspective of science knowledge that also perpetuates larger meritocratic, hegemonic systems of scientific thinking.

Social Justice and Science Education

Social justice teaching and learning is vaguely defined in the literature. While many scholars have developed their own perspectives of a social justice education framework, today it appears to be a collective outcome of many similar multicultural-

equity- and justice-based frameworks. Scholars have used culturally responsive and relevant pedagogy.(Gay & Banks, 2000; Ladson-Billings, 1995b, 2008), multicultural education (Banks, 1993; Banks & McGee, 2010), and equity pedagogies (Banks & Banks, 1995) to denote a direct or indirect social justice lens for education. No matter the term and subtle differences, scholars' descriptions of these strategies and curricula are similar in their explanations, intent, and outcome of justice-centered curricula and pedagogies. The specifics of these bodies of work are not as important as their shared foci that critiques science education's myopic views and, most important to this study, the provision of different solutions to universalist foundations. Still others acknowledge that social justice remains undertheorized, particularly in connection to science education (Dimick, 2012; Maulucci, 2012; Steinberg & Kincheloe, 2012). While some researchers are developing examples of curricula that connect social justice with science education (Morales-Doyle, 2017, 2018), these examples are limited and are not used within classrooms of privileged students. In this sense, "privileged" applies to individuals who are sheltered from thinking about forms of oppression and have an undeveloped level of critical consciousness of their own ontologies (Gaztambide-Fernandez & Howard, 2013). Ultimately, however, the most important point of

consideration is how do the students we consider to be privileged understand what it means to have a commitment to social justice?

Social justice typically refers to action(s) taken based on knowledge of unjust situations (Hackman, 2005; North, 2006; Patterson & Gray, 2019; Santos, 2009). Therefore, a person acts in socially just ways by first acquiring socially just knowledge and then next putting those skills into practice. In the classroom, it could also be viewed as the development of a mindset that teachers, students, and the school community work towards. It is not a destination or a goal. It is a mission and/or a collective value that provides the groundwork for learning in classrooms. As discussed earlier, social justice can also be a larger social construct. In this study, there is a specific focus on students' social action skills and their questioning how those actions might possibly contribute to larger systemic solutions and thereby develop critical consciousness and cultural competency. Social justice-inspired action happens when individuals understand power structures well enough to feel empowered to act. In the case of social justice within the context of science education, as learning about science content takes place, students also learn about the connection of power and oppression to science. Through this understanding, students can be inspired to act. However, this is an

arduous and involved process, since the forces of history, political and economic power constantly push against change.

Chemiosmosis in all cells provides a simple analogy to the challenges involved in working towards social justice. Chemiosmosis is the movement of ions across a semipermeable membrane against their electrochemical gradient. In every cell, homeostasis or natural balance is important. At times, however, disruption of this balance is required to allow necessary changes to occur, and this disruption happens at significant energy cost to the cell. Even in the cell, action is an outcome of seamless systems working together. Working towards social justice, disrupting the status quo, and challenging hegemony, is not very different. It requires an expenditure of energy in the form of dissonance, reimagining curriculum, challenging traditional ways of teaching, and learning in the hopes of students using their knowledge to do the same on their own. The energy produced from these actions may be far greater than the energy expended. In the classroom, the initial energy investment happens through universal constant questioning of the curriculum and pedagogy.

Framework for Teaching Science for Social Justice

Teaching science for social justice is a conceptual framework developed from Dover's (2009) conceptual framework teaching for social justice but applied in a critical

pedagogical and science educational context. Critical Pedagogy (CP) takes a critical stance against dominant societal structures. Inspired by the works of Paulo Freire (1970), CP is philosophically driven by the desire to disrupt hegemonic and dialectical ideals and challenge social structures propagated in discourse and action. CP situates educational systems as centers of social justice training, student empowerment, and transformational mediums for liberation, not oppression (Blackburn, 2000; Calabrese Barton, 2001; Cummings, 2017; McLaren, 2017). As proffered by Santos's (2009) Freirean perspective for scientific literacy, "it is not enough to show students how science is present in daily life; it is necessary to show the contradiction of this presence in the society (p. 370). Drawing from Santos' application of Freirean ideals to science education, critical approaches to science pedagogy should be dialectical, rely on socially relevant themes (e.g., Socioscientific Issues or SSI), and seek sociopolitical action. Pedagogy should identify science in daily life and highlight "the contradiction of this presence in the society and the struggle for greater justice and social equity" (p. 370). This process facilitates effective pedagogy and develops students' critical comprehension of social reality (critical consciousness) and the desire to transform it. Students must be involved in SSI conversions within the classroom to, "interact with the world, discuss their living conditions and become committed to social change" (p. 374).

These critical components overlap with the current Vision II (Roberts & Bybee, 2014) and Vision III (Sjöström & Eilks, 2018) direction of science education which focuses on understanding social issues and considering oppressive situations to enact change, hallmarks of a critical pedagogical approach.

Dover's (2009) conceptual framework. teaching for social justice, provides both a rationale and a foundation for future empirical research that affects student outcomes in science K-12 classrooms (see Figure 1). Her framework "offers a concrete model for teaching for social justice in K-12 classrooms that is supported by existing research related to student's academic, behavioral/motivational, and attitudinal outcomes combined" (p. 508). Teaching for social justice is an adaptation of Cochran-Smith's (1999, 2004) six principles of socially-just teacher education that highlight the similarities among five justice-oriented conceptual frameworks.

These frameworks include social justice education (e.g., Adams et al., 2016; Chapman & Hobbel, 2010; Chubbuck, 2010), culturally responsive education (e.g., Gay & Banks, 2000; Ladson-Billings, 1995a, 1995b), multicultural education (e.g., McGee & Banks, 1993; Nieto, 2017; Sleeter, 2014; Sleeter & Grant, 1999; Suzuki, 1984), critical pedagogy (e.g., Apple, 2011; Darder et al., 2017; Freire, 1970; McLaren, 2017), and democratic education (Dewey, 1916; Westheimer & Kahne, 2004). Specifically, Dover

Adapted from, Dover (2009)

Figure 1. Conceptual and Pedagogical Foundations of Teaching Science for Social Justice

(2013) highlights a need for future studies to observe the "relationship across teachers' social justice intentions, classroom practices, and students' outcomes" (p. 10), or in the case of this study, science pedagogy, science curriculum, and student action.

Building on her prior work in 2009, Dover (2013) explains that three areas contribute to teaching for social justice: curriculum, pedagogy, and social action. The

curriculum reflects students' personal and cultural identities, including explicit instruction about oppression, prejudice, and inequity, and connects curricular standards and social justice topics. Pedagogy should create a supportive classroom climate that embraces multiple perspectives, emphasizes critical thinking and inquiry-based instruction, and promotes students' academic, civic, and personal growth. Social action focuses on teachers' sense of themselves as social activists, aiming to raise students' awareness of inequity and injustice and promote civic participation and social action among students. This study reimagines teaching for social justice by encompassing the foundations of Dover's framework within a critical pedagogical and scientific context. Teaching Science for Social Justice examines a specific focus on science curriculum, science pedagogy, and science-related social action or critical science agency.

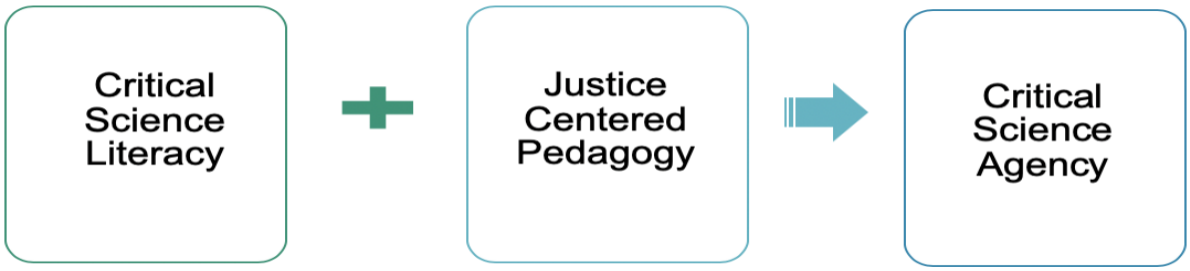


Figure 2. *Teaching Science for Social Justice: Critical Science Literacy, Justice-Centered Pedagogy Leads to Critical Science Agency*

In Figure 2 the teaching science for social justice conceptual framework is pictured as the combination of critical science literacy and justice-centered science pedagogy for critical science agency. Each are of the components of the conceptual framework examined in more detail below.

Critical Science Literacy

Critical science literacy (Atwater et al., 2013, p. 45) is the development of students' scientific literacy via socially relevant scientific content. This development requires students to use and produce their own scientific knowledge while critically examining the intersections between society and science (Ashby & Mensah, 2018; Fusco & Calabrese Barton, 2001). Hodson (2003) and others (Garibay, 2015; Sadler, 2011; Zeidler, 2016) argue that scientific knowledge is not just for preparing students for careers in professional science or engineering. We often overlook the fact that all educational disciplines, including science, have larger social, political, and citizenship-related impacts. For example, the authors of *Science for All Americans* discuss the use of scientific knowledge to facilitate a socially compassionate and environmentally responsible democracy that provides solutions to local and global scientific problems. What the authors do not include, however, is an opportunity to use scientific literacy to act in socially just ways. This omission is notable, especially given the current justice-

based issues that continue to affect marginalized communities locally, nationally, and globally. Often, the solution to this omission is the inclusion of examples in curricula that support science as a value-laden subject. However, scientific content is often taught without value-laden pedagogy. These attempts are well meaning, but not useful (Pedretti, 1999). Since values are attached to everything, teaching science in this way adds to the problem of students being ill-prepared to deal with and participate in the societal decisions. We instead should consider questions like, "what can and should be changed to achieve a more socially just democracy?" and "how do we do this using science pedagogy and curricula that can teach science in value-laden ways and apply this knowledge for the purpose of social action?"

Justice-Centered Science Pedagogy

Justice-centered pedagogy identifies and acknowledges the social and political implications of learning that incorporates individual freedoms and social responsibilities. Students engage in critique of unethical abuses of power and explore the role science can play in reaching social justice goals (Vakil, 2018). This goes beyond common social justice foci on the access-based needs of students and additionally requires students to construct and produce their own knowledge and understanding rather than passively acquiring information transmitted by authoritative sources

(Sensoy & DiAngelo, 2013). For example, youth can often deepen their understanding of the historical rootedness of injustice as they investigate local scientific inequities such as low air quality, lack of access to green spaces and the prominence of fracking sites in underprivileged communities. In a justice-centered science classroom the teacher might explore, the connections between scientific habits of mind and social issues, how to mitigate existing barriers to students' engagement and achievement in science (Maulucci & Fann, 2016) and aims to support alternate pathways for social transformation through science education (Morales-Doyle, 2017).

Critical Science Agency

Critical science agency (CSA) is an outcome of the critical justice perspectives on science education. CSA is a form of agency youth enact when they collectively use their scientific understanding in conjunction with other forms of expertise to investigate and redress injustice in their lives through seeking more equitable alternatives (Basu et al., 2009). This development of student agency can happen individually or at community levels. Basu et al. (2009) suggest that CSA is essential for the development of scientific literacy. Youth critically understand their worlds and learn to expose and understand

oppressive norms and structures. This expertise in both science content and their community contexts support their ability to identify and act in justice-oriented ways.

Statement of Problem

The purpose of this study is to explore the enactment of teaching science for social justice in independent school classrooms. The context of the study will focus on classrooms in a suburban, independent school setting where most students come from a dominant cultural background. Typically, students would be white, straight, Christian, middle to upper class, from first language English speaking families who can afford to enroll in private school. Most children who attend elite schools are likely to come from privileged backgrounds and this privilege may lead to positions of power and influence (Swalwell, 2013, 2015). This study's focus on privileged populations is not in opposition to the important work done within marginalized school communities, but instead provides an opportunity to question theoretical foundations of curriculum and pedagogy in settings where students are privileged. The perception within privileged schools is often that injustice is something that happens "out there and not here," nothing is perceived as broken, and curriculum is rarely questioned. Trueba (1999) and Freire (1970) remind us that Conscientization, or critical awareness of one's social reality based on praxis and reflection, is difficult to achieve. More importantly, this awareness

becomes less impactful without reciprocal awareness of the oppressor. A just society will not arise by solely focusing on empowering those who are or may become oppressed. Without the "reflective awareness of the rights and obligations of all humans", empowerment, equity and liberation efforts are thwarted (Trueba, 1999, p. 593). It is essential, then, that research begins to ask the question that is the overarching focus of this study: What does it look like to teach science for social justice and how does this impact the students in the independent school classroom?

Research Questions

This research aims to address this overarching question by collaboratively developing a curriculum that promotes critical scientific learning and science for social justice as inspired by the work of Dover (2009, 2013). This study will specifically address the following research questions.

Research Question 1

How do independent school students understand science within a classroom using teaching science for social justice?

Rationale. Science and technology cannot be divorced from their social purposes and responsibilities, and moral and ethical reasoning is implicit in the understanding of the relationship between science and social justice (Pedretti, 1999). The research

concludes that educators must account for the ways in which power and positionality impact set frames of knowing. Rose & Calabrese Barton (2012) discuss the need to address this relationship in science education literature.

Values and beliefs play a role in moral and ethical decisions (Zeidler & Sadler, 2007). However, little attention has been paid to how these values and beliefs are individually practiced in sociocultural contexts (Rose & Calabrese Barton, 2012). Therefore, there is a need to focus on how students' values and beliefs impact how they learn in a social justice context and what decisions facilitate their desire to act. Research on social justice in elite schools is a burgeoning area, but still not discipline or subject specific. Research on the teaching of science for social justice has also been primarily focused on practicing schoolteachers, school-university partnerships and marginalized student populations (Lee & Buxton, 2010). If the goal of social justice education is social action mores studies that focus on overlapping of elite schools, science, and social justice are needed. Therefore, this study intends to substantively contribute to an emerging and promising line of scholarly inquiry.

Research Question 1a

In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom?

Rationale. I seek to understand two specific types of student experiences in the classroom: the process through which the students develop their critical scientific literacy and the ways in which social justice perspectives influence the development of critical science agency. The daily experiences of students in the classroom, school, and community in which the students interact may also affect their learning of science. For example, since justice-centered pedagogy and curriculum are based in larger social, political, and historical contexts, the current social and political state of our country may influence student understanding of scientific content. The specific curriculum topic could also influence their interest levels. I am interested in students' conceptual development of scientific knowledge, how the perspective of their knowledge changes, and to what extent social justice themes arise.

Research Question 1b

To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?

Rationale. The curricular and pedagogical pillars of this study are meant to

challenge students understanding of science content by helping them recognize the complex relationship between power and privilege. There is a need for future observational literature to address the "relationship across teachers' social justice intentions, classroom practices, and students' outcomes. For example, how teaching for social justice facilitates content learning, critical thinking, and cultural competence" (Dover, 2013, p. 32). For example, students could begin to discuss how their scientific knowledge of the ecosystem connects to examples of injustice in their local community. Additionally, I am also interested in how this knowledge may facilitate student social action. Expressing empathy in response to injustice, recognizing personal reasonability to stand up or speak out against injustice, collaborate with others to take collective action against bias and injustice by evaluating which strategies are most effective are some examples of how student may demonstrate. social action (Chiariello et al., 2014)

Definition of Terms

Critical*:* A perspective where individuals use the knowledge gained to critique the world in which they live and, when necessary to intervene in socially just ways to create transformative change.

Critical Consciousness: an awareness the role one an individual can play in liberating and disenfranchising inequity using via a transformative stance against structural inequalities and injustices.

Critical Pedagogy - is a teaching method for developing student skills that encourage them to question societal norms, develop their own voice and advocacy, and work toward social justice.

Critical Science Agency: an outcome of critical justice views of science education; a form of agency youth enacts when they collectively use their scientific understanding in conjunction with other forms of expertise to investigate and redress injustice in their lives through seeking more equitable alternatives.

Social Justice (science context): a focus on science teaching and learning practices that empower children, build solidarity, and initiate societal changes to develop values of a socially just and democratic society.

Teaching Science for Social Justice: The relationship between the intentions of teachers' pedagogy and implementation of critical science curriculum and connect to student's development of critical consciousness and social actions.

Positionality

To share the perspectives and foundation of my interest in this topic, it is important to explain my positional identity as it influences the selected the topics discussed in this study and how I view science and the world. When working within social justice frameworks, it is especially important to convey an adequate understanding of my positional identity respective to the theory and practice of social justice (Maulucci, 2012). I identify as an American black woman with roots in Jamaican culture. My interaction with these cultures is unique. While I was born in the United States, I was raised in Jamaica until my late teen years.

I have been a K-12 science teacher for 11 years. I have experience working in the public-school system, but I have taught predominantly in independent (private) middle schools and led teacher and administrator professional development. Throughout my career I have consistently been one of the few teachers of color on staff and often the only teacher of color in the science department or on a leadership team. Excluding my public-school experiences all my classrooms have had been predominantly White students. I find it challenging to address dominant deep-rooted White perspectives within the science curriculum that I teach. I pedagogically challenge the ways in which "Science for All" is enacted in classroom spaces of privilege that additionally

marginalized students of color. I am deeply committed to finding methods to combat hegemonic ways of teaching, understanding, and implementing science and science research in the hopes of transforming students understanding science. Kincheloe & McLaren (2002) state that critical theory researchers acknowledge that an individual's values, ideas, and facts are shaped by social, political, cultural, economic, gender and ethnic experiences, with a specific focus on the inequality and the power dynamics in human interactions. I strongly identify with these ideas and often find that my work attempts to challenge social interactions that are fundamentally mediated by power relations.

Chapter Summary

To provide a bases for these research questions, Chapter 1 began by outlining the social contexts of this study to provide a rationale for teaching science for social justice in independent schools. The need for a more critical focus within science education was established, first in the students' ability to take social action that benefit their lives and additionally to contribute to the greater community in socially just ways. The chapter went on to briefly outline teaching for social justice to further establish the foundation for the proposed conceptual framework of this study: teaching science for social justice.

This conceptual framework entails a combination of critical science literacy and justice-centered pedagogy for the enactment of social action via critical science agency.

Chapter 2 presents a review of the foundational literature for this study, the implications of this research and the gaps that this study hopes to fill in the larger body of knowledge. After instantiating this study within the relevant existing literature, the chapter identifies and defines the theoretical frameworks through which this research was conducted.

CHAPTER TWO: REVIEW OF LITERATURE

This literature review provides a summary of scholarly literature from empirical studies with an emphasis on social justice-inspired curricula in the science classroom. The chapter is composed of two main sections. The first section reviews theoretical lens and perspectives that support the completion of this study in an elite independent school. The questions guiding the first portion of the review are: 1) How does critical pedagogy provide a theoretical basis for studying social justice in science education? 2) How does hegemony in science contribute to a lack of social justice in science classrooms? 3) What characteristics describe independent schools and why do these characteristics show a need for teaching science for social justice?

The second part of this chapter focuses on the theoretical lenses that frame teaching of science for social justice. Two questions guide the second portion of this review: 1) What studies support the development of a teaching science for social justice framework? and 2) How do these studies discuss science curriculum, science pedagogy and social action from a social justice perspective? To answer these questions this review examines teaching for social justice, factors that support its implementation within the classroom and curriculum, pedagogy and social action examples that

support teaching science for social justice in the science classroom. Together, these two sections highlight the collective implications of the findings of this review and serve to identify gaps within the literature that provide a foundation for this study.

The literature review process began by searching for peer-reviewed empirical articles that include pK-12 participants, focus on justice and equity-centered curriculum, and pedagogies in the science classroom. Articles were retrieved from Google Scholar and the University of South Florida online library databases such as Educational Resources Information Center (ERIC) and Web of Science using the following key terms: science education, equity, critical pedagogy, critical science agency, justice-centered pedagogy, social action, social justice, elite education, social responsibility, social change, and hegemony. These articles were published within the last 30 years in various parts of the world, including Australia, New Zealand, Canada, Asia, and various African countries. However, most sources came from the United States. Several publications were added to this review from disciplines other than science education (e.g., math, engineering, technology) if they appeared to discuss teaching for social justice. This review is not exhaustive but instead provides a comprehensive understanding of teaching science for social justice and how it supports student action and commitment to social change.

Critical Pedagogy

Critical Pedagogy (CP) uses a critical lens to examine dominant structures within society. Inspired by the works of Paulo Freire (1970) , CP is philosophically driven by the desire to disrupt hegemonic and dialectical ideals and challenge social structures propagated in discourse and action. CP situates educational systems as centers of social justice training, student and teacher empowerment, and transformational mediums for liberation rather than oppression (Calabrese Barton, 2001; Darder et al., 2017; Gramsci, 1971; McLaren & Kincheloe, 2007). Students and teachers embedded within a CP framework learn to question instructional goals and whose knowledge is being privileged. As a result, students and teachers learn that there are multiple epistemologies and that there is no one legitimate way of internalizing learning.

History of Critical Pedagogy

CP draws from the seminal work of several scholars, many of whom are connected to the critical theory framework. In summarizing the work of Adorno, Horkheimer and Marcuse of The Frankfurt School, Giroux (1983) explains that critical theory is committed to challenging objectivity. Critical theory reimagines the meaning of human emancipation by assessing how forms of capitalism connect to forms of domination. This process involves self-conscious critique and the development of a

discourse of social transformation and emancipation that requires ongoing confrontation of its own theory as it operates in the real world. CP questions the notion of objectivity of the relationships between culture, psychology, and individuals and asserts that they are in fact subjective and historically contingent upon relationships of domination and subordination.

This dialectical process of critique is a key feature of self-emancipation and social change and is required for the development of radical pedagogies like CP. Critical pedagogy views schools as cultural sites with conflicting political values, historicity, and practices. Educators and researchers committed to CP use dialectical models of critique to "stress the brakes, discontinuities, and tensions in history," that "highlight the centrality of human agency and struggle while simultaneously revealing the gap between society as it presently exists and society as it might be" (Giroux, 1983, p. 30). McLaren's body of work describes this balance between individual and society as interactive in context with neither side having a higher priority in analysis. Educational researchers can then focus on both sides of social contradictions and understand that school communities act as both places both domination and liberation. The community educators co-construct for students can foster epistemological identities around both freedom and oppression.

Despite the understanding that CP critiques both liberated and oppressive outcomes of education some find its broader appeal to more progressive political stances as problematic. Null (2011) explains that more radical views of CP are unappealing because of its progressive revolutionary perspectives that are in opposition to conservative ideas. Teachers, school leaders and students may not agree with working towards social justice or simply regard its perspectives as a conspiracy theory. Others dislike the constant focus on criticizing power structures and mislabel them as emotionally driven causes devoid of evidence-based arguments. Some may view social justice work as theoretical, aiming for a world that is ill imagined due to overwhelming and distracted foci on the path to a just world. This argument is mirrored in our current reality. So much research is devoted to demonstrating why more critical stances are needed in science education and the theory that supports these directions, but less is shared on what this looks like in practice within a classroom and even a smaller focus is on predominantly white pK-12 schools. Critical science pedagogy enacts this critical way of thinking in the context of science education.

Critical Science Pedagogy

This study is theoretically guided by the overlapping of CP and science education. Learning and knowledge are political in nature (Freire, 1970). The ways

society generates and uses collective scientific knowledge is directly linked to social, political, and economic factors (Fusco & Calabrese Barton, 2001; Hodson, 2003; Morales-Doyle, 2019; Sadler, 2009; Weinstein, 2009). Since "science is a product of its time and place and can change quite radically the ways in which people think and act," (Hodson, 2003, p. 45) the socioscientific issues of today have a direct effect on learning inside and outside of the classroom. To prepare students to navigate such a world, the social and political contexts of school communities that either privilege or impinge upon student's lives must be considered in curriculum development. More importantly, the curriculum should help students to "better understand and critique their social position and context," combat inequality and be critically conscious by navigating past, present, and future social contexts (Ladson-Billings, 2009, p. 37). Together this focus on the current zeitgeist and critical consciousness creates empowered and transformative learners that understand power structures no matter their social position.

To create critical consciousness through science curriculum, or critical science consciousness (Crabtree & Stephan, 2022; Crabtree, in press) teachers must guide students through many forms of macro and micro objectives. McLaren & Kincheloe (2007) explain that micro-objectives focus on specific science content (the curriculum) and that macro-objectives situate science content in larger social and political

worldviews. Comprehending and dismantling the relationship between micro and macro components of scientific issues within this context requires not only an understanding of the social, political, and economic state, but also an understanding of the power structures that control it. Since cultural contexts have a hierarchy of levels (dominant, subordinate and subcultures), dominant cultures can maintain hegemonic practices and knowledge, preventing individuals from learning about other cultural and social contexts of knowledge. To address this dominance, research must disrupt the relationship between power and privileged knowledge in the scientific classroom. More importantly, discussing cultural hierarchies in society directs student learning towards critical consciousness rather than a mere acquisition of knowledge.

When schools choose to not foster levels of critical science consciousness (Crabtree & Stephan, 2021) they fall into the trap of becoming institutions of social reproduction (McLaren & Kincheloe, 2007). Social reproduction occurs "when schools perpetuate or reproduce the social relationships and attitudes needed to sustain the existing dominant economic and class relations of a larger society… or the intergenerational reproduction of social class... by establishing social practices and characteristics of the wider society" (Darder et al., 2017, p. 72; see also Giroux, 1984). Critical science pedagogy aims to disrupt social reproduction. Within the science

classroom this goal can be achieved by using curricula to foster critical science consciousness via critical scientific literacy.

CP sees schools as politized places of indoctrination, socialization, and instruction, but also recognizes the cultural terrains that can promote social justice, student empowerment and self-transformation despite hegemonic reproductions. In science curriculum and pedagogy, this dialectical process requires an explicit critical perspective as opposed to a focus on content in an arbitrary social context. This critical requirement rejects the objectivity of science, problematizes its history, and disrupts the status quo through social and civic action. Once the requirement for criticality is realized, to change the curriculum's message to one of liberation, one must first identify its hegemonic challenges.

Hegemony Within Science Education

Hegemony is a process of social control that is carried out through the moral and intellectual leadership of a dominant socio-cultural class over subordinate groups (Darder et al., 2017; Gramsci, 1971). While hegemony itself may be overt, it is often a silent process. It operates covertly within visible systemic structures like racism and neoliberalism to uphold the status quo. As such, those who are marginalized and oppressed can unknowingly perpetuate hegemonic structures through their actions that

support the systemic foundations of the same structures which caused their oppression (Freire, 1970, 2000). Counter-hegemony is the antithesis of this process. It disrupts and reconstructs power relationships to bring to the forefront perspectives that are traditionally marginalized and excluded from educational foci (Roth & Calabrese Barton, 2004). While counter-hegemony is simple in theory, it is difficult to achieve in practice. Counter-hegemony challenges individuals to resist the status quo, to not only liberate themselves and others, but to also abandon systems that uphold the dominant ideologies of society.

Science education is affected by historical, political, and moral dimensions that situate it in a hegemonic and problematic space (Morales-Doyle, 2019; Mutegi, 2011; Tolbert & Bazzul, 2017). These dimensions are often used to reinforce universalist and technocratic arguments that attempt to challenge and dismantle conversations about equitable and socially just science pedagogy (Sheth, 2019). As a result, science remains a component of larger systems of structural racism, settler colonialism, heteropatriarchy, and neoliberal capitalism (Morales-Doyle, 2019) which hinder counter-hegemonic approaches to curriculum and pedagogical practices. Mutegi (2011) for example, posits that, despite 30 years of "*science for all*" science education reform, educators have not yet developed curricula that is inclusive of all students. Atwater and Suriel (2010) explain

that AAAS' call for "s*cience for all"* was misleading since multiple perspectives of science education marginalize minoritized groups and is indeed not *science for all students* as it was suggested. They suggest the use of social justice in a multicultural context to promote anti-racist science curricula for social justice outcomes. Dzurick (2018) further highlights that "s*cience for all"* additionally omits the perspectives of those who identify as LGBTA . It appeals to teachers who wish to create culturally relevant curriculum, who see scientific knowledge as universal, and who wish to address inequitable practices. Furthermore, no one would argue with the term "science for all." It sounds equitable, but hegemonic traits are easy to overlook and easily permeate their way into science curriculum. So, while "science for all" initially seems unproblematic, when viewed with a more critical lens it has multiple meanings and excludes individuals from the conversion.

Science itself is not perpetuating these problems, those who practice science from inequitable perspectives, for inequitable means, and those who control how others come to know science permit inequitable epistemologies to thrive (Marks, 2017). Still, the realization that individuals do not always use scientific knowledge for good and for the benefit of "all" people needs more attention. For example, for much of the 20th century socioeconomic disparities were linked to the lower average IQ of African

Americans when compared to White Americans. However, socio-political factors that explain this disparity are overlooked. Smedley & Smedley (2018), unpack the usage of scientific knowledge to justify centuries of racism and the creation of a racialized worldview in the United States. For example, in the 19th century, scholarly individuals like Joseph Le Conte, Nathaniel Shailer and Herbert Spencer advanced racism by validating false views about the so-called scientific justification of race. This information was widely shared in publications and leading journals such as *Science, Scientific Monthly, The American Naturalist and Popular Science*. Today we know that there is no scientific evidence to support claims of genetic difference between races. However, those in power relied upon this misinformation to make decisions and legislate public policies that still disproportionally affect marginalized individuals today (Donovan et al., 2019; Marks, 2017). More central to the classroom is the glossing over this same topic in high school biology classes. Review of 19th century mendelian genetics is seldom taught from a perspective of racial intolerance; therefore, unfounded genetic rationales for human difference continue to persist. Donovan et al. (2019) surveyed 721 students from affluent, majority-white high schools in the United States and found that one in five agreed with genetic essentialism. Donavan and his colleagues also found that teaching about human variation in the domain of genetics from a social perspective

potentially can have powerful effects on social cognition during adolescence and reduce racial bias. Thus, as educators challenge scientific objectivity and its usage to promote inequities and racism in social systems, solutions to these challenges must be prioritized in educational reform.

Resistance to the status quo in schools is an act of liberation for policy makers, teachers, and students. Enacting a type of sustainable praxis in the classroom promotes counter-hegemony (Freire, 1970), which entails a cyclical process of reflection and action or more appropriately, reflection in action (Fleischer, 2009). Today, in hopes of minimizing the proliferation of inequitable science learning, contemporary research focuses on teachers recognizing resurgence of hegemony in the science classroom. However, specific research regarding hegemony within curriculum is limited. It is wonderful that teachers are developing their own critical consciousness to address inequitable practices in the classroom. This development is the goal of frameworks like culturally responsive pedagogy, democratic education, and multicultural education. Since teachers and school leaders are the gatekeepers within school communities, these frameworks seem to predominantly focus on their praxis in relation to curriculum and pedagogy. However, this study intends to investigate the relationship between curriculum and pedagogy and students' individual praxis process. Critical science

agency (discussed later) appropriately promotes the enactment of praxis for social justice for students. Next, this literature review will justify the need for a more critical focus on science pedagogy and curriculum in elite school communities.

Social Justice and Privilege in Independent School Education

In the Digest of Educational Statistics (Snyder et al., 2019) commissioned by the National Center for Education Statistics (NCES) in the 2017 - 2018 school year, 100,000 public schools in the United States reported that 55% on average of their enrollment identified as White. Of those 100,000 public schools, 30% had an enrollment of 80% White or higher. In that same year there were approximately 32,500 private schools in the United States and their total student enrollment was recorded as 68% White on average: 13% higher than public schools. Comparatively, of those 32,500 schools, almost half (48%) were 80% White or higher. In comparison to public schools, almost half of nation's private can be classified as predominantly White; with enrollment that is least 80% white.

Predominantly White schools can also be defined as communities of privilege, which additionally are not explicitly studied in connection to social justice, science, or education. In this study the terms “communities of privilege” and the “privileged”, are described as those who are conditioned to “be the beneficiaries of injustice and see

themselves as implicated and having some collective responsibility for the perpetuation of injustice" (Choules, 2007, p. 474). These terms are however used with caution since scholars have warned that the term "privilege(d)" often obscures the subject of domination by describing oppression as happening without the knowledge of the oppressors. For example, Hernández-Sheets (2000) mentions that this "nice word" can "reinforce feelings of superiority and help construct personal and group identities based on the devaluation of others" (p. 19). To avoid reinforcing injustice, McIntosh (1992) describes "privilege" as a set of unearned advantages based upon socially constructed categories (race, gender, sexual orientation, etc.) and bestowed upon people who are largely unable to avoid benefiting from it regardless of their level of consciousness. In this respect, the benefits are attempted to be separated from the individual. Hackman (2005) designed a process to identify who is privileged and who is marginalized in each situation. For example, her taxonomy identifies dominant individuals as people who are actively taught not to see their privilege, believe their life and its privileges are the 'norm' for society and humanity, and have done nothing to earn the benefits that accompany privilege. Hackman's taxonomy however excludes those who have identified their invisible privileges.

Goodman (2011) further refines this identification process by distinguishing

among different types of privileged individuals such as: 1) lack consciousness regarding privilege and its benefits, 2) easily deny or avoid the privileging process, or 3) those who hold a sense of superiority and entitlement that their needs should be met, even if it is at the expense of the oppressed. Goodman's last distinction is particularly poignant and closely connects communities of privilege to social justice and hegemonic driven discussions. For Goodman privileged individuals can also be those who maintain cultural and institutional domination by 1) creating structures and systems that reflect and promote the internalization of privileged values, 2) normalize their values and beliefs by supporting certain policies and practices, 3) believe in the superiority of their privileged values, and 4) actively grant material and psychological benefits to others at the expense of subjugated groups. This description highlights both subtle and explicit intentions that are hegemonic in nature. These same systems can be perpetuated in school communities and classrooms.

The dismantling of hegemonic practices in predominantly White schools requires attention in science education research. Howard and Maxwell (2018) state that "the undoing of privilege occurs not by individuals confessing their privileges or trying to think themselves into a new subject position, but through the creation of collective structures that dismantle the systems that enable these privileges" (p. 263). Further, the

individual transformation toward more socially just views of the world must take place concurrently with efforts to transform the institutions that structure individuals' everyday experiences. Bergerson (2003) explains that White individuals do not see their own race and thus are not always aware of their own privilege. There can be an inability or unwillingness to see the impact of their whiteness, especially since class, race, and issues of equity are not explicit conversations within classrooms due to tacit acceptance of values and assumptions held by privileged ontologies and epistemologies (Hinchey, 2010; hooks, 1994). However, the explicit exploration of hegemonic practices within science teaching and learning creates unique challenges when attempting to disrupt dominant perspectives in the privileged classroom (Braaten & Sheth, 2017; Parsons, 2014).

Privileged Students

Despite support and desire for social justice pedagogy in privileged education communities, some literature concludes that addressing social justice learning within a privileged space can inherently reproduce hegemonic structures (Seider, 2008). Students often learn about social justice through examples of disadvantage and deficit perspectives, limiting their understanding of how inequity operates in social and economic systems and the role privileged individuals have in reproducing these

systems (Howard and Maxwell, 2018). Additionally, affluent families reflect upon their own privilege and class by a hierarchy of comparison (Seider, 2008). As a result, affluent children often grow up with a lack of social responsibly and empathy in response to the challenges of other individuals in their local, national, and global communities.

Given the perspectives of privileged and elite school communities, what can educators do to support students' development of social justice thinking? Swalwell (2013) analyzed observation and interview data during a case study of eleven elite private high school history class students. Using Westheimer and Kahne's (2004) framework for justice-oriented citizenship, Swalwell's (2013) findings reveal a disconnect between students' conception of justice and the goals of justice-centered pedagogy. Rather than encouraging critical reflection or action, elite student education supports the development of individual character traits that (in)advertently equate good citizens with those who maintain the status quo. Even though students didn't reject the idea of being justice-oriented citizens, they overlaid their perception of justice onto "a deeply embedded logic of privilege that naturalizes hierarchies and disembodies injustices from individual and structural re-instantiations of supremacy" (p. 8). Schools' silent "embedded logic of privilege" is a superficial commitment to social justice that reinforces privilege in the minds of students. Recall the chemiosmotic

concentration gradient analogy from chapter one. Swalwell also agrees that social justice work, especially in elite spaces, requires a dedication to disrupt many "deeply held worldviews produced, supported and made invisible by the systems that privilege them" (p.8).

Other studies report that pK-12 students have less resistance to change, but still feel guilt, fear, and discomfort in response to learning about to social justice issues. This may result from students' and teachers' lack of critical consciousness, underdeveloped cultural competence and limited experiences with oppression (Seider, 2008). In a mixed method comparison of two high school literature and justice courses, Seider (2008) shows that students in the justice-centered treatment class displayed a significant decline in their support for educational equity over the course of the semester in comparison to their peers in the control group. Educational disparities in the United States based on socioeconomic status were not concerns for the treatment class. Instead, those students adopted the privileged perspective that wealthier communities have a right to higher quality education and that their tax revenues should not be redistributed from wealthy towns to poorer towns to create more equitable educational opportunities. Qualitative data from the same study showed more students were fearful of becoming poor or homeless or not becoming "one of those people" (p. 25). The study

did not discuss how participants' opinions were unpacked or confronted in the classroom or how curriculum was used to highlight the need for social change. However, Seider acknowledged that future research is needed to address two other study outcomes: some students developed compassion towards the less privileged, and some students developed a deeper commitment to social justice and social responsibility. Curry-Stevens (2007) conducted a qualitative study of twenty community-based practitioners working with privileged learners around race, class, and gender in Canada. This study used a political, counter-hegemonic, and transformative "pedagogy of the privilege" framework to create allies in the fight for justice and broader societal change. What is specifically unique about Curry-Stevens' framework is the distinct understanding that the path to the catalysis of critical consciousness and cultural competence of privileged students might be different than the of marginalized communities. A significant finding of this study was the understanding that the transformative process of participants needed "certain learning to be accomplished before more resistance-inducing and psychologically imperiling lessons could be learned" (p. 55) and that awareness-building must be partnered with confidence-building activities to prepare learners to act as allies for change.

Gaztambide-Fernandez et al. (2013) would disagree that privileged individuals

are often ignorant of the benefits of their elitism. In their response to Swalwell's (2013) study, Gaztambide-Fernandez et al. problematize the relationship between economically privileged groups and the oppressed. Since privilege is often defined based on what others do not have, there is almost a need to uphold the differences between the two groups. Therefore, the economically elite need the poor to define their place as elite. Since the elite have very limited contact with disadvantaged individuals, those that are committed to socially just change are often simply doing so to uphold the public image of the privileged. Additionally, Swalwell's study reported most students focused on presenting themselves as good people with good moral character and that these desires were justice-oriented, but Gaztambide-Fernández et al. add that these good acts may also be motivated by a desire to distance themselves from their privileged circumstances. Therefore, there is an "important symbolic role that economically disadvantaged groups play in the imagery of students who attend elite private schools" and unless privileged individuals concurrently examine their sense of entitlement and challenge their own privileged ways of knowing and doing," justice-centered acts may continue to be about their own self-improvement (p. 4).

There continues to be a need for studies to unpack the limited ways students view their sense of social responsibility as elite individuals, to challenge their privileged

beyond gender race and sexuality, and to understand how the background of students may influence students' ability to participate in social action (Swalwell, 2013).

Justice-Centered Science in Elite School Education

Multiple researchers in science education have shown that justice-centered approaches to science curriculum create positive science experiences for marginalized youth (Braaten & Sheth, 2017; Sheth, 2019; Walls, 2016). Other studies highlight the connection between the sociopolitical and critical actions of students and the ways these actions contribute to the development of their science learning (Morales-Doyle, 2017; Upadhyay & Gifford, 2010). However, similar studies have not been conducted in elite and privileged school contexts. There is a faulty assumption that elite schools provide the best science education and that their students are being taught to explicitly address inequities within larger oppressive systems. Freire (1970, 2000) reminds us that building a more humanistic and democratic society requires oppressed individuals to not only liberate themselves, but also liberate their oppressors. Since members of privileged and elite school communities are likely to be the same adults that occupy positions of power in their adult lives, they also need critical consciousness to orient themselves towards justice-centered decision making (Swalwell, 2013). However, this deep understanding

of hegemonic practices within science teaching and learning is limited and needs to be explored (Braaten & Sheth, 2017; Parsons, 2014).

In agreement with creating a just society for all, recognizing one's responsibility to challenge hegemony and dismantle structures that perpetuate cultural marginalization of subordinate groups is something that should not be ignored (Darder et al., 2017). Consequently, as we expand our focus of preparing science teachers to become educators who use social justice practices with racially and ethnically diverse students, we should also prepare teachers to do the same within predominantly white classrooms. To disrupt the status quo in elite school classrooms, teachers need to be pedagogically deliberate. Socially just discussions and thinking must be an explicit and desired outcome of curriculum; otherwise, intentional critical thinking around social issues will not occur. The science classroom presents an opportunity to implement a curriculum that can promote justice-centered learning to support the development of critical science agency. The second section of this literature review will describe the theoretical foundations for teaching science for social justice.

Teaching for Social Justice

In this section of the literature review, the proposed conceptual framework and the literature that supports the rationales for this study will be explained. A general

description of teaching for social justice will be followed by an explanation and analysis of studies that support the development of teaching science for social justice.

Social justice education examines how educational institutions both unintentionally and intentionally reproduce social inequity based on social group membership, power, and privilege (Burrell-Storms, 2014; Picower, 2012). Equity-based research emphasizes the idea that society is unjust and operates through systematic relationships of power that promote, reinforce, and sometimes thrive upon inequities (Dimick, 2012). While many would argue that today the definition of social justice is unclear or vague, and requires further definition and theorizing (Chubbuck, 2010; Dimick, 2012; Maulucci, 2012; Morales-Doyle, 2018; Novak, 2000), the lack of clarity does not suggest dismissal of its goals and its application in an educational setting. For example, Hackman (2005) explains that social justice education includes "tools for critical analysis" and "tools for action and social change." The use of these tools enables students to "critique systems of power and inequality in society" and "learn that social action is fundamental to the everyday workings of their lives" (p. 106). Chubbuck's (2010) perspective centers on social justice practices being implemented by teachers from an individual and structural orientation. She organizes social justice teaching into three parts that will: 1) improve the learning and life opportunities of *all* students, 2)

inspire teachers to challenge and transform educational policies that diminish students' learning opportunities, and 3) create curriculum that challenges students to look beyond the adds that social justice education in marginalized communities should 1) balance emotional and cognitive components of learning, 2) acknowledge and support personal experiences while illuminating systemic problems, 3) attend to relationships within the classroom, and 4) utilize praxis as tools for student centered learning, value awareness and personal growth.

These examples have subtle differences, but each shares a commitment to transformative processes and the explicit need to address oppressive and inequitable systems within schools, classrooms, and students' lives. Social justice education will continue to evolve, but what is most important to note is that its meaning and application change based on the context of its use (Grant & Agosto, 2008). Social justice science examines "science teaching and learning practices that empower children, build solidarity, and initiate societal changes" to develop "values of a socially just and democratic society" (Zembylas, 2005, p. 710). However, what should the focus of science education be? Equitable science teaching methods, teaching students how to be more equitable individuals, or both? Inspiring students to act in more socially just ways and what that looks like in the science classroom is the focus of this study.

Framework for Teaching Science for Social Justice

Science education has its own development of similar theoretical intersections that promote teaching for social justice. For example, science teaching for critical literacy (Hodson, 2003; Weinstein, 2009; Zeidler et al., 2016), teaching science for social justice (Calabrese Barton & Upadhyay, 2010; Maulucci & Fann, 2016), multicultural science education(Atwater, 2010; Atwater et al., 2013), anti-racist and inclusive science education (Braaten & Sheth, 2017; Parsons, 2014), sociotransformative science curricula (Mutegi, 2011; Rodriguez, 1998, 2015), and critical science agency for students (Basu et al., 2009; Schenkel & Calabrese Barton, 2020). Other scholars have developed socially transformative frameworks that foster development for students to disrupt the status quo and hegemony (Morales-Doyle, 2017; Mutegi, 2011; Rodriguez & Berryman, 2002; Santos, 2009). As these areas begin to develop, others still acknowledge that social justice is undertheorized in connection to science education (Dimick, 2012; Maulucci, 2012).

A review of the literature on the changes in justice- centered science pedagogy reveals two diverging areas: social justice science teaching and teaching science for social justice. Social justice science teaching focuses on children having access to good teachers, materials for learning, and the opportunity to achieve success (Calabrese

Barton & Upadhyay, 2010; Moje, 2007). Similarly, Atwater & Suriel (2010) agree that a critical stance to social justice can be used to "analyze and examine the inclusion of all students in the learning process of science so they all obtain quality science education" (p. 275). All students certainly need access to quality science pedagogy that allows them to develop science knowledge and the habits of mind for engaging in the world in empowering ways (Calabrese Barton & Upadhyay, 2010). Unfortunately, conventional pedagogies often reproduce cultural dominance and risk assimilating all people into a dominant perspective (Cobb et al., 2015). Social justice in science learning is about (a) fairness and equal access to the most challenging and beneficial educational experiences; (b) full participation that enables teachers and students to see, understand and apply science to their lives; and (c) relevance and resisting the social evils of the world (Ayers et al., 2009). A social justice science curriculum is not a simple matter; it is about relevance, rigor, and, possibly, revolution. In this case, "revolution means activism and change from the status quo" (Atwater, 2010, p. 104). However, this study will focus less on the challenges of access and equitable teaching and more on the ability for students to develop their sense of social justice thinking.

Teaching science for social justice focuses primarily on curriculum and pedagogy by providing "opportunities to question, challenge, and reconstruct knowledge… [and]

offer possibilities for transformation, not only of the learner, but also of the social and political contexts in which learning and other social action take place" (Moje, 2007, p. 4). Barton and Upadhyay (2010) explain that these are crucial focuses for science education. Access provides skills for functional scientific literacy but ignores skills required for the development of cultural competence and the critical consciousness of students. Teaching and learning science for social justice, therefore, "challenges the socio-political context of science teaching and learning that exists in the current system, thus challenging the functional view of science literacy" (p. 3).

Rodriguez and Morrison (2019) researched the need to better conceptualize and operationalize the construct of social justice in science education research. In their analysis, they conclude that the operationalization of social justice requires a deeper conceptual understanding and ideological repositioning of the impact of research. Specifically, research needs to identify the ways in which diversity and equity are leveraged towards the goal of social justice. These studies need to occur within classrooms, in teacher professional development, pre-service teacher education programs, school leadership and informal learning settings. This broad scope of social justice science education will inform ways to decolonize science teaching and learning. Rodriguez and Morrison also present a counter-perspective to traditional foundations

of research. They challenge researchers to consider that we must be willing to redirect our gaze from traditional gap gazing (e.g., focusing on what's lacking) to gazing inward and focusing on the transformative role we can (and should) play to make our research efforts more responsive (and responsible) to the communities with which we work (p. 279).

This redirection of our research lens is an important point of consideration. I also take this to mean that as pioneers of social justice research we are called to not only conduct research to fill gaps but question implications that have not been identified in current research. Meeting this challenge is especially important to this study because independent schools are non-traditional locations for research, and the questions that may arise from this niche are overlooked by educational researchers who focus on public pK-12 and higher education.

For the purposes of this review, Dover's (2009) conceptual framework for teaching for social justice is used to provide a rationale for teaching for social justice in K-12 science classrooms (see figure 1). The model draws from five conceptual and pedagogically related frameworks of educational theory that reference six elements of teaching for social justice (critical pedagogy, multicultural education, culturally responsive education, social justice education and democratic education). From these

educational frameworks, Dover established the following six integrated themes for educators who wish to teach for social justice in K-12 classrooms which are:

1. Assumes all students are participants in knowledge construction, have high expectations for students and themselves and foster learning communities.
2. Acknowledges, value and builds upon on students' existing knowledge, interests, cultural and linguistic resources.
3. Teaches specific academic skills and bridge gaps in students learning.
4. Works in reciprocal partnership with student' families and communities.
5. Critiques and employs multiple forms of assessment, and
6. Explicitly teaches about activism, power, and inequity in schools and society.

Building on the work of Cochran-Smith (1999, 2004), Dover creates a foundation for future empirical research that centralizes the concept that teaching for social justice impacts student's ability to enact social justice thinking in their own lives. Specifically, she emphasizes a need for future studies to observe the "relationship across teachers' social justice intentions, classroom practices, and students' outcomes. For example, how teaching for social justice facilitates content learning, critical thinking, and cultural competence" (Dover, 2013, p. 10). How Dover's framework impacts students' learning of science content, critical thinking and their cultural competence is of specific interest

to this study (corresponds to principles, 1, 2 and 6 listed above). Recent work has expanded into an area called justice-centered or justice-oriented pedagogies. This area of research problematizes privileged forms of science and focuses on larger justice-centered outcomes of learning (Bang & Vossoughi, 2016; Davis & Schaeffer, 2019; Philip & Azevedo, 2017) by relying on students' funds of knowledge and acceptance of multiple epistemologies of science pedagogy (Calabrese Barton & Yang, 2000; Nasir & Hand, 2006).This requires students to examine socioscientific issues that are personally relevant, and community based.

Dimick's (2012) student empowerment framework is one such example of teaching science for social justice. This case study of an urban charter high school environmental science classroom examined: how student empowerment aligned with teaching and learning social justice science education, what ways students experience empowerment within the classroom, and how does the teacher facilitate experiences of empowerment for his students? The three areas of empowerment were academic, social, and political empowerment. The study takes place in a white male teacher's environmental science classroom with 24 African American students in 11th and 12th grades while students study the pollution of their local Green River. Dimick describes the enactment of academic empowerment as a requirement for students to learn

scientific knowledge that is useful to their lives in a social, economic, historical, and political context. This type of science learning is integrated and provides more opportunities for student to use science to problem solve, think critically, and make better decisions. Social empowerment focuses on the interactions between student and teacher and student and student in the classroom that are "safe, nondiscriminatory and anti-oppressive" (p. 995). It is a continued analysis of how pedagogic practices influence the social dynamic of the classroom. The teacher plays a large role in social empowerment and their pedagogical decisions help bolster the ability for students to foster these skills. Lastly, political empowerment is "students' recognition and intentional, critical examination of the structures and forces that establish and maintain power inequities within the sphere of political participation (p. 995). The real-life experience of students having their own control, influence and enactment of their knowledge can manifest within the classroom (student directed learning) or outside the classroom (community connections, environmental activism).

Dimick's study parallels all the aspects of Dover's (2009, 2013) framework and six specific tenants for teaching for social justice from Cochran-Smith (1999, 2004). Her study is informed by a CP theoretical framework, its parallels to multicultural science education, culturally responsive science education, social justice science education and

democratic science education. Additionally, students participated in knowledge instruction as they built on their existing knowledge in a cultural context. They partnered with members of their local community to address environmental issues about Green River, and they explicitly learned about activism, power and equity. There was no specific mention of multiple forms of assessment, but given's Dimick's research focus on empowerment, that may have been outside of the scope of the study. The findings show that students believed they improved their own social and political empowerment, but the participants highlighted a lack of focus on science content during the project. This suggests that research should continue to identify how to balance pedagogical and content-based goals in the science classroom when fostering social justice thinking is a desired goal.

Dimick's study also serves one additional purpose. The three themes of student empowerment are not unlike additional work done by Dover to explain her teaching for social justice framework. In addition to her 2009 study, Dover theorized that there are three areas that contribute to the development of classroom communities that enact teaching for social justice. Her study included 24 secondary English teachers in urban classrooms of mostly student of color from marginalized communities. The findings thematized the teacher's descriptions of how their introduction of social justice teaching

into their classrooms related to three themes: curriculum, pedagogy, and social action (Dover, 2013). Dimick's study serves as science classroom-based example of these themes quite well. Academic empowerment prioritizes how students connect with science curriculum, social empowerment mirrors pedagogical decision making made by the teacher to help develop socially just learning through relationships in the classroom and political empowerment parallels social action by inspiring students to participate politically and work towards a more socially just society. Studies that promote teaching for social justice do not always parallel curriculum, pedagogy, and social action as seamlessly as Dimick's work, there are those that address teaching for social justice through one, two or all three themes in some way. What follows next is an analysis of the three components of teaching science for social justice, critical science literacy, justice-centered science pedagogy and critical science agency.

Critical Science Literacy

Curriculum according to Null (2011) is a combination of the philosophical, ethical and teleological foundations of the information taught or not taught in the classroom. For curriculum to be enacted it requires the participation of teachers, learners, subject matter, context, and the actual creation the curriculum. Dimick (2012), calls this academic empowerment, but it also serves as a contributor to social justice

learning. In science the focus of curriculum is then on learning science knowledge, the processes, or methodologies that scientists use, and of most interest this study the applications of that science in society.

Questioning power, knowledge, and the production of science in school is not a new objective for science education. Using critical race theory, feminist and multicultural frameworks as theoretical lenses have challenged the direction of science for at least 20 years (Suriel & Atwater, 2012). Empirical studies have highlighted the need for these perspectives but adding criticality to science curriculum is still being substantiated. Letts (2001) citing the work of Hess (1995) shares that often our ideas about what science content should be is at odds with the trajectory of research. Many scientists and engineers feel the question of content is "anathema if not nonsensical", because theories, methods, and technical design are often assumed to be neutral and separate from culture (p. 253). Everyday science knowledge and habits of mind need to be more nuanced to meet the needs of most people, not the few that will be in formal science careers (Kahn & Zeidler, 2016; Zeidler & Sadler, 2011). Hodson (2003, 2011) says that ordinary people are asked to make decisions about social situations that are ungirded by science and technological knowledge with much wider considerations. Unfortunately, science curriculum tends to be used as mechanism for what it means to

"know and do science" instead of a means of empowerment where individuals learn and are valued for their abilities to use science knowledge to contribute to, critique, and partake in a just society (Roth & Calabrese Barton, 2004; Sadler, 2011; Zeidler, 2014). Scientific literacy has been the encompassing term that science education research uses to connect the purposes of the curriculum and its necessary outcomes.

Reimagining Scientific Literacy and Socioscientific Issues for Social Justice. The term scientific literacy has been placed at the forefront of science education reform for more than 50 years. While there has been disagreement about its meaning, there is consensus that it is an important and overarching goal of school science (Hurd, 1958; Sadler, 2004). As a result of its scope of meanings, it is important to identify the context in which this study intends to use the term scientific literacy (Roberts, 2007; Roberts & Bybee, 2014). In relation to social justice science curricula, scientific literacy is the "development of an individual's understanding or ability to grasp how scientific enterprises are embedded within socioscientific issues or SSI" (Zeidler, 2014, p. 697). This is exemplified when students apply their scientific knowledge to solve socioscientific problems in the real world. Roberts (2007) has extensively reviewed the evolution of scientific literacy and its application in science curriculum and policy in attempt to identify common uses of the term. Specifically, Roberts & Bybee (2014)

identify two visions of scientific literacy. Vision I, the more traditional and common implementation, introduces students to "the enterprise of science" via practicing scientific skills implemented by science professionals. The American Association for the Advancement of Science (AAAS, 1990) describes this as using "scientific knowledge and scientific ways of thinking for individual and social purposes" (p.4). This view limits the focus of science to one that relies solely on science content as the source for student's scientific knowledge.

In contrast, the vision II understanding of scientific literacy uses a more integrated approach. By looking outside of science disciplines to build curriculum, vision II connects personal and societal perspectives including political, economic, and ethical considerations. Under the vision II understanding, scientifically literate citizens make decisions mediated by their ability to understand how their individual choices affect the local and global community. This is exemplified by students understanding of sources of scientific information, critically reflecting on the presence or absence of information, and taking part in discourse with others. Students are required to gather and rely upon multiple sources and perspectives to become scientifically literate. This more functional view of scientific literacy is more theoretically based and requires "evaluation of moral and ethical factors in making judgments about the validity and

viability of situated scientific data and information" (Zeidler, 2014, p. 697). As a result, students can make more informed decisions that utilize science content to connect with and navigate SSI curricula and additionally promote their epistemological, cognitive and moral development (Zeidler & Kahn, 2014).

Specifically, SSI are open ended, controversial, socially charged issues that are impacted by politics, economics, and ethics. The SSI framework was mentioned as early as 1986 in science education literature, but it did not become popular as a research and practice framework until the late 1990's (Sadler & Dawson, 2012). It encompasses an understanding of the nature of science, the skills necessary to think both scientifically and ethically about everyday issues and it requires moral and ethical decision making, character development, social interactions and discourse (Zeidler & Keefer, 2003; Zeidler et al., 2004). Together these essential components stress the cultivation of empathetic concerns, moral and ethical reasoning, perspective-taking, and the usage of evidence and argumentation (Sadler, 2009; Sadler & Zeidler, 2009). These characteristics supports the Vision II approach to scientific literacy emphasizing personal decision making about socially based issues (Roberts, 2007, Roberts & Bybee 2014). Functional scientific literacy paves a way forward for more in depth thinking about SSI that facilitate the social, political, and historical embeddedness of scientific phenomenon. If

functional scientific literacy is the aim of science education, teachers must include attention to morality and ethics (Sadler, 2004). This point not only highlights the reasons SSI connects to the Vision II of scientific literacy; it also highlights a need for critical and social justice theoretical basis.

The Need for Critical Science Literacy. SSI-based approaches to science education can include a concern for developing scientific habits of mind in students and a social justice component. Overall, understanding science in a situated way can potentially lead to an informed citizenry, better prepared to participate in a democratic society. Critical science literacy however explicitly "requires an analysis of the shortcomings of the language of science and science education to adequately explain what appears to be the commonplace reality of the modern world—a reality that assumes society must have a hierarchy of power" (Ashby & Mensah, 2018, p. 5). There is a need for a more critical perspective for science education through more justice-centered and critical pedagogical lenses (Fusco & Barton, 2001; Tan & Barton, 2010) and specific scholars like Hodson (2003) urge future curriculum reformists to take a more critical perspective to scientific literacy in the classroom. One such example of that can be seen in justice-centered science curricula (discussed next) that focus on functional scientific literacy as Zeidler (2014) imagined but uses a more critical basis.

Recently an extension to the Vison II view of scientific literacy has been be developed to extend functional scientific literacy as Zeidler explained to include a focus on scientific engagement and "knowing-in-action"(Sjöström & Eilks, 2018). Vision III implies "a politicized science education aiming at emancipation and socio-ecojustice" and further depends on the "awareness that our view of scientific content knowledge is dependent on our culture…norms, values and worldviews, and it is dependent on the time we are living in" (p. 67). Vision III creates a critical basis for SSI demonstrating that scientific literacy requires specific aims tied to critical component. This is the basis for the use of Critical pedagogy in this study. The SSI movement aims to empower students to consider how their decision-making process reflects moral principles and qualities of virtue that encompass their own lives as well the physical world around them (Evagorou et al., 2020; Zeidler et al., 2019). However, Justice-centered pedagogy builds upon theoretical foundations of SSI to include tenants of the Vision III of scientific literacy.

Morrison et al. (2020) explain that students use their moral and ethical decision making and reasoning to address multiple perspectives in science. However, an explicit requirement for critical grounding in history, addressing inequity as components of larger oppressive systems and the requirement to connect the development of scientific

knowledge in the context of action for justice is not a required outcome. These are foundations of a critical pedagogical perspective. This does not mean that critical outcomes may not happen in an SSI centered classroom, it means that they are not explicitly required. Studies show that it is common for some pre-service teachers to reveal resistance, discomfort and pushback in response to social justice-based coursework (Cochran-Smith et al., 2008; Picower, 2012) and others discuss that if systems of inequity are not explicitly highlighted, they often are ignored or do not get addressed either pedagogically or within science content.

Additionally, recall that social justice education is most concerned with developing students' ability to critique power structures for engagement in sociopolitical action. In relation to social justice science curricula, scientific literacy is the "development of an individual's understanding or ability to grasp how scientific enterprises are embedded within socioscientific issues or SSI" (Zeidler, 2014, p. 697). This is exemplified when students apply their scientific knowledge to solve socioscientific problems in the real world not only learn about socioscientific issues.

This critical call to action as explained by Vision III is not explicitly addressed in literature focused on scientific literacy or functional scientific literacy. Sadler's (2004) review of literature highlights the effectiveness of using SSI in the classroom and

concludes that SSI may not automatically improve scientific literacy skills required to develop informed citizens. If SSI serve as curricular vehicles that stimulate intellectual growth and critical thinking in the hopes of using this knowledge in everyday life, then students must have opportunities to practice the process of reasoning, contemplation of evidence and data, and practice acting on this information. Therefore, the need to capitalize on students' emotive responses towards SSI to implement social action that can transform social practices using more critical means becomes more viable (Hodson, 2011; Santos, 2009).

Zeidler and Zeidler et al. (2014; 2019) support that one major theme and goal of SSI curricular research is to develop character, citizenship, responsibility and further extend SSI theory and practice. He asked, how can the SSI framework develop a sense of responsibility, civic obligation and activism and how can the framework of CP empower SSI research and practice? This study could serve us one such example of implementing a critical pedagogical lens to show more support for more social justice perspectives to science curriculum that focus on citizenship, character development, responsibility and further develop the theory and practice of science learning in the classroom for social justice means.

Justice-Centered Science Curricula. Next are specific examples of critical science curricular frameworks and studies that demonstrate teaching science for social justice with similar characteristics theorized by Dover (2013) which include 3 goals: 1) reflect students' personal and cultural identities; 2) include explicit instruction about oppression, prejudice, and inequity and 3) makes connections between curricular standards and social justice topics. Work by Hodson (2003), Atwater (2010), Mutegi (2011), and Morales-Doyle (2017) provide examples of the development of socially just science curricula that parallel the themes outlined by Dover.

Hodson (2003), calls his socially just minded view of science curriculum critical science literacy. In this four-level model of sophistication, students develop science inspired critical thinking about themselves and society as learning opportunities arise. These 4 levels are as follows:

- Level 1: Appreciating the societal impact of scientific and technological change, and recognizing that Science and Technology are, to some, culturally determined.
- Level 2: Recognizing that decisions about scientific and technological development are taken and pursuit of interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and

technological development are inextricably linked with the distribution of power and wealth.

- Level 3: Developing one's own views and establishing one's own underlying value positions.
- Level 4: Preparing for and taking social action.

The purpose of curriculum guided by these goals is to prepare students to increase their critical consciousness. Specifically, the ability and the commitment to take appropriate, responsible, and effective action in response to social and economic issues that are value-laden and require moral and ethical decision making. This cannot occur without students learning in a socio-political context within the classroom that provides opportunities for students to take ownership of their scientific knowledge and translate that knowledge into empowerment and action. Without personal investment and a deep understanding of the implications it is difficult to achieve this motivation. The 4 levels of CSL provide a framework for these curricula to help students go deeper and asks what it means to function in society.

Mutegi (2011) merges both a multicultural (Banks & McGee, 2010; Bennett, 2001) and anti-racist (Atwater, 2010; Nieto, 1992) focus to create a framework for socially transformative curriculum. Inspired by Freire's work, Mutegi (2011) saw the need for an

alternative to traditional western science curricula that addresses the oppression of African American students. Mutegi's 5C model for socially transformative curriculum outlines five goals, mastery of science standards (content), cultural competence (currency), racial awareness (context), critical engagement (critique), and social action (conduct). This curriculum reflects students' personal and cultural identities by investing in cultural competence, including explicit instruction about oppression with the focus on racial awareness and critical engagements, which both collectively make connections between content and social justice topics.

Social justice science issues (SJSI), developed by Morales-Doyle (2017) is a specific overlapping of socioscientific issues and culturally relevant curricula frameworks. SJSI uses a problem-posing model that acknowledges the political and social underpinnings of learning by helping students "understand and eradicate social domination and inequality" (p. 1036) by utilizing their learning in local contexts. Expanding upon the work of Dos Santos' (2009) framework of Freirean scientific literacy, problems are understood from real political and oppressive contexts. In a study of twenty 11th graders and nine 12th graders in a predominantly Latinx AP Chemistry classroom, Morales-Doyle (2017) found that student's awareness of environmental racism of coal power plant pollution was not just a SSI, but a lager generative

oppressive embedded issue, a social justice science issue. This coal power plant unit and other curriculum content supported development of students' academic achievement and provided opportunities for students to fully participate in society.

These examples parallel a similar trend that highlight a justice-centered foci of science education. They demonstrate a commitment to students' personal and cultural identities, include an explicit reliance on students learning about inequity, oppression and power and commit to prioritization of a social justice view of content for example. These similarities to Dover's work support that science curriculum can promote the development of critical science literacy for social justice outcomes.

Hodson, Morales-Doyle, and Mutegi identify some important barriers or resistance to justice-centered science curricula. Specifically, the challenges that teachers will face in implementation. Asking teachers to transition to a justice-centered approach, could severely test their competence and their confidence and will require encouragement and support through professional development and leadership to become critically literate about their own educational practice. This process should also include a commitment to continuous rigorous scrutiny and critical appraisal of their own pedagogy and curriculum (Hodson, 2003). However, problematizing ideas in science education that are typically not problematic might also receive push back from

teachers who need to develop their own critical consciousness. This requires substantial community engagement, content learning and political clarity on the part of the teacher (Morales-Doyle, 2017). Additionally, since these models go beyond super imposing anti-racist or anti-colonial thought over a colonial schooling structure, a restructuring or circumnavigating of the current system of schooling is needed (Mutegi, 2011). Curriculum must subvert schools' historical rules as producers of social inequality which requires reimagining schools and classrooms that are constructed by communities working in general collaboration with educators (Morales-Doyle, 2017). Lastly, teachers might find it difficult to assess this type of curriculum and its integrated framework (Hodson, 2003), feeling the curriculum belongs in a more humanities and language arts-based classroom (Mutegi, 2011).

The work noted above, provides examples for imagining a curriculum that supports the enactment of students' critical scientific literacy using context rich student-centered, anti-racist ways that are reflective of the political and socioeconomic foundations of societal issues. The proposed curriculum units in this study seek to understand how this kind curriculum promotes students using knowledge acquired to act in socially just ways. While there is much work documenting the benefits of these types of curricula and the challenges teachers face in their implementation, the

perspectives and outcomes on students is far less prevalent. Morales-Doyle (2017) stresses that to truly understand if science education can respond to larger issues of oppression and its effects on student's knowledge, research needs more case studies in a wide variety of contexts. Mutegi (2011) acknowledges that research should look at how students are better positioned to do what the curriculum is intending them to do versus what it looks like to teach it. He asked questions like, how is a certain curriculum moving students towards racial awareness? or what curriculum question strategies are most useful in helping students become more critically conscious? and do students respond more readily to these activities that foster practice versus those that require content mastery? Additionally, this work did not highlight any studies of justice-centered curricula being implemented in an independent school context.

Justice-Centered Science Pedagogy

Pedagogy is what one needs to know, and the skills related to justifying the decisions made in the classroom. It is the practice of "attendant discourse of education theories, values, evidence, and justifications" (Alexander, 2013, p. 47). From a teaching for social justice perspective Dover's (2013) framework uses two themes to represent pedagogy: 1) pedagogical practices carried out by the teacher that create a supportive classroom climate that embraces multiple perspectives; and 2) pedagogical practices emphasize

critical thinking and inquiry-based instruction while promoting students' academic, civic, and personal growth. In science education there are many pedagogical theories that support this perspective and while a few are highlighted below, it is not a comprehensive list, but merely a sampling to exemplify how this type of pedagogy supports teaching science for social justice.

Rodriguez (1998, 2002) uses a social constructivist lens in the development of a science pedagogy to meet social justice goals. The sociotransformative constructivism or STC framework centralizes on power as the "currency for social change" (Rodriguez, 1998, p. 599). This framework includes four components: dialogic conversation, authentic activity, metacognition, and reflexivity. The last two are similar Dover's requirement to an emphasis on critical thought and inquiry-based teaching while promoting students' academic, civic, and personal growth. Through metacognition and reflexivity teachers do more than basic thinking about thinking. Teachers and students consider power dynamics and focus on critically questioning what counts as scientific knowledge. For example, an STC approach questions whose ideas matter in science, who gets positioned as a scientist, and how issues like funding and ideology impact scientific research. Rodriguez (2002) applied STC to in many contexts like learning of pre-service or novice teachers and elementary school science learners. His study

extends the application of STC to a secondary science context to understand how justice-centered science pedagogy supports students' development of critical consciousness and cultural competence. The difference between the STC approach and others proposed under individual constructivism is that in addition to doing minds-on, hands-on activities, teachers are urged to reflect on how their pedagogy is socio-culturally relevant and tied to everyday life. Rodriguez (1998, 2008) explains that his studies do not provide guidance or empirical evidence about how proposed changes for an explicitly anti-racist education can be implemented in the classroom and that even fewer resources are available that describe effective practices from multicultural science education.

Rodriguez' findings do, however, include descriptions of strong resistance to ideological changes to science curricula by preservice teachers. He concludes that it will take more than appealing to educators' social conscience to affect change in the current methods of teaching science. The STC framework shows promise in assisting preservice teachers to critically examine their prior beliefs about what it means to be a successful science teacher who also demonstrates strong resistance to hegemonic ideological and pedagogical changes.

The STC framework provides a link between teaching for social justice and

teaching for understanding in the hopes that teachers and learners explore how issues of power and privilege, ethnicity, gender and voice influence what counts as knowledge and whose interests are protected. These strategies for counter resistance helped many participants see teaching and learning science as a socially constructed process and situated science classrooms as places of empowerment. Despite these realizations, there is a need challenge and expand teacher views of multicultural education away from a need to focus on racial difference and why teachers are opposed to these this type of pedagogy. Stronger links between the theory of social justice and social constructivism as a theory of learning are needed to provide more strategies for counter resistance and help teachers learn to teach for social justice and understanding.

While Rodriguez focuses on incorporating an understanding of power into teacher practice, Dos Santos (2009) focuses on including an understanding of oppression. Dos Santos (2009) theorized a Freirean inspired critical pedagogical approach to science that uses ill-structured social contradictions (Gutstein, 2012) or SSI as means to a dismantle oppression. His framework considers three aspects: 1) discussion of SSI relevant to student lives 2) establishment of a dialogical process involving students and teachers and 3) a commitment to sociopolitical praxis. He uses "generative words" or generative themes (Dover, 2013) and a commitment to problem-

posing pedagogy. These generative words/themes are ill structured SSI examples selected by teachers that are relevant to students, represent larger political structures and forms of domination and exploitation in society. These are then presented as problem-posing models that students and teachers are meant to find solutions for together using a dialectical process. Segura et al. (2019) shares of how two experienced science teachers and their student teachers co-constructed justice-oriented science teaching for their high school science classes in a multiple case study. They specifically focused on how pedagogical structures influenced and were influenced by their ability to teach from a social justice perspective in their classrooms. The dialectical process that balances the structure of the classroom and agency of students was an important consideration that arose from the study. One teacher realized the importance of building relationships with students was more central the integration of social justice aspects. Whereas a second teacher emphasized social justice aspects as a more central component. Each student teacher directed their attention towards what was most important based on the needs of the students but did so differently. The researchers concluded that teaching for social justice is not a short-term process, but a dialectical one between teachers and students that needs continual development over time.

Similarly, Braaten and Sheth (2017) acknowledge that teaching to disrupt the

status quo or teaching against the grain is a challenge for practitioners (see also Cochran-Smith, p. 191). In a study conducted both in a science classroom and informal after school program, one teacher explored how their teaching practices in both settings supported diverse student groups learning science. The researchers found that teachers use a mixture of ambitious pedagogical practices in the classroom that support teaching for social justice and other times they do not. For example, the teacher in their study could clearly articulate how she wanted to implement justice-centered practices in the classroom, but the challenges involved were roadblocks to her success. While this framework does seek out some similar social justice tenants, it also does not explicitly fulfil attention to critical reflection that develops students' critical consciousness.

Critical Science Agency

Social action is not a new term. It has been discussed in many forms in history and philosophy as praxis. Hannah Arendt as explained by d'Entreves (2019) developed a theory of action called *a fundamental condition of life* which includes three components, work, labor and action. The two central features of action are freedom and plurality. For Arendt, freedom is the ability to begin or do the unexpected, a gift that is given to all human beings at birth. Plurality is the requirement of that action being seen or its ability to elicit the consent of others. Central to Arendt's characterization of an individual's

power is this dialectical relationship between freedom and plurality that is realized through communicative interactions or speech and language. An individual's actions are only actualized when "word and deed have not parted company", "words are not used to veil intentions but to disclose realities, and deeds are not used to violate and destroy but, to establish relations and create new realities" (Arendt, 1958, p. 200). Similarly, to Arendt, Freire (1970) too discusses the importance of words in his discussion of dialogue but links it to a dialectical process between action and reflection; also identifying a dichotomous relationship between of the two terms. He explains that, "if one is scarified-even in part- the other immediately suffers (p. 87). Through praxis of Freire's action/reflection or Arendt's freedom/plurality dichotomy, individuals can transform the world through dialogue.

Overlaying these philosophies into today's classroom, the importance of dialogue and its connection to students' sense of agency (power over their ability to act) becomes apparent. This means that, teaching provides opportunities through curriculum and pedagogy for students to discuss science, interact with and learn scientific content. With the addition of transformative practices like justice-centered pedagogy and critical science literacy, students can use these experiences to bring about a more just society. They reflect upon the content being learned and exercise their

freedom to act by addressing inequities in their lives and communities, and they obtain plurality when others around them see and accept these actions.

An integral goal of teaching for social justice is social action which is comprised of three themes modified from Dover's 2013 framework 1) students' sense of themselves as social activists; 2) students' awareness of inequity and injustice and, 3) Student's intent to promote civic participation and social action among students promotes a socially just response. The balance between teacher's development and co-construction of pedagogy and curriculum support students' cultivation and motivation to act. The previous curricula and pedagogical frameworks all mentioned some form of social action enacted by students and or teachers.

It is essential that what students learn via curriculum about the world around them promotes responsible scientific behaviors for environmental topics, but also other socioscientific issues (Holdren, 2008; Vaz, 2005). As such, the science curriculum should include content and inquiry-specific goals and a focus on action at the individual and community levels. Freire (1970) reminds us that participation can often only be internalized through the experience of the actor so pedagogical frameworks build the classroom community that fosters the usage of curriculum to that end.

The need for teaching science for social justice to place social action as its goal is

an important and necessary one. If we hope for future generations to challenge the status quo, science education must continue to foster youth's commitment to social change. While there have been some national calls for a more critical approach to science education (Garibay, 2015) recent curriculum and pedagogical reform has not been doing enough to support the growth of skills connected to social action. Garibay (2015) found that undergraduate STEM students feel less committed to and do not see the importance of working toward social change when compared to non-stem majors. He further acknowledged white STEM majors have lower social agency in comparison to underrepresented students. This becomes problematic, in a world facing scientifically related challenges like global pandemics, global warming, climate change and renewable resources. Justice-centered pedagogies challenge students to focus more on the relationship between their social agency and their use of science in that moment and as their future careers (Alimo, 2012).

Social action can take many forms and occur at micro (individual) and macro institutional) levels. Alimo (2012), separates social action into a) self-directed, (b) other-directed, and (c) intergroup collaborative forms. Self-directed actions help individuals take steps towards addressing social inequality. Self-directed actions can include checking individual biases, learning to use inclusive language, educating oneself about

people from diverse backgrounds by reading books or community experiences. Other-directed actions are "how individuals address or respond to witnessing social inequalities exhibited by other people." Such actions include challenging racist situations within the classroom or with family, reinforcing behaviors that support diversity and anti-racism, sharing stories of personal growth related to social justice with others, informing a local legislator or business about inequitable or environmentally unsafe practices as part of a class project. Intergroup collaborative actions are "behaviors in which individuals engage with their community in some form to work toward the betterment of society". For example, joining advocacy groups at school, participating in a student led or community led protest.

It is my perspective and that of other scholars (Burrell-Storms, 2014; Nagda et al., 2003) that social action comes about from the enactment of both curriculum and pedagogy in the classroom and both are needed facilitate students' dispositions and confidence towards social action (Schenkel & Calabrese Barton, 2020). McNeill and Vaughn (2012) share that a focus only on the development of scientific literacy is not enough if the expectation of a more just world is our goal. A Vision III and critical view of science education disputes the current expectations of learning outcomes and instead turns attention toward

critical science literacy and critical agency such as using science knowledge to take action by inspiring students' passion for the hopes of social transformation (Schenkel & Calabrese Barton, 2020; Schenkel et al., 2019).

Using pedagogy and curriculum to teach science for social justice and enacting critical science agency in the classroom, is an area of research that needs more attention (Schenkel & Calabrese Barton, 2020). Critical Science Agency (CSA) embodies a focus on social action for social justice minded students. It is the capacity to act towards the realization of personal goals while merging scientific and other forms of knowledge to address instances of injustice with the power to transform reality (Basu & Calabrese Barton, 2010; Basu et al., 2009; Basu et al., 2011) Students who are enacting their critical science agency, 1) develop expertise in science with community context; 2) use expertise to identify and collectively take action on community problems and, 3) these actions are justice-centered (Schenkel et al., 2019). To develop the ability to take social action students must have a critical understanding of the world's oppressive and normal structures and have a sense of the historical, political, and economic implications of injustice. The earlier discussion of justice-inspired pedagogy and curricula support these criteria. Youth experiences push us to understand the ways in which the dominant narrative about equity focused on access to and the acquiring of narrowly

defined science knowledge and practices fails to position youth to use science in meaningful ways (Schenkel & Barton, 2020).

Democratic science pedagogy, according to Basu and Barton's (2010) study, promotes the growth of CSA by researching ways the ideas and assets of students and teachers participate in teaching science for social justice. CSA for Basu and Barton includes how teachers and students operationalize and enact democratic science pedagogy beyond the existing descriptions of democratic education in the literature. Their findings suggest that integral to a democratic classroom is the prioritization of student choice and voice which together foster a sense of agency. The enactment of student agency is seen through, instances of students documenting issues of power and injustice, practicing subject matter expertise, demonstrating engagement, and leveraging that expertise to reflect and act on injustice in their lives.

Schenkel et al. (2017) conducted a critical ethnography during a week-long informal summer STEM program for 6th graders that focused on community sustainability. In particular, their goal was to support youth in developing science practices and knowledge as they deepened their understanding of community challenges while working on engineering designs. To demonstrate a commitment to democratic pedagogy and the enactment of CSA, the curriculum was co-revised with

student participants, 10 girls and 2 boys from diverse SES backgrounds and ethnicities. Their findings show that students began to identify the intersecting components of injustice in their community with larger and systemic patterns of injustice. Enacting CSA involved a growth in political consciousness through the simultaneous process of scientific sensemaking between content and personal experiences. As a result, youth reshaped their own knowledge and the hierarchy of their communities as they sought solutions to their problems. They realized the power of collaboration with one another and with community members was more effective than working to break down privilege notions and power individually. The authors acknowledge that power imbalances within the structure of science as a discipline can create and sustain dominant views of science that has a colonizing effect rather than equity-oriented one. A critical science agency lens requires those who will become critically scientifically literate to use their knowledge and the practices of science in an integrated manner. This includes but is not limited to social action in response to critical issues and a use more equity-oriented approaches in the classroom that merge scientific knowledge and practice to address instances of injustice.

The CSA framework embodies the requirements of Dover's teaching for social justice with a scientific perspective. It does an excellent job of balancing the input from

the teacher, but centers on the social action being completed by the student. It increases student's awareness of inequity and injustice and their intent to promote civic participation and social action.

However, much of the work cited in this section has emerged in the last 11 years (2011 – 2020) which indicates a need for more development of the framework and empirical studies in diverse settings. A need remains to explore and understand how and what actions students in science classrooms seek to take that originate from their understanding of sociopolitical issues connected to them and their communities (Upadhyay et al., 2020). Like the earlier review of justice-oriented curriculum and pedagogy, more research is needed regarding youths' enactment of social change in elite and privileged science classrooms.

Chapter Summary

The literature synthesized in this chapter discussed examples that support a vision for teaching science for social justice in an independent school context. My goal was to answer multiple questions to highlight the collective implications of the findings of this review and serve to identify gaps within the literature that provide a foundation for this study.

Most research centered on social justice continues to be conducted in in urban,

diverse, high poverty schools. As educators, we have a responsibly to research multiple settings including predominantly white, elite schools that are traditionally overlooked and absent from research in many disciplines, including science education. Owens, Sadler & Zeidler (2017) point out the challenge that science educators face, given the divisive times that face us, of getting students to recognize multiple perspectives and be open to evaluating evidence that may conflict with their normative beliefs in order to engage in civil discourse. Given the current social and political climate of the United States, we additionally have a responsibly to these communities to "prepare them to lead change and dismantle inequities in our society into the future" (Anderson, 2019, p. 54). I illustrated the complex nature of teaching for social justice and its range of meanings. These interpretations require educators to clearly denote the educational context in which justice-oriented goals are being centered, to mitigate the challenges of that lack of clarity.

There is significant research in science education that discusses a distributive approach to social justice but, research is needed on student outcomes (Dover, 2013), in multiple contexts (Morales-Doyle, 2019) and theoretical frameworks (Rodriguez & Morrison, 2019). Research also focuses on the challenges that teachers face implementing justice-inspired curriculum and pedagogy, but the lack of resources and

frameworks that inform how to do so are limited.

CHAPTER THREE: METHODS

This study was an embedded multiple case study that aimed to understand the experiences of two teachers and students from their classrooms as they taught, reflected upon, and experienced a justice-centered science course. Using the Teaching science for social justice conceptual framework model I observed how teachers implemented a justice-centered science pedagogy (JCSP), observed students' and teachers' evidence of critical science literacy, identified students' demonstration of critical science literacy in their classrooms observed lessons, reviewed unit plans, collected student artifacts, and interviewed both teachers and students. I also collected information about their school and its support of justice-centered practices to provide the context of an independent school community. Through this process, I gained an understanding of how these two teachers enacted their planned JCSP lessons and students' perceptions of science and justice-related goals.

In this chapter I will review the purpose and research questions guiding this study, present the design for the study, introduce the participants, describe the recruitment processes, and make statements regarding quality criteria, ethics, and limitations.

Research Questions

The research questions provided a guide as I gained an overall perspective of what it looks like to teach JCSP in the two selected independent school classrooms. Rationales for each individual question, which are embedded in the extant literature, have been previously presented in chapter one and figure 3.

RQ1) How do independent school students understand science within a classroom using teaching science for social justice?

RQ1a) In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom?

RQ1b) To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?

Purpose and Research Design

The aim of this study is to understand the classroom community at an independent school and the impact of social justice-driven pedagogy and curriculum on students' development of science expertise and critical science agency. This development requires a critical understanding of the world, the historical rootedness of injustice and its oppressive norms and structures (Schenkel & Calabrese Barton, 2020).

Classrooms are complex interlinked environments with multiple contexts and phenomena occurring simultaneously. Students come from a variety of backgrounds and have unique interactions with the science curriculum and their teacher's pedagogy. Specifically, this study explored social phenomena, human behavior and interactions in the science classroom which relied on verbal and visual communication to support answers to this study's research questions. Case study design provided the methodology to analyze collected data in this real-life context from multiple perspectives of complexity (Creswell, 2012; Flyvbjerg, 2011; Stake, 1995; Thomas, 2016).

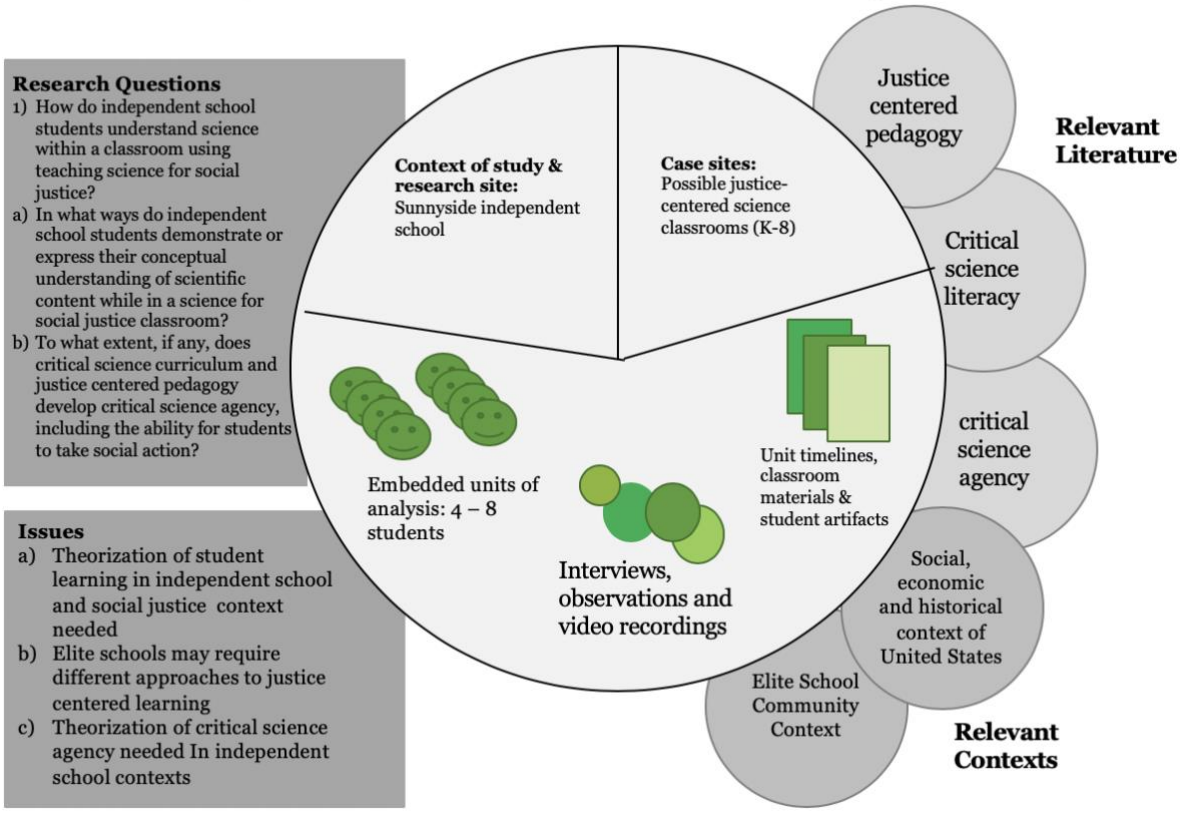
Multiple Case Study

The methodology of case study emphasizes exploring the uniqueness of a single unit within researcher defined boundaries to create a three-dimensional picture that examines a research subject from several directions (Schwandt & Gates, 2018; Thomas, 2016). Multiple case study research however, is concerned with cross-analysis among cases rather than a narrower view of one individual unit of study (Stake, 1995; Thomas, 2016).

The case selection started with "recognizing what concept or idea binds the cases together" (Stake, 2006, p. 23). The teachers in this study are committed to social justice teaching (described in more detail below) and described themselves as teachers who

implement social justice practices in their science lessons. The collective cases (the classrooms) and their embedded units of analysis (the students) are not replicates, but singular representative examples of justice-centered science classrooms selected to assist in describing the phenomena being explored. Therefore, the selection of a multiple case study design provided a sound process for understanding teaching science for social justice within the context of the classroom and the school in which this phenomenon exists.

Stake (2006) uses the term "quintain" to represent what a researcher wants to understand more thoroughly and emphasizes that cases are bounded systems rather than just processes. Figure 3 is a visual representation of the quintain examined: justice-centered science classrooms at independent schools. On the left side of the central circle are rectangles that include the research questions and issues that will guide observations, interview questions and other data sources. On the right of the diagram are circles that contain larger relevant literature, critical pedagogical foundations, and the supporting contexts of this study. The central circle represents the boundaries of the case study, which encompassed individual classroom cases, embedded units of analysis, and data sources.



From Stake (2006)

Figure 3. *Graphic Representation of Study's Case Study Design*

Context

This case study was bounded by several contexts, the teacher's pedagogy, their backgrounds, students themselves and their experiences as students learning science from a justice-centered teacher, and the setting of an independent school. Using a Critical pedagogy lens, this study viewed the relationships and resulting interactions between these overlapping contexts.

School Context

Palm Tree School (pseudonym) is a non-profit independent, pK-12 college preparatory independent school enrolling 950 students. The school is divided in the three sub-schools, lower (pK to 4th grade), middle (5th to 8th grade) and upper (9th - 12th grade) divisions. At the time of the study there was a focus on academic performance, project and inquiry-based learning and character development through curriculum. At its core, PTS's goal is to meet the needs and desires of their students' future endeavors while offering choice, balance, and support. The school's student enrolment is 4.7% Asian, 3.1% black, 0.9 % Middle Eastern, 0.25% Native American and 65.6% White (17% selected unsure or did not answer). In the past few years, the student body increased in diversity, enrolling students from bilingual families, parents born outside of the U.S., diverse religious beliefs, and more non-traditional family units.

Selection of Participants

When selecting participants for a case study managing the depth of the analysis in conjunction with its breadth is an important consideration to allow for more meaning-making with each participant. Fewer participants are more appropriate when depth is desired. Stake (2006) suggests the number of participants ideal for multiple case study lies between four and ten and acknowledges that case selection process often

begins with cases that have already been partially identified. At the time of this study, the researcher was employed at PTS consequently, there was knowledge to inform the successful selection of teachers and student participants. However, to follow acceptable research practices, each selected teacher and student completed the recruitment process as explained below in table 1. Given that the researcher was a full-time science educator at the time of this study, it was important to select a school site that would meet the parameters of this study. Consequently, the only school that met these needs within the inclusion and exclusion criteria was the Palm Tree School.

Table 1. Unit of Analysis Summary

Unit	Inclusion Criteria	Exclusion Criteria	Rationale
Schools	• Independent School • Has a middle and elementary School • Predominantly white (>60%) • Median Family Income > $150,000	• Independent schools without progressive mission statements • Schools without out a written commitment to social justice	Fills a gap in the literature concerning equity related studies conducting in science classrooms at independent schools with limited Therefore, to meet this need school selected must a mission and goals tied to equity
Teachers & Classroom	• Teach middle or elementary school • Teaching for a minimum of 3 years at school • Progressive teaching philosophy • Committed to Teaching for Social Justice • Strong to moderate science pedagogy	• Novice teachers • Uncomfortable with technology and new teaching styles • Technology and math teachers	Teachers with 3 are more years at school will be comfortable with the community. Having a progressive philosophy and commitment to justice centered
Students	• Middle and elementary School Student • All ethnicities	• Receiving academic support services	Must be students in the teachers' classes selected above. Students are volunteered rather than selected to limit bias.

Recruitment

Table 2 below show a three-phase timeline of the executed study for both classrooms including lesson sequences. Phase 1 outlines participant recruitment procedures including assent and consent, phase 2 includes all data collections procedures, and phase 3 includes data analysis. After fulfilling all the requirements of University of South Florida's Institutional Review Board using the inclusion and exclusion criteria listed in table 1 recruitment began in October 2020.

Participant selection (phase 1) began by contacting the school administrators to obtain official permission to begin the study and recruitment. An email was sent to 27 teachers with an explanation of the goals of the study, copies of consent forms and an invitation to complete a preliminary questionnaire, interview, and subsequent parts of the study (see Appendix A). Five teachers completed the survey and responded to the recruitment email. However, only the two teachers in this study met all the inclusion criteria and had teaching schedules that would facilitate an in-depth study of their classroom activities.

Once teacher consent was obtained, volunteer parental consent from each teacher's classrooms was requested. Following student assent, three students requested not to be included in the interview portion of the study resulting in a total of eleven students participating (nine in 3rd grade and two in 7th grade classrooms). Given that students volunteered for the study it was impossible to maintain control of certain

factors such as race, gender, and other demographic characteristics. This resulted in a convenience sample being utilized.

Table 2. *Timeline for Third grade Science Class Study*

Essential Science Questions: - How are organisms in a wetland interconnected and thrive?

		Science Content	Research Component
Phase 1: Participant Recruitment, Assent & Consent		No classroom related Procedures	• Administrative approval from school • Teacher recruitment & vetting process • Teacher consent • Teacher semi-structured interviews • Plan Student interview dates with participating teachers
Phase 2: Classroom Instruction and Data Collection	Informed Assent	• Explain study to class to invite volunteers	• Conduct beginning student interviews and teacher interviews
	Unit introduction	• Visit to maintenance shed to explore simple machines • Simple machine booklet	• Teacher provided summary
	Unit activities and lessons	• Simple Machine Exploration • Simple Machine Book Creator Activity • Guest speakers	• Classroom Observations
	Final project development	• Peer review activities	• Classroom observations
	Project shares	• Sharing Knowledge	• Conduct final student interviews • Final teacher interviews
Phase 3: Individual and Cross Case Data Analysis			

Data Collection

Throughout this case study I collected three main sources of data from students and teachers: 1) Interviews; (2) observations and (3) classroom artifacts (Thomas, 2016). Collectively these data sources provided support for my research questions. Table 3 summarizes how each data source supports each research question.

Teacher and Student Interviews. Interviews are a common practice used to triangulate data in qualitative case study research (Stake, 2006). Teacher interviews occurred soon after teacher recruitment and at the end of the science instructional period and student interviews occurred during the first and last week of each classroom's science instructional period. Teacher interviews were 60 minutes and took place in their classrooms or virtually to accommodate teacher schedules and researcher availability. Student interviews were approximately 20 to 30 minutes long. Since their class was completely virtual the interviews of two 7th grade participants happened via video conference. The interviews of 3rd grade participants happened in person in a common area outside their classroom in groups of two or three due to limited time in their class's daily schedule.

Roulston (2010) discusses the importance of using audio recording during interview sessions for fidelity and triangulation. All interviews with teachers and students were audio recorded if in-person or videotaped if virtual. Teacher and student semi-structured interview protocols (Appendix D) used a series of open-ended

questions guided by the framework of this study, information gathered from the school curriculum repository, preliminary teacher surveys and observations from the classroom.

Observations. Unstructured observation takes place when the researcher immerses themselves in a social situation to understand what is going on (Thomas, 2016). This study used participant style observation, since the researcher became a member of the classroom setting while collecting data. The observation process involved "talking to people, watching, reading documents, keeping notes or anything that involves you understanding a situation" (Thomas, 2016, p. 198). Participating in the observation did not interrupt the flow of the activities in the classroom, but instead I became a part of the classroom community to authentically interact with participants. Observations followed a teacher approved schedule and used a semi structured observation protocol (see Appendix E). During the observations, the students participated in activities and/or discussions to help them understand science content. Observations were selected based on key activities shared by the teacher that matched empirical evidence cited in chapter two (see table 2) Table 3 shows the alignment of research questions findings informed by each data source.

Table 3 *Alignment of Research Questions and Data Sources*

Data Source	Time of Collection	Aligned Research Question
Teacher Recruitment Survey Responses	First week of Study	RQ2 - In what ways do independent school science teachers' pedagogy apply justice-centered science in their classroom?
Teacher Interview 1	3rd week of study	RQ2 - In what ways do independent school science teachers' pedagogy apply justice-centered science in their classroom?
Student Interview 1	First week of 7th grade cluster & First week of 3rd grade cluster	RQ1a - In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? RQ1b - To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?
Classroom Observations & Student Artifacts	Varied for each participant and spanned from the seventh week of the study to the final, twelfth, week	RQ1a - In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? RQ1b - To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action? RQ2 - In what ways do independent school science teachers' pedagogy apply justice-centered science in their classroom?

Table 3 Continued

Student Interview 2	5th week of 7th grade cluster & 6th week of 3rd grade cluster	RQ1a - In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? RQ1b - To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?
Teacher interview 2	6th week of 7th grade cluster & 8th week of 3rd grade cluster	RQ2 - In what ways do independent school science teachers' pedagogy apply justice-centered science in their classroom?
Lesson materials	Varied for each participant and spanned from the seventh week of the study to the final, twelfth, week	RQ1a - In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? RQ1b - To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action? RQ2 - In what ways do independent school science teachers' pedagogy apply justice-centered science in their classroom?

Artifacts and Other Documents. In case study research it is important to gather the types of documents that will support the answering of a study's research questions (Thomas, 2016). Therefore, artifacts included student work, photographs, unit timelines, classroom materials, and other reflective notes to further provide thick descriptions. Other resources to support the context of school environment included, school

documentation such as strategic plans, mission statements and other information to construct a detailed narrative of the study's context.

Data Analysis

This study used a multiple case study design, analysis occurred in two main phases, at the individual case level and across all cases (Merriam & Tisdell, 2015). All recordings collected were transcribed using Transcribe Me software and stored on the university Box account in folders by classroom and date. Once the data were organized and transcribed, they were transferred to the Dedoose qualitative software for analysis.

Each transcript and observation were coded in serval rounds. Saldana describes a code as "a researcher-generated construct that symbolizes and thus attributes interpreted meaning to each individual datum for later purposes of pattern detection, categorization, theory building, and other analytic processes" (p. 4). Therefore, data were coded in cycles to identify attributes of teacher's pedagogy, student's perception of that pedagogy and how it may have contributed to their learning and understanding of science through a social justice lens.

First, I created a secure Box folder for each classroom's collective materials. Since the 7th grade instructional unit occurred before 3rd grade, I collected and completed a simple analysis of the 7th grade data in winter 2021. The analysis involved reading each transcript, taking notes on any interesting patterns, and summarizing observations into analytical memos (see appendix E). The preliminary round analysis occurred in this

order, Ms. Amanda's first interview, student participant's first interview, collection of classroom observations and artifacts, student participant's second interview, and Ms. Amanda's final teacher interview. The student's final interviews were analyzed before teacher's second interview to provide important context to any questions or clarifications that needed to be explained during Ms. Amanda's final interview. I followed the same sequence for Ms. Erica's 3rd grade instruction unit when it occurred in the Spring of 2021.

Given the research questions aim to understand what teaching for social justice looks like in the Palm Tree School's classrooms, an open inductive coding process was completed first to allow codes to emerge (Grbich, 2013). Since coding is a cyclical and iterative process (Saldana, 2016) to facilitate the first round of identifying and interpreting the participants' descriptions, justifications, and explanations to create inductive codes. These codes were then consolidated into categories and recorded in a codebook with respective definitions and corresponding examples from the data.

In the third and fourth coding cycles, emerging themes were used to further identify connections to the proposed conceptual framework of teaching science for social justice, which is composed of three areas, critical science literacy, justice-centered science pedagogy and critical science agency. Afterwards, a thematic and cross-case analysis was done to describe the story the data collectively reveals about teaching

science for social justice; to identify connections among overarching themes and the study's research questions.

Role of The Researcher

Palm Tree School is a very collaborative community. Teachers' students and staff work with each other across divisions, and grade levels to create a supportive learning environment for students. The researcher had professional working relationship with the Palm tree school creating a sample of convivence and allowing my presence in the on the school grounds and in classrooms as a researcher from the perspective of community member rather than an unfamiliar researcher.

The qualitative nature of this study coupled with my involvement in the school community allowed me to have serval roles like, professional colleague, mentor, and instructor with participating teachers and students. These roles had overlapping impacts and could not have been isolated on the outcomes of this study. During classroom observations, teachers may have called on me to add to the ongoing classroom discussion, especially during more social justice centered topics. Knowing that I was also a science teacher, students incorporated my presence into their learning process, asking me questions for example if their teacher was helping another student.

Triangulation

Triangulation is inspecting information from several points of view to achieve trustworthiness. The process of triangulation is facilitated through using multiple

methods of data collection which included focus groups, individual interviews, classroom observations, audio and video recordings and artifacts (Thomas, 2016). Member checking is an important part of triangulating the researcher's observations and interpretations with participant intentions. When research participants review interview transcripts, observation notes or narrative text they often provide corroboration and feedback (Stake, 1995). Each teacher research participant was given three opportunities to review data materials and provide further response to the research questions. Participants were sent copies of transcripts to clarify answers from previous interviews, classroom activities, and excerpts from data analysis. Due to the nature of the school year, teachers reviewed specific data related to students since I no longer had access to students in the classroom. Two secondary researchers, Ph.D., and critical pedagogy scholars, evaluated excerpts from the data alongside my analysis. Their views will serve as either a different perspective or a means of confirming the study's findings.

Quality

According to Stake (1995), a researcher can address quality by attending to ethical obligations that "minimize misrepresentation and misunderstanding" in research analysis and results" to present a substantial body of uncontestable information (p. 110). Gaining an understanding of the participants experiences as students in a justice-centered classroom and as teachers facilitating social justice inspired pedagogy requires

significant contextualization. Various data sources from multiple contexts will assist in authentic representation of participant experiences. For example, in interviews, I plan to record the sessions, and take my own notes. I will attempt to connect interview responses with my observations from classes and student artifacts to share a holistic understanding each unit of analysis.

Credibility

Credibility refers to the trustworthiness, verisimilitude, and plausibility of the research findings through triangulation (Tracy, 2010). This is achieved through thick descriptions from various sources of data and then analyzing that data from multiple perspectives. While each individual classroom case is being analyzed, creditably was achieved by the consistence of themes emerging from each data source. Table 3 above, demonstrates how each research question is mapped to each of the proposed data sources. The interview protocols in Appendix A and B, additionally show how each interview questions connects to one or more of the research questions. Finally, credibility will be address through participant member checks by the participating teacher and students (Tracy, 2010).

Ethical Considerations

This study followed all USF Institutional Review Board (IRB) guidelines. To protect participants' privacy, they were informed both orally and in writing about the study's goals and the data collection, analysis, and storage methods used in the study.

The recordings from the interviews and transcriptions were stored in a locked filing cabinet in the researcher's office, and electronic copies were stored on a password-protected cloud-based database such as Box. Before conducting an interview, each participant was informed of their right to withdraw from the study at any time.

Chapter Summary

This chapter explained the procedures used to execute a multiple case study to answer the study's research questions. Specifically, my participants and the context of the study, including the school, teachers, and students where the study took place. The chapter summarized the recruitment process and data collection procedures followed by data analysis procedures. The chapter concluded with a description of quality and ethical consideration of this study.

CHAPTER FOUR: EMBEDDED CASE DESCRIPTION

The purpose of this qualitative embedded case study was to understand science instruction when taught by educators who self-identify as justice-centered teachers. Data was collected from one 3rd and 7th grade science class at a suburban K - 12 private/independent school in the Southeastern United States to understand what it looks like to learn science in a justice-centered context. In alignment with Merriam (1998), the segments of this study's research findings contain general and interpretive descriptions to provide an immersive account of each case.

This chapter presents evidence of how teachers and students conceptualize their school community. This evidence is presented in 2 sections. The first includes an analysis of the Palm Tree School community and its history, its connection to diversity, equity, and inclusion, and how these attributes contribute to the success and challenges of teaching science for social justice. The second section summarizes the data collected from the two classrooms (3rd grade Elementary and 7th grade Middle School Science) and their respective students. Two educators and students from their respective classrooms agreed to participate in this study and share their experiences teaching justice-centered pedagogy and learning science in an independent school classroom. Given the occasional sensitive nature of the topics, special attention has been given to

protecting the identity of all participants by using pseudonyms, and other general modifications of community-specific terms were changed.

Context of Independent School Community

About Palm Tree School

Palm Tree School (PTS) is an independent school, which means it is a mission-driven school whose head of school (i.e., the principal) is managed by a board of trustees. Like other independent schools in the area, PTS's mission focuses on three main things: educational excellence, collaboration, and preparing students to be socially responsible citizens.

Historically, PTS began to provide education to families who traveled to Florida during the winter. Over 75 years ago, the school's founder and those who originally attended were categorically known as "snowbirds," people who visit a warmer area to escape the cold weather during their winter months. Having the option to move your family hundreds of miles to facilitate the choice to avoid cold weather is something that many families at that time could not do or relate to. So, PTS was founded to serve the needs of an affluent group of people who could afford to travel during the academic school year. While PTS now serves a more diverse and inclusive community, its history still lingers in affecting those who choose to make PTS their school of choice.

Today, the school, like many K-12 independent schools, is divided into three divisions (Elementary, Middle, and High School), like those used in the public school

system but housed on the same physical campus. Each division has a separate building on a large campus surrounded by sports fields, gymnasiums, and open play spaces. Student parking lots are filled with newer models of expensive cars and several uniformly painted one- and two-story buildings. The school grounds are so extensive that maintenance staff and other employees may choose to get around by golf cart. During this study, the school constructed a new building that serves as a multifunctional educational space with STEM-related activities, a second library, a cafeteria, and other innovative spaces. There are plenty of green spaces, no discernable trash or litter, and on any day, you will see small groups of classes outside on the field or walking with a teacher to explore.

If you could walk the grounds of PTS, you would hear birds in trees mixed in with the sound of children's academic chatter. The school is blanketed with peaceful sounds that hopeful parents would want to hear as they roam the hallways and visit classrooms. Students collaborate, share their excitement in response to an activity, or play happily outdoors on the grounds.

Commitment to Diversity, Equity, and Inclusion. PTS's longstanding commitment to Diversity, Equity, and Inclusion (DEI) make it a perfect choice for this study. From the outside, looking in, it checks all the appropriate boxes. As early as 2010, PTS had an inclusivity statement posted on its website that listed how it hoped the community could engage in conversation about DEI. In 2017, they hired their first

Diversity and Inclusion Director; five years later, each division has a representative DEI liaison and teachers known to facilitate social justice through their curriculum.

Equity and inclusion are a specific focus within PTS's recent 2020 strategic plan. While their new Diversity and Inclusion Director has started programs with teachers and parents, less than 5% of the groups attend. Additionally, there are no explicit expectations for teachers to teach for social justice or use social justice-based practices in the classroom. However, given its strategic goals, teachers do not meet administrative resistance when using justice-centered curricula in their classrooms. Some teachers have individually decided to implement such methods in their classrooms.

The DEI director has spearheaded many initiatives in the last five years. Before their arrival, the school hosted international days and Latinx Fairs and completed many surface-level activities to incorporate DEI into the school community. Today, courses are being taught in high school, affinity groups at divisional levels, and equity workshop series for teachers and parents. In these five years, the high school sent several student delegations and teachers to the National Association of Independent Schools' People of Color Conference. PTS is not a place where DEI is purposely overlooked. It is a part of their mission and vision, which includes words like "social responsibility," "lifelong learning," and "inclusive." A specific focus on culture, community, and DEI is part of their ongoing strategic plan. Within the last year, a committee of teachers, parents, alumni, staff, and board members was gathered to make

recommendations to the board of trustees to further their initiatives related to DEI.

Teacher Description of School

This study included two teachers at the PTS, Ms. Erica from 3rd grade and Ms. Amanda from 7th grade. During their first interview, both were asked to describe their school community. Overall, they agree that PTS is a top school in their local community that provides a competitive education to their students. Their interviews highlighted the economic status and privilege of children's families and the lack of student and teacher diversity. As shared above, PTS has several ongoing DEI initiatives, including recruiting a diverse student pool reflective of the surrounding community. However, these two teachers feel it is part of the mission but do not know what is being done to further that initiative. This goal may be ongoing, but the teachers are not updated on the progress or recruitment of more diverse families and teachers.

The elementary division at PTS is the most diverse in terms of student and faculty racial diversity. Ms. Erica's class contains "diverse identities" containing students' race, sexual orientation, religion, and socio-economic status. However, Ms. Amanda says her current grade and middle school are predominantly white, with a larger than usual Asian student group but only two African American students in her grade level.

Uniquely, Ms. Amanda specifically shares PTS is not a non-religious school but an a-religious one. Rather than embrace everyone's religious backgrounds, PTS gives

the impression that religion should not be discussed. She connects this more to the middle school not providing enough room for students to share that part of their identities, especially if they are in a less common religious group, like Islam or Hinduism.

Teachers at PTS would agree they have flexibility and autonomy in their classrooms. They feel supported and have access to professional development opportunities to grow their pedagogical practice. Ms. Amanda shares that the administration has a "certain amount of trust in us as professionals" and likes the opportunities to collaborate with other teachers.

Student Description of School

Students in the middle and elementary school divisions at PTS are happy and overall love their school. They feel welcome, safe, and valued. Richard, in 3rd grade, shares that Ms. Erica "makes you feel special. That's important to you when you come to school that you feel special. I like that." Students in this study feel their community in elementary and middle school is inclusive of others. When asked about the diversity in her class and grade Emma, in 3rd grade says "well, they all look different, and people like they don't have to feel left out here." Shyla, also in 3rd grade, says PTS "meets other people's needs, especially cause, like, why would you go to a school that doesn't meet people's needs that only meets the needs of an average human? You should match it to everyone's IQ." One middle-schooler shared, "you get to be yourself, almost like you

get to learn in a way that's best for you. And they teach you a lot about like life and just how to live in the world." When asked about what things PTS could do to improve, the students had very little to offer. It was most important to them that they liked their teachers and felt they could learn and make friends.

Educationally, students shared positive responses about their learning and their teacher's pedagogy. They feel their learning accommodations are being met, and technology integration enhances their learning. Third graders shared, "Palm Tree is very academic, but the classes are enjoyable, and sometimes it doesn't even feel like you're learning… it just feels like you're not even at school. It's just like you're playing games to learn." Middle Schoolers liked project-based learning "instead of just teaching us about [content]. So, you could experience it", but also share it can be "a bit challenging, but never boring because you can do like sports and academics. It's just perfectly balanced." A different student shares, "so you learn a bunch of different things and… all the classes are different, and it's like you're not doing the same thing over and over again… and it's hands-on learning." The only negative comment was about lunch and variety in their now 3-year-old cafeteria. Overall, the students at PTS love coming to school each day because PTS "is such a fun place and it's so fun learning here… it is an amazing school that, like words, can't describe its greatness!"

Overview of Study Participants

This study includes one 3rd grade and one 7th grade classroom. The study is not meant to compare the classrooms, especially since they are two different grade levels, but to identify collective ideas, methods and themes that emerge from how both teachers enact their idea of justice-centered science pedagogy in their classrooms and how that may be translated to students.

Next, each teacher participant overview describes their historical and educational background, their understanding and implementation of justice-centered science in their classroom, and the effects of the Covid-19 pandemic on their process. This background is followed by a collective description of each specific classroom's student participants and the respective teacher's class responses to questions about their understanding of science, artifacts from their work, and conceptualizing social justice and science. Using each data source, I provide a rich and holistic story of each classroom, teacher, and student, allowing the reader to see the contexts of each classroom case community.

Both participant teachers have a working professional relationship with the researcher. As educators at PTS, we contribute to school-wide initiatives (e.g., DEI committees, curriculum alignment teams), and participate in school-wide professional development. Ms. Amanda and I are middle school science teachers at similar schools, I spoke to both teachers about the science curriculum sequence.

Ms. Erica - Third Grade Elementary Teacher

Historical and Educational Background. Ms. Erica is a cis-gendered black woman in her 10th year of teaching and 5th year at PTS. Before her time at PTS, she taught in the public school system and left for the "opportunity to disconnect from being so invested in [her] job." She specifically noticed that the boundary between her life and work was becoming too blurred and she wanted to have a better separation between the two. She is still very invested in her role at PTS but, she wanted to teach at a school where she could not take too much emotional work home at the end of her workday. As a third-grade teacher, Ms. Erica has led on-campus marches for change with her students, taught her classes about the "true story of slavery," and has recently been appointed as the elementary division DEI coordinator.

She is an alumna of the school and from the local community but feels included and separate from the community at the same time:

> I grew up in a separate community but attended PTS... it was not as affluent of a community [so] from the hours of like seven-thirty to about five, I lived the life of my [current] students, and then after five-thirty, I'm going back to my natural community where, you know, things, cultures, traditions, practices were different.

When asked what has been the spark that led to her committing to being a justice-centered educator, she shares heartfelt stories about her grandmother:

> My grandmother has always been my champion. She told me literally every day, "don't take no wooden knuckles," let them know who you are and whose you are and whom you represent. I knew that I was different. And that was [what], kind of created my understanding of "stand out"… I knew to be critical, ask questions, be proud. Don't shy away.

Ms. Erica is describing the shared experience of many black students in independent schools. Hiding parts of your identity is common occurrence for black students. Some choose or feel like they cannot come to school as their whole self and often live separated lives from school and home. Her grandmother being an educator, hoped to support her in navigating that construct by telling her to ignore those challenges. Saying "don't take no wooden knuckles" or "don't take no wooden nickels" means not to take fake "currency" from others in her school. Adding on to her experience with that, Ms. Erica also shares:

> I really was the only black kid in my grade for at least eight years. I feel like I was the only one getting that message (chuckle). You know what I mean? Like no other kids were all being told, like, "Be proud of who you are, who you represent." Or at least not in the same fashion that I was getting it.

While there is no way to know if her classmates were getting a similar message, for Ms. Erica, it was a message that gave her the room to be herself as much as she felt she could stay at school.

Ms. Erica tells a story of her grandmother going to school to advocate for her when she was teased because of her hair: “Once she threatened to sue PTS for discrimination. Because kids would make horse noises when I walked past them, they would go "(whinny sound)" and they would say: "horses run around the track, give them horses their hair back." It was a challenging, upsetting, and defeating experience for Ms. Erica, but her grandmother was her staunch advocate.

> The next day my grandmother came in with an empty attaché, as she called it. I am like, "That's a briefcase" She goes "it's an attaché.", The thing was empty! She did not have not a lick of paper in there! She demanded a meeting with the principal and threatened to sue the school for discrimination. And then years after that, there is a discrimination clause in the handbook based on how students will be treated at this school.

In addition to being her most prominent advocate, Ms. Erica was also inspired to become a teacher by her grandmother, a retired public-school educator. Growing up, she used her grandmother’s “teaching editions” to play school with her teddy bears.

Ms. Erica learned growing up that when you have someone to advocate for, you can create change, the fight can make a difference.

> Seeing her go to bat for me and go to a school with an empty briefcase! I'm like, if that's what she's willing to do… Like, she has no grounding. She didn’t know anything that she needs to say, but she knows that this is what she feels like she

needs to do. And so from that moment on, I was like, "damn, I want to be that bold in my convictions when I feel like I know something is wrong; I want to have a hand in creating that type of education for kids… So, this is my opportunity to make this space... Where you know better. And so that's like really what influences me, like those moments oh, my gosh, like no white kid can say that in this day and ages!

The independent school profession is a white and female-dominated environment, therefore having an African American woman who is also an alumnus of the school, and teaches social justice is a unique overlapping of identities.

Curriculum and Justice- Centered Pedagogy. In the third grade, science is taught as a series of 6 to 9-week units, twice a year. They start with eight weeks of studying the Florida Wetlands and "How are organisms in the wetlands interconnected?" Later in the year and in the part of the curriculum that was observed by this study, classes learn about forces and motion in conjunction with animal adaptations. When asked for a summary of the justice-centered curriculum she hopes to teach, Ms. Erica says, "We have them create something to help those with a physical limitation. We also had them look at certain school environments to ensure that they were equitable for everyone's ability, and last, when we study ecosystems, we removed invasive plants from our lakes."

At PTS and independent schools in general, teachers have the autonomy to

design their curriculum to meet the needs of their students and have the creativity to build themes into their lessons to guide students through content goals and objectives. Ms. Erica sees herself as a justice-oriented teacher with a well-developed critical consciousness but acknowledges that she still has much to learn. She shares that "social justice is an essential part of education and giving it more visibility in my science lessons is a priority. I know it should be done, and I want to make sure I do it right." Ms. Erica, however, does find the work challenging, but only because she holds herself to a high standard and is committed to becoming better. When it comes to integrating justice-centered science pedagogy (JCSP) into her coursework, she finds it challenging. She recognizes there is room to grow in science specifically "because I think I don't consider certain things when teaching specific content and how social responsibility can be a part of it." She also shares in her interview that specifically participating in this study, she hoped it would challenge her to "be more intentional" in science class. Overall, Ms. Erica is a leader in her school in social justice topics.

The pandemic, however, caused third-grade teachers to make modifications to lesson sequences. While Ms. Erica did not have to teach in-person and online classes simultaneously, to ensure students in both groups were all in similar places and facilitate any quarantine, all teachers had to be in the same place in the curriculum. This last-minute change created limitations for Ms. Erica. What may happen in her classroom tied explicitly to Social Justice themes needed to be was slightly different this

year to accommodate third-grade classes.

The pandemic also prevented all field trips limiting some of her class's regular trips and students' ability to work with community members. In the past, the simple machine unit encompassed students interviewing community members, conducting research, and participating in field experiences. Instead, this year, these community interactions had to come from members of the faculty and staff who were allowed to be on campus. For example, instead of an offsite trip, Ms. Erica's class visited the maintenance shed on campus and observed simple machines in action; two guest speakers were faculty members, one, an avid cyclist who explained gears and their impact on forces required to change speeds and the second shared about planes and flight.

Due to time constraints and community access, the third graders' final project was also impacted. Typically, students use the research and observation notes collected throughout their lessons to choose a topic they would like to learn more about and interview a person in their community to help with a simple machine. When teaching students about force and motion, Ms. Erica says,

> We've had them create something to help those with a physical limitation. We also had them relook at specific school environments to ensure equitable access for everyone's ability. When we were studying ecosystems, we removed invasive plants from our lakes. Their unit culminates with a final research presentation at

a project share.

They could not do something this extensive this year due to Covid, and it drastically affected the anticipated work product of the students.

Students and Student Interviews. When you enter Ms. Erica's classroom, you may first think it's a regular classroom with students busy at work, but you realize it is a special place for the students. Individual desks are paired and arranged in a "U" shape around the classroom carpet area. Walls are covered with anchor charts and student work is displayed for all to see. The work displayed showed student learning and the connections they made between what they have learned about simple machines. It is a place where the students feel at home, exhibit a family aspect, and enjoy learning.

The more I spent time there, the more I got chills from the ways students interacted with her and each other. There was an underlying tone of love and respect in how students collaborated and how Ms. Erica spoke to her students. In this classroom, students were not afraid to collaborate and ask questions. There are several routines that both students and Ms. Erica use that allow students to practice independence and assess their own learning and practice inclusive conversation with each other. These routines fostered a classroom environment that Is equitable to all learners. Table 4 summarizes student demographics, including age, self-reported gender, and race/ethnicity.

Table 4 *Summary of Student Participant Demographics in Third Grade*

Name	Age	Gender	Race/Ethnicity
Shyla	8	Girl	Indian
Delpha	8	Girl	White
Noah	8	Boy	White
Megan	7	Girl	White
Darius	8	Boy	White
Emma	8	Girl	Black
Alex	7	Girl	Latina
Kayla	7	Girl	White
Richard	8	Boy	Asian

The students were interviewed in focus groups of two and three due to time constraints in the project and the PTSs Covid-related rules. Table 5 summarizes each student's thoughts about the meaning of science. Overall, their response was categorized into learning about the world or exploration, science for a career or job, and science as something scientists do.

Table 5 *Third Grade Students' Understanding of the Meaning of Science*

Student Participant	What is Science and Why do we learn Science?	Researcher's Interpretation
Shyla	Science is the study of everything on Earth, in the galaxy. Science is the study of how us beings live and cooperate. It the study of everything, everything from a phone to a brick in the wall.	Science helps people learn about the world around them. Science connects to everything and how things work together.
Delpha	I think we learn science because there are so many things in the whole wide world and we can't, like, just know them all immediately. We have to learn about them. And yeah, that's why I think we learn science.	
Noah	I mean, because science is everywhere. And even that book is science because it that has the spine at the end and it opens them up which tool a lot of science	
Emma	Because it's an everyday thing. There's science all around us. And sometimes you need to learn like how science, like what science is to know what's around you.	
Richard	Anything because anything... can be like anything can be like... And I think... almost every can be science, like... I just think that science, well, just a lot things are science.	
Megan	…if you didn't learn science in school, then like your life would be pretty limited. Researcher: 00:08:13.510 In what way... Megan: Like you can't have certain jobs when you're older because you wouldn't know about certain science.	Science is needed for a career to get a job
Darius	it's really... it it helps you learn about... When you grow up you might want to be a scientist. Science is really, you get to learn new things that you might never have learned math project work and other subjects, and you might not ever get to mess around with chemicals. And if you pour a chemical in then you get an explosion or something. You're never going to get to put mints in coke and take the mints out and watch it explode.	Science focuses on the act of being a scientist or doing chemistry and using this knowledge in school for the purpose of being or doing experiments

Table 5 Continued

Kayla	Well, science is really cool. And if you learn more about it, the more things that you'll know... the more that you know, the more you can know more about! Like if you know how to perform an experiment, a science experiment... you learn new things and then you can do an experiment on those things. And science keeps growing and growing and growing. And you're never really done learning science because science is never really done!	
Alex	Science just someone taking a risk taking and hmm mmm. Researcher: What are they doing when the risk taking? Alex: Um ....um like if they're doing, um if they were if they were doing a science experiment with gravity. They're taking a risk and doing something new and something that is, that's kind of unusual for them to do they are taking a risk.	Science is an exploration of unknown things

Students reflected on their end of year projects that were meant to demonstrate how simple machines can help others and shared their experiences with science and social justice during the second focus group. Table 6 provides a summary and analysis of their responses. Since focus groups are conversational and students learn from each other in class and during the discussion, some experts contain two students dialoguing. Students share various thoughts about why their teacher implements social justice in their classroom or how it is experienced in their classroom community.

Table 6 *Third Grade Students Understanding of Social Justice*

Student	Why is it important to learn about social justice?	Researcher's Interpretation
Shyla & Kayla	*Kayla*: I think that it's just to show us how different people around the world are living. Because, like, things happen to people sometimes and she's teaching us how to react when you see it happen. *Researcher:* Do you feel like you learn from the scenarios? *Shayla:* mmm hmmm. cause you also get to hear other people's opinions, so like maybe some other people's opinions will help you make up your mind for your opinion…Hearing other people's opinions could give you thought on your if yours if you haven't told them yet.	Students recognize they are learning about how to respect and be inclusive of others' opinions which connects to the importance of learning about multiple perspectives.
Delpha	*Delpha*: Social Justice time... is basically talking about justice and asking us questions about what our opinions are on justice. For example, we're like black kids could only come to the table with parents and the and the white people could come by themselves or with parents. So, we were given the chance to tell Ms. Erica our opinion.	Students' understanding of social justice is strongly tied to their teacher. In other places they say things like "My Teacher" or I learned in Social Justice Time.
Megan & Alex	*Megan:* Because maybe Ms. Erica is kind of hoping that when we're older we will be like an activist. *Researcher:* What's an activist? *Alex:* Someone that doesn't just say that they're going to do it with words but goes ahead and does it.	

Social justice is a huge part of the experience in Ms. Erica's class. She has an allotted time titled "social justice time" or SJT as part of her class's morning daily routine. At the end of her simple Machine unit to formatively understand her implementation of justice centered science, during the last week of school Ms. Erica

asked her students: What have you earned about social justice this year, and how can social justice help us learn about science? Table 7 captures three exemplar artifacts that represent their ideas with some teacher commentary. Several the students drew the world as they thought it should be, (see Noah's drawing), while others drew a depiction of what they see happening today versus a more justice-oriented option (see Delpha's drawing) others wrote a narrative to explain their thinking (see Darius's drawing).

Table 7 *Social Justice Drawings of Students in Ms. Erica's Third Grade Class*

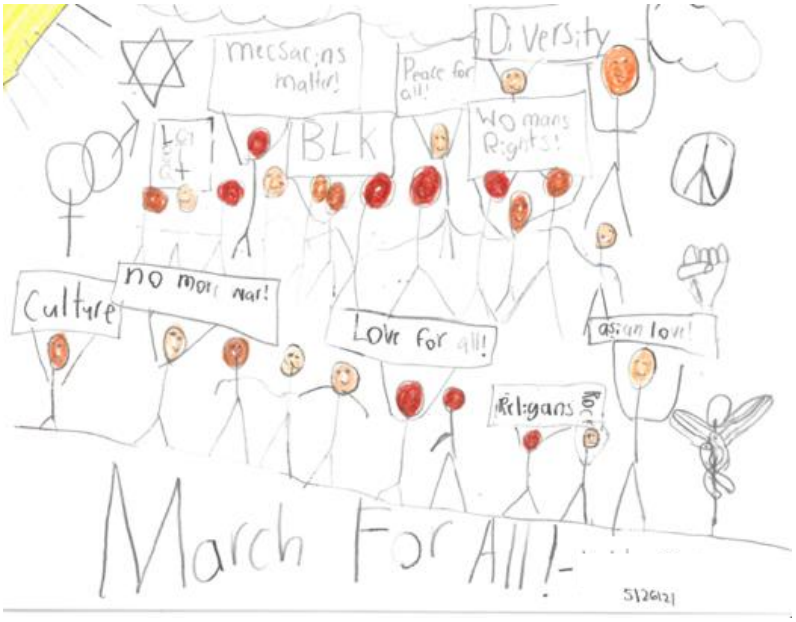
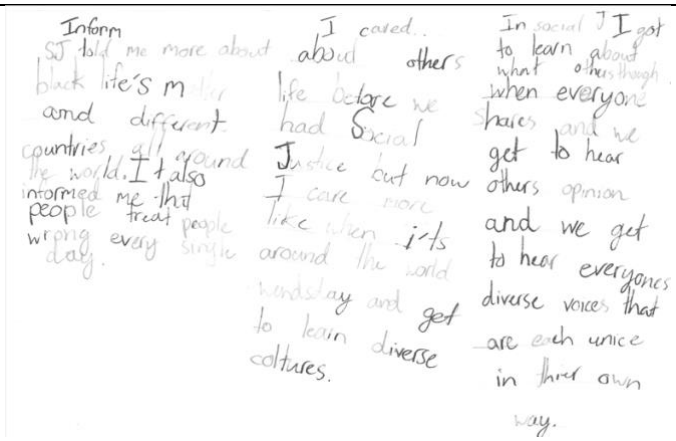
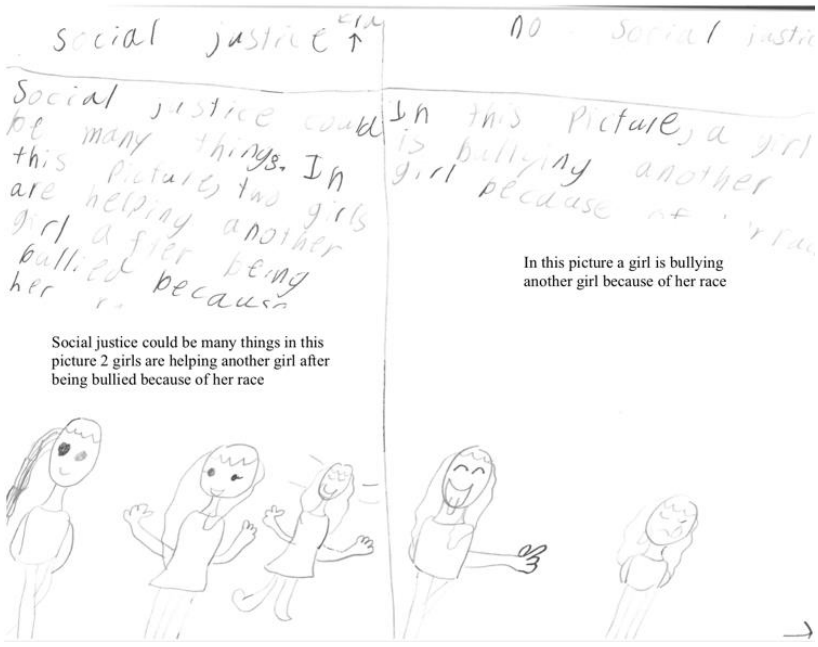
Student	Drawing	Researcher and teacher Interpretation
Noah		Students understand there are ways of thinking differently and ways of exemplifying social justice. However, they are also demonstrating their desire to be a part of a shift towards acceptance and creating a sense of belongingness in their community and the world.
Darius	 Text: Social Justice told me more about black life's matter and different countries all around the world. It also informed me that people treat people wrong every single day. I cared about others life before we has social jsutice but now I care more like when its Around the World Wednesday and get to learn diverse cultures. In social justice I got to learn about what others thought when everyone shares abd we get to heear others opinion and we get to hear everyones diverse voices that are unice in their own way.	Students' express examples of what social justice looked like or could look like in comparison to their view of the world today. Shows they recognize

Table 7 continued

Delphia	a need for change.



Ms. Amanda - Seventh Grade Science Teacher

Historical and Educational Background. Ms. Amanda is a white cis-gendered female from the Midwest of the United States. She relocated from the western United States to Florida to begin here at PTS, as a 7th-grade science teacher.

Unlike Ms. Erica, she had no familiarity with the local community growing up. Her culture is "German, Scottish, Irish, and southern United States, the offspring of sharecroppers and, you know, like. Poor, poor white people of the South." specifically, rural Alabama.

Ms. Amanda attended predominantly black public schools as she grew

up. She shares, 1st through 8th grade, "my brother and I were the only white kids on the bus, and we lived in a house surrounded by cotton fields that did not belong to me." However, her school was in a very urban area and attended "by military family kids, kids from other poorer areas, including the projects or subsidized housing on the west side of my city. At school, I was in the minority." She shares,

> When I was in school, we went to a majority-white church like elementary and middle school. So, like the way I interacted with my friends at school, and the way I interacted with my friends at church or at gymnastics, you know, whatever, it was all very different.

However, in high school, the demographics of her school swapped, changing to a primarily middle-class and upper-middle-class population mixed in with rural poor racially and ethnically poor students of color. She shares, "I was in the majority, so it was kind of like a swap. I hated it. It was like all these preppy white folks. It took a while to get used to; it was different. This swapping of the racial demographics of her schools was a significant experience for Ms. Amanda that contributed to her identity development as a teacher aware of inequity.

Like Ms. Erica, Ms. Amanda self-identified as a teacher passionate about justice-centered practices. Still, she recognizes she is not as developed as some other colleagues. She highlights Ms. Erica as a teacher at PTS who is making significant strides in incorporating social justice into her lessons. Ms. Amanda, however, shares

throughout her interviews that she can identify with the struggles of underrepresented groups, and she empathizes with what it is like to hide who you are to fit in.

> When I went to church, we were the poorest, having to navigate not having people know how poor I was… and understand the sort of tools that you create for yourself to navigate that. I think has given me the sort of perspective that a lot of other folks don't have. And has allowed me to like make connections between what's really going on. And I can attach that to my experience in ways that maybe other people can't. So, trying to help other people make connections between what's going on or to ask deeper questions or because I knew that I was like hiding a lot of who I was… or masking or putting on different faces, depending on where I was.

Through her commitment to justice-centered pedagogy, she wants her students to understand that different communities of people in the world may be outside of what they know. She says, "students of privilege need to understand others in the world for their excellence."

Curriculum and Justice Centered Pedagogy. In 7th grade, PTS's science curriculum focuses on spiraling through three main science disciplines. There is a focus on chemistry and biology, but throughout the unit aims to focus on curiosity, inquiry, and problem-solving. Students reviewed the physiology of

cells, how biologists sort and classify organisms, and biogeochemical cycles during this study. There is a specific focus on students becoming naturalists and using practical skills for observation and technology to explore Florida's native organisms and ecosystem. During this study, comments took place during the history of the disease unit, which gave students an introductory understanding of bacteria, viruses, and basic microbiology techniques such as culturing bacteria. Ms. Amanda has many ideas about what she would like to implement in her classroom as a JCS educator many of which would be acceptable to support the development of students' CSA. For example,

> In seventh grade… the disease unit and the disease project… one big focus is … waterborne illness, which helps kids to see … where in the world is waterborne illness happening?... it's in these really impoverished areas. Why… they don't have sanitation? And what countries are those? … bringing in like the disparity of and the impact of poverty on like who gets what disease and who's able to get helped and who's not?

Due to the Covid-19 pandemic and scheduling of the researcher's time who also taught at PTS, the observations of Ms. Amanda's class took place in a virtual setting. Her classroom was set up in a traditional science lab with materials and resources available for students to use. Desks were sometimes in rows or small groups of three or four. Even though this study focused on her virtual class, Ms. Amanda taught four other courses in person. She starts each class with a quote of the day written on the board,

which sometimes features something a student said. However, her online students saw very little of Ms. Amanda's classroom, limited to the small view of the screen. Each day she starts her class with a nature quote of the week that highlights voices from a diverse group of scientists and naturalists that connect to the content she is teaching. She highlighted Dr. Martin Luther King Jr, Alder Leopold, Jane Goodall, and Ravi Suhag, a neurodiverse Indian polymath[1] software developer during the study. Ms. Amanda says these are ways she brings history and multiple perspectives into her lessons. She solicits student voices about the quotes and guides them through connection with the person and or section and the curriculum.

Student Summary and Descriptions

Four students participated in the 7th-grade portion of the study and observed classes in a virtual setting. However, in the middle of the study two students declined to participate. Due to challenges happening elsewhere in the school related to Covid-19 pandemic and scheduling difficulties, the researcher could only to observe Ms. Amanda's virtual course. Table 8 summarizes students' comments related to the meaning of science. Like the younger grades, students' view of science focuses on

1: Neurodiverse: range of differences in individual brain function and behavioral traits, regarded as part of normal variation in the human population; used especially in the context of autistic spectrum disorders or learning differences. (Merriam-Webster)[1]

learning about the work and connecting their learning to how things work.

Table 8. *Students' Summaries of the Meaning of Science*

Student Participant	What is Science?	Researcher's Interpretation
Alaina	Science is like how the world works, and so gotta learn how the world works and it's teaching you about a bunch of stuff in life like disease and how people handle that.	
Jonathon	It teaches us more about the world around us, because. Everything is kind of a result of science, really. Like this book (holds up a book) like paper is basically a result of science (chuckles) and like, different stuff happening. And like when we learn about, like nature, we learn about what's outside and around us.	Science helps people learn about the world around them and connects to everything and how things work together.

Chapter Summary

In this chapter, evidence of how teachers and students conceptualize their school community was presented to share an analysis of how Palm Tree School's community context contributes to the success and challenges of teaching science for social justice and summaries of the data collected from the two classrooms (3rd grade Elementary and 7th grade Middle School Science) and their respective students.

CHAPTER FIVE - CROSS CASE ANALYSIS AND FINDINGS

This chapter presents six themes from the cross-case analysis of two classrooms and students collectively at Palm Tree School (PTS) participating in this study, Critical Science Education, Impacts of Critical Science Curriculum, Pedagogical Strategies, Critical Science Agency, Teaching in The Covid-19 Pandemic and Challenges and Support for Justice Centered Practices. The themes were identified based on coding patterns from each classroom's observations, teacher interviews, student interviews, or the overall school context. To become a theme, supported emerging codes had to be identified three times in a combination of those individual classroom contexts and be discussed by participants at least two times within the same source. The chapter concludes with a table that describes connections among indicators that support the conceptual framework via to these themes to the three larger components of the conceptual framework, justice-centered science pedagogy, critical science literacy, and critical science agency.

Theme 1: Critical Science Education

Science education can be a powerful tool for dismantling unjust social constructs. Our intertwined social identities significantly impact how we interact with the world around us. Often, our identities shape our opportunities

throughout our lives, resulting in social benefits and drawbacks. With Critical Science Education, teachers can encourage identity growth by encouraging students to participate in social justice-inspired projects informed by science.

Justice-oriented science educators should engage in culturally-based pedagogies that identify and leverage students' and communities' knowledge, so that science education can be used to support more just, sustainable, and culturally thriving futures—especially for those who have historically been and continue to be disenfranchised from science (Bang et al., 2017).

In this study, teachers shared how they use science to foster social justice in their classrooms. According to Ms. Erica, science teaching can promote unity by making sense of how the world has been and continues to be universal across diverse cultures. For her, there is not always a clear path to seamlessly incorporating social justice and science curriculum.

> Oh, the science relates [to social justice] because science involves history and science involves the past, and should the past be like it is today. I feel like they're really trying to - it's funny because I wouldn't connect, I don't necessarily think of science and history - but like, it's so intertwined because of so many things that happen as part of history are obvious, it involves science and discoveries and things like that and what people have around them.

Ms. Erica, at this moment, had an epiphany. As she attempts to develop science lessons,

the connection to social justice is not always clear in her mind. As she shared her unclear connection between history and science, she also talked about her struggle to connect science to current topics that provide positive stories that empower students. Instead, like many teachers navigating the challenges of justice-centered science, she relies on highlighting past scientific blunders or challenging past science-related decisions to begin critical science conversations. This is not a problematic way to connect science and justice-related topics, but there are other pathways to use science as a tool to facilitate students' social justice understanding.

Teachers can also use science content to foster justice by encouraging the inclusion of all racial identities and teaching with a focus on human well-being. This makes the classroom environment elevate the consideration of diversity. For example, Ms. Erica uses books from authors with different ethnic backgrounds that foster respect for all human identities. Ms. Amanda, who does not teach multiple subjects like Ms. Erica, relies on project-based learning and connecting the scientific observation skill.

> That's one thing science can do is like teaching how to be a keener observer. And to ask questions about the things that you're seeing. It can be something that is motivating towards action… I mean, other curricula in other classes, you can do that, too, but I think that is something that could be used and developed in science curriculum. Or like kind of jumped on as a good basis for social justice

work and like being a good observer and asking, why is this happening this way?

For Ms. Erica, problem-solving skill development via science learning is prominent in her classroom. “Right now, it looks like the diversity of thought and being able to have unfiltered students’ kind of bring their problem-solving ideas.” Since social justice can be a very abstract term for students, teachers must be facilitators of justice-centered learning in their classrooms. As facilitators, science teachers help students connect school experiences with their lives and science content. Ms. Erica shares:

> I would say one of our very first activities where we were talking about the simple machines and having the kids look at how each simple device was a part of a larger purpose and a greater good, and it was connected because we were kind of like isolating each object. But we also had to, like, talk about the function of the object… the thing like it has much more of a purpose than like what you just see here. And then it was easy to kind of like relate that to them [the students] being similar to a simple machine…And kind of like a part of the bigger scheme of things. You too are related to the bigger scheme of things. And how are we seeing the value in this machine and what it can really do and how are you seeing the value in you, and how are you're seeing the value in yourself and others?

Ms. Erica shares how she made the cognitive path from simple machines to more

significant concepts of connectedness for her students. Since science is often taught from a western perspective, it can be difficult for teachers to connect to social justice without having a critical lens. Ms. Erica uses her critical lens to create cognitive scaffolds for her students so that they can see justice-oriented connections where they may be hidden by hegemonic and status quo pedagogy. Her students pick up on these salient critical components in-class discussion. Alaina, in 7th grade, mentioned the need for inclusion when she reported that "our diversity or identity doesn't matter; we are all human. We all need to do our part to make society a better place." She continues to share that:

> Viruses don't ask you to show me your paycheck before it decides to infect you. Bacteria don't look at your skin color, and check that out. However, many times, you know, different groups of people are unequally affected or suffer more than others. So, we're trying to look at not just what like, how things spread, but why certain people are infected more than other people because that's going to help us figure out how to make the world a better place and a more equitable place.

Alaina connects her class discussion of diseases to an understanding of the importance of learning science with a critical context. Her knowledge goes beyond covering content and focuses on the social impact of scientific decisions.

Theme 2: Impacts of Critical Science Curriculum

The curriculum should reflect students' culture and identity, be explicit about immersing in the concept of oppression and inequity into the curriculum and create

natural parallels between science curriculum and social justice. Both teachers discussed challenging topics with students that drew from content being covered and students' real-life experiences. They took teachable moments as opportunities to discuss the connections between science and justice-related topics and let students share their thoughts.

Teaching about Power and Privilege

Addressing and discussing power and privilege is essential for implementing justice-centered pedagogy in an independent school. Teaching students about freedom and power is not a simple task at the elementary and middle school level. In this study's 3rd and 7th-grade classrooms, teachers described how they discuss power and privilege in age-appropriate ways while lesson planning, through their advisory roles and in class discussion.

Sharing how she implements justice-centered curriculum in her 7th grade class, Ms. Amanda talked about her thoughts on some of her challenges, "it's hard, they struggle more to see outside of what's like them, so they need to see that people aren't like them." She also shares that privileged students may have "a power they don't realize they have." and she strives to provide opportunities to help students see their privilege and recognize they can use their privileged to make an impact, "they just need to be able to see it. And use their power for good in the world, and they could do like awesome stuff. Don't you think?".

Ms. Amanda does not do this explicitly by using the words “privilege” or “social justice” in her lessons. Instead, she prefers to infuse salient points into class discussions. For example, while discussing the repercussions of AIDS in the LGBTQ+ community, she says, “when it was like in the 80s and 90s, that our government looked at it very much as well, “that's what you get gay people!” for being sinful and whatever. That's not the majority thought anymore, but there are still people that think that.” In her second interview, Ms. Amanda brought up this virtual class discussion because she was proud of her student’s reactions. They said things like "that is so not OK that they would be treated like that,” and I was thrilled to see the students… they didn't just privately send that to me. For them to say that in front of the whole class via chat, just to sort of stand up in that way for those people, I thought I was great.

Like Ms. Amanda, Ms. Erica wants students to recognize that they have a responsibility to be “critical” and be “even more determined to do this for other people, kids or even adults.” However, Ms. Erica models critical actions and thinking by examining her privilege through her identity as a Black woman. As she shares stories about her experiences, students can emulate their own reflection on their privilege. She is purposely more direct than Amanda in her conversations with students.

> I have my students recognize their privilege towards the end of the year. My white students especially… and then for my students who are children of color. I

have them recognize their privilege in the same way that I recognize my privilege; I go, "Well, I don't think that I have racial privilege, I experience privileges of, well, you guys might be financially privileged, but I said, "my experiences give me the privilege.", because it gives me more of an awareness and ideas and thoughts and beliefs and thinking that some people may never have if they don't ever have those same experiences."

Commitment to Student Empowerment

Student empowerment could be seen as a precursor to social action or as the action step before a social justice act occurs. In their interviews, both teachers attempted to develop student empowerment in their classroom community, and students shared some salient recognition of their empowerment in class discussions and interviews. This is an essential component of critical science curriculum and pedagogy; however, both teachers view student empowerment differently.

Ms. Amanda shared that teaching for social justice can mean motivating students towards action by helping them become "a keener observer" or inspiring them to "ask questions about the things that you're seeing and not seeing. She says, "I think that could be used and developed in science curriculum… or a good basis for social justice work and like being a good observer and asking, why is this happening or not happening this way?" Ms. Amanda does think her students would be able to notice instances of injustice but "I don't know how empowered some of them would feel to

say or do something about something they see happening that's wrong. But I think the first step is just that they can recognize that something is not right". Ms. Amanda is also unsure how she could be a conduit for this process. She agrees there are topics to facilitate the conversation, but she struggles with implementation.

Ms. Erica, however, talks about this differently. She focuses on helping students become more comfortable with acting by providing understanding and context to make up their minds about controversial topics. Since her students are younger, she focuses more on recognizing why specific issues are contentious or garnering emotion from certain groups. She does not always do this in science class specifically, more or these conversations happen during her class's morning meetings and social justice time.

> "Honestly, right now, we meet them where they are, which I think is huge because it allows for every kid to have a seat at the table and in uncertain regard and kind of feel validated by the experience that they hold, which I think is as a part of it."

She leads discussion with her students that talk about activism in relevant and appropriate ways for their ages. Emma shares an activist is "someone that doesn't just say that they're going to do it with words, but goes ahead and does it" then, later Emma mentions the specific role her teacher played in her empowerment. She states: "Because maybe Ms. Erica is kind of hoping that when we're older, we will be like an activist," showing that her sense of empowerment was facilitated via her teacher. Whether she

enacts her idea of activism, she attributes some of her understanding of activism to her teacher. In this example, there was no direct tie to Emma's science class experiences, but the overall focus of her classroom community facilitated her incorporating an understanding of what activism is.

One possible way Ms. Erica's students share that they feel "empowered" in her class is to realize they have the agency to make an impact. Shayla shares, "In Ms. Erica's class, everyone's equal. Because aces are usually at the top, but everyone's equal, everyone's an ace here." Shayla is alluding to an activity where Ms. Erica uses the analogy of a deck of cards to discuss how she will treat them in class and sets the expectation for how she would like them to treat others. Everyone in her class is an ace card, the most powerful card in the deck and infuses the idea of the power of self. Ms. Erica shared her feeling about this comment in her final interview. This idea of power and the ability to make change as an activist appeared in serval of her student's drawings. Students exemplified an understand of social justice by comparing a drawing of some justice related challenges that occur to day side by side with a picture of a future with a more equitable and just reality. When asked why they should learn about social justice at school, Shayla says, "because I think we may be young, but we still deserve to know what's going on in the world so we can do something about it." Shayla exemplifies how Ms. Erica contributes to her understanding of her agency and power in her learning. However, it is more complex for Ms. Erica than just helping them learn

about what is going on it the world.

> I think because my students have some knowledge of all things, but they, like, know nothing (laughter)... Whether like Black Lives Matter or Columbus Day or like "first female this," or why is there so much going on, like on the news... And so, you can sense when they're in a position to try to feel out a conversation because they're curious about the knowledge, but also very uncomfortable with presenting it because of others. And so, I felt like for me; it was important to provide them with the context because they want to know. So let me provide as much of the picture as I can so that you can understand why this is even so complicated.

Multiple Perspectives

Developing students' ability to appreciate, recognize and accept multiple perspectives is a critical component of critical education in the science classroom. Teacher participants in this study made deliberate choices about the examples they used with students to facilitate an appreciation for multiple perspectives. These pedagogical choices were also reflected in the content they chose to use as exemplars and how they allowed students to interact with that content. Multiple perspectives for the teachers did not only mean learning about other opinions and thoughts, but also teaching to students to apply a diversity of thought to learning and demonstrating what they know. Ms. Erica shared an example of how this recently happened in her class.

> I'm teaching, and a student says, "Ms. Erica, it looks like a lot of us did it this way, but who did it another way?"… another student shouted "Yeah! who did it another way?" Before I could even say it, they were like wanting to know, like someone else's method or a way of doing it.

Ms. Erica wants her students to be invested in being "someone who's engaged in what other people think, feel and do, but also take pride in the fact that you are a part of this process and impacting what other people think and feel and do" so that they can continue their growth in social justice learning. Here, she connects understanding multiple perspectives to a central knowledge of social justice and how she pedagogically enacts it in her class. Students need to have various perspectives to understand the complexity of some current issues and why they are so difficult for others to talk about.

Ms. Erica models' healthy ways to grapple with conflicting opinions. This is also exemplified during a discussion in a science lesson on how to get an object across the room using minimal supplies. Here students went back and forth with ideas but listened to each other and respectfully never shot down answers of others, but specifically found ways to include, after some testing, everyone's thoughts. During observations on several occasions, I noticed that while differing opinions among classmates were found, upon further unpacking, those students showed minimal resistance to changing their position if another classmate presented a better idea. For

example, in a social justice time conversation about equal pay for women and men, one student had a perspective different than his peers. Students carefully and calmly disagreed with the student's points and specifically said, "I see it differently, but we both can have our idea." Ms. Erica tells her students are "not listening to debate, but they're listening to understand. And that, I think, is so huge with social justice." For Ms. Erica, the implications of guiding students to understand and include others' ways of thinking is integral in connecting to larger social structures.

> We're in a space in our community and country where you're either right or wrong. And for [my students], it was a matter of now you see why people have different ways of thinking. So, it takes that desire to be right or wrong away; you just come out with a level of understanding… The ability to understand that someone may, first of all, have a different idea or a different opinion or a different way of doing something and that it's OK, that it does not have to be a challenge or take away anything from you.

Making a connection to larger political and social construction happens often Ms. Erica's class. Her students are comfortable asking her about contentious topics and she allows them to discuss as a class to share ideas and allow for discourse. Ms. Erica has the utmost confidence in her students' abilities to discuss, understand and even challenge their perceptions of complex social topics. In her classroom, students learn to trust their thoughts but also respect other ways of understanding.

Theme 3: Pedagogical Strategies

Teachers' Motivations for Enacting Justice-centered Science Pedagogy

Teaching for social justice is the attempt by classroom teachers to use their position in the classroom to affect meaningful change in the school community. Teachers for social justice: (1) assume all students are participants in knowledge construction, have high expectations for students and themselves, and foster learning communities; (2) acknowledge, value, and build upon students existing knowledge, interests, and cultural and linguistic resources; (3) teach specific skills and bridge gaps in students' learning; (4) work in a reciprocal partnership with students' families and communities; (5) critique and employ multiple forms of assessment; and (6) explicitly teach about activism, power, and inequity in schools and society (Dover, 2009 p. 518).

Teachers described social justice as either a desired or central theme in developing lesson plans for their classes and a part of their goals as educators. Hernandez et al. (2013), citing Villegas and Lucas (2002) and Ladson-Billings (1995b), defines teaching for social justice as "a teacher's willingness to "act as agents of change," while encouraging their students to question and challenge the status quo "to aid them in the development of sociopolitical or critical consciousness"(p. 810). For example, Ms. Erica vocalized a strong desire to advocate social justice in her classroom and serve as a professional resource for others. She says,

People these days are known for something…I want to be known for that… I

> want it to be known that not that only did I like obtain this information, but that I was a champion for educating so many people of the beauty of this type of education, this type of mindset, this type of thinking, this type of living, and critical consciousness… That is my goal in life.

Partnered with a desire to teach for social justice, both teachers were able to identify how they enact their understanding of social justice in their classrooms. When asked to give their thoughts on the meaning of teaching for social justice, they each shared a clear understanding of the concept. Ms. Amanda says social justice is,

> Introducing students to diverse ways of being in the world. Teaching the major content and skills … and sometimes just sprinkling, where you can, ties to society… like pointing out or drawing on relationships to inequalities in society. What has been done, what we can do, what kids can do to try and rectify some of those inequalities?

Ms. Erica shares: "When I teach for social justice, it means that I'm teaching humanity to my students… I am making other students comfortable with who they are, also comfortable with other people…to live, or like how to be day in and day out." While the specific words of the Hernandez et al. (2013) definition of teaching for social justice were not used, both teachers vocalized essential components of the description. Ms. Amanda recognizes how to use curriculum design to facilitate specific skills to show connections between her students and the larger society. While Ms. Erica hopes for the

transformation of the ways students think about and see the world. In other conversations, Ms. Erica mentions explicitly wanting to "facilitate the development of critical consciousness" by helping students "understand their power and privilege." These data show that both Ms. Amanda and Ms. Erica recognize their role as agents for change and the desire to help students become agents of change by increasing their critical science agency (CSA).

Teachers' Knowledge of Justice-Centered Science Pedagogy

Both Ms. Amanda and Ms. Erica understood the tenets of teaching for social justice. They also recognized how the science curriculum could facilitate critical consciousness and CSA with their students. Justice-centered science pedagogy merges teaching for social justice with science pedagogical practices that aim to enable science curriculum learning through socially charged generative themes (Basu et al., 2009; Morales-Doyle, 2017). Ms. Amanda hopes her students learn about the invisible societal structures that led to multiple inequitable impacts on different racial and social groups during the Covid-19 pandemic. She planned to help students unpack published reports from the local health department to challenge students thinking about higher infection rates based on location, types of employment, socioeconomic status, and types of privilege. She then held a parallel discussion to connect other historical events related to disease-related outbreaks, such as asymptomatic disease transmission during the typhoid fever epidemic and AIDS transmission within LGBTQ communities in the

1980s.

Similarly, Ms. Erica says she demonstrated her use of justice-centered pedagogy by "using practices, making lessons, and building skills in students that allow them to see connections between themselves and people. In times [and] in places that aren't like them." As an elementary level teacher, she explains that she has an easier time drawing from other experiences outside of the scientific context to facilitate "making connections between what we're learning and the real-world problems and issues [by] trying to find the roots to those problems and then having students take what they're learning and think, what can I do to make a change for the better?" In her forces and motion unit, she hoped that for their final projects her students would, "create something that would make a person's life easier. Then interview someone who has limited mobility. To facilitate the development of students' critical consciousness, she wanted students to "ideate what would make their life easier in some way, shape or form... this just transferred that passion over to the students." It is evident that both teachers shared the desire to teach in a justice-centered manner and for their students to see science through a justice-oriented lens. They share specific experiences that set them on the path of empowering students to develop critical consciousness.

Teacher Development of Critical Literacy

The impact of teachers' life experiences before becoming educators seemed to have perceived effects on teachers' development of their current desire

to be justice-centered science teachers; Ms. Erica and Ms. Amanda grew up in very different communities yet have pledged a commitment to bringing justice-centered perspectives into how they teach science. Justice-centered and culturally relevant pedagogy were not prominent theories during their teacher preparation coursework. When asked how they came to be justice-oriented teachers or what specific experiences led them to these critical perspectives, both teachers pointed to early experiences in their K-16 years.

As previously described in chapter 4, both teachers grew up in environments that challenged their worldviews. For Ms. Erica, her grandmother was integral to her development of critical consciousness. Ms. Erica also discussed being involved in activist rallies and learning more about the "black experience" while in college. She says she was "able to use the resistance I learned in high school." She was involved in protests and gained the epistemological information to become an activist.

For Ms. Amanda having to confront her whiteness daily but being the racial minority in her elementary and middle school years gave her some insight into the experiences of underrepresented peers. When she transitioned to a predominately white high school, she felt out of place and knew that something was different about the community. However, what did not arise in interview conversations were teachers connecting the development of a critical stance on education to their work as science teachers.

Theme 4: Critical Science Agency

CSA is a form of agency youth enact when they collectively use their scientific understanding and other forms of expertise to investigate and redress injustice in their lives by seeking more equitable alternatives (Basu et al., 2009). Teachers' expectations and their social identity-related biases impact the academic achievement of their students (Aronson, 2004; Dee, 2007; Irvine, 1990). Teachers' dedication may influence students' exposure to social justice, and that evidence could be visible in students' agency both inside and outside the classroom. Since CSA is an essential contributor to scientific literacy expertise in science content and their community, it supports their ability to identify and act in justice-oriented ways.

Students' Perception of Justice-Centered Science Pedagogy

Speaking with teachers presents one side of the justice-centered classroom. This theme focuses on students' perceived uptake of teachers' justice-centered pedagogy and curriculum in connection to students' CSA. Interviews captured students' thoughts within these two classrooms and asked about their understanding of science's ability to facilitate learning about social issues.

One 7th grade participant said, "We learned about diseases in society, we can see how it impacts us and how something so small [like a virus] that we don't really see... so now we can see it happening, especially during a time like Covid-19." The observations of Ms. Amanda's class and interview data show that

students could connect with the importance of learning about a real real-world scientific problem as it happens and use science class as a resource to grow their understanding of its current impacts. However, the specific connection to oppression or sociopolitical consciousness may not have been addressed. Still, the ability to provide a context to the global pandemic through their learning contributed to students' socio-political consciousness development.

Ms. Erica's third-grade students were more direct in their answers, demonstrating a more robust knowledge of social-justice-related issues but lacked a specific connection to science. Shyla says, "We should learn about social justice because if you are taught one way, there could be so many different ways to learn that one thing." After bringing up examples of social problems they learned about in their class, the researcher asked, "Can we talk about topics like George Floyd or other things that are happening outside of school?... Can we share that at school?" Shyla responded, "yeah, because I think we may be young, but we still deserve to know what's going on in the world." Despite discussing various examples in their classes about simple machines and social issues, the researcher observed that only one student explicitly mentioned that science could be linked to history and social justice. When asked, "Do you think that science has helped you learn more about social justice?" 3rd grader, Richard shares,

> "It helps that we've learned about a lot of plants and invasive species in animals in science. And I notice that we don't learn about it in any other project, barely. We write about it. We don't really do math about it. It's just not it doesn't really show up in a lot of subjects."

Students don't perceive a natural or frequent link to justice-centered science pedagogy and are more central in Social Justice time (see chapter 4). However, this student connected a previously learned environmental justice topic, not their current physical science simple machine unit. When asked a similar question, other students responded that science does not relate to social justice.

Classroom Community

Independent schools are beginning to expand the importance of Diversity, equity, and inclusion in their schools. The accrediting body of PTS, the National Association of Independent Schools, has been urging schools to include a sense of belonging to their DEI initiatives. Developing an understanding of belongingness for students includes creating a classroom community where students can belong.

Discussing challenging justice-related topics with students is not always something a teacher can do right away. A community where students can be their authentic selves is challenged by their teacher's pedagogy, critical science literacy, and agency curriculum. Ms. Erica shares the crucial role that building

community plays in her classroom,

> "I feel like I set up that community space for them to understand what, like understand my heart, understand my intention, understand my mindset, you know." In theme 3, I discussed the importance of teachers being comfortable with their identity as justice-centered educators and their role in influencing students' development of CSA. Steele highlights the joy he has about going to school because of the safety he feels in his classroom "Maybe, maybe because… [Ms. Erica] makes you feel special, so that's important to you when you come to school that you feel special. I like that".

Ms. Erica fosters a sense of belongingness and community by giving every student a unique nickname. Below is a conversation between two student participants and the research describing the purpose of the handles; their actual nicknames have been redacted to protect student identity.

> Emma: So she gives everyone a nickname based on like their personality. My nickname is [Student Nickname]. Because, like, I'm a trailblazer, and I'm like a good leader.
>
> Shyla: My name's [Student Nickname] cause…because they think that I will become president… Because I think I'm bold and able to, like, lead people in the right way. Lead by don't "Don't be a dictator. Lead by example."
>
> Researcher: So, I really like the names! Do you think there's a reason why Ms.

Erica does that?

Shyla: To truly feel like for kids that like that don't feel as good about themselves and feel like, don't feel like as big as an accomplishment. That is a lot of encouragement.

Ms. Erica provides more context to this student discussion as she shares the pedagogical importance of nicknames, their connection to school family (community), and how it develops students' identity. She says:

It's kind of like a way to create more of a connection between my students and myself and the classroom. For me, I always want to make sure that I establish like I know who you are, but also to take it a step further, like once you become a part of a family, then you kind of assume a new name… Then you start to be identified by the people who are around you, by the ways that they relate to you, and by the way that they connect to you.

[For Example] So there are names like [Nickname blinded] because you think outside the box, the way you think is very 3D, or one kid's nickname is [Nickname blinded] because he's such a statistician that no matter what numbers, it's just that he's incredible with. But just like that mindset. And that's something that you need to be validated in that some situations might not honor that. They always look forward to it, so I feel like it's kind of like a rite of passage, but it's something that just brings us closer together. I think it has a lot

> to do with identity, you know, and a lot of times, especially in third grade, kids have no idea what they're good at. And they're always trying to figure out, like, what can I be like known for, like, what's my skill, what's my talent? And I feel like sometimes the nicknames kind of allude to that and give them some sense of identity and validation when they might still be they might be looking for that, you know.

These names are a large part of Ms. Erica's student experience in class. They honor each other's strengths and know the meaning of their peers' names. They were creating a larger sense of validation and inclusion of personal characteristics. The names also serve as a reoccurring reminder to students to be who they are and respect who other students are in the classroom. It is so unique that even two years later, when they get to middle school, where I work, the students draw from the meaning of their name to understand their identity. This is another example of teachers modeling or creating structures in their classrooms to model a microcosm of a just society.

Ms. Amanda creates a unique community in her classroom by relying on expected trends in science and removing barriers to science connection. She uses what he calls 'Nature Quotes of the Week" and "Super Sassy Science" words to create a classroom space that is approachable to students. Ms. Amanda described this to encourage her students and help students connect science to the real world. More specifically, it combines the curriculum with a diverse set of scientists contributing to science. Table 9

shows the quotes used throughout classroom observations and their curriculum connections. One of her students shares the quote: “about nature, from someone dead or alive, and it's basically about the natural world around us and what is special about it. Sometimes a student can send in an idea, and she will do it.”

Table 9 *Examples of Ms. Amanda's Seventh Grade Nature Quotes of the Week*

Quote Author	Quote	Curriculum Connection
Rutvik Oza Poly Mathematician Social Activist Software developer	Happiness and bacteria have one thing in common; they multiply by dividing (2/5)	Demonstrates diversity of thought and inclusion of neurodiverse individuals
Aldo Leopold Conservationist, Philosopher, and educator	"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."	Leopold is known for his focus on ethical, caring relationships between people and nature.
Dr. Martin Luther King Jr. Civil Rights Activist	"It really boils does to this: that all life is interrelated. We are all caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one's destiny. Whatever affects one destiny, affects all indirectly." "For in the true nature of things, if we rightly consider, every green tree is far more glorious than if it were made of gold and silver." (2/23)	Quotes used when learning about microbes and their classification. Used to demonstrate the biodiversity of the world and how there is a connection between all living organisms
John Muir National Park conservationist environmentalist	"In every walk with nature, one receives far more than he seeks."	Class centrally focuses on nature due to Ms. Amanda's personal connection to the outdoors

Theme 5: Teaching in the Covid-19 Pandemic

The Covid-19 pandemic came with many limitations; these limitations restricted teachers from doing activities that would enrich justice-centered foci embedded in courses. The pandemic forced teachers to operate in a constant environment of flux; in

which any day groups of students could be quarantined or return from virtual learning, a new procedure would need to be implemented immediately to keep students or themselves safe, and the masks, why couldn't students K-12 just keep on their mask? Several points during this study both teachers had to suspending work on a lab or activity never to restart, work from home while their students remained at school due to Covid-19 exposure, help a student deal with an anxious situation due to fear of the pandemic outcomes, talk to a student about losing a family member not because it was their job but because their student trusted them to share. The largest challenge for teachers however was how much longer of slower the pave of their classes went, so much that sections that were planned to be taught during this study had to be changed, reimaged or not taught at all.

Ms. Amanda was impacted by this most directly since she taught five classes one of which was virtual. At one point due to students having to quarantine from exposure half the 7th grade was in her virtual class. If all the students joined at the same time maybe it would have been manageable, but they joined in the middle of a lab activity – there were three groups of students in difference places in the experiment.

All the other [in person] kids here at school are still running a lab. And I'll have to come up with a whole new set of lesson plans to be working with these [virtual] guys. And half of them were already halfway into the lab before they had to leave. So,

it's like they would have done all that work for nothing and had to start something new to do it the virtual way.

Before Covid, teachers at PTS prided their pedagogy on being one that provided enrichment and opportunities for choice for all levels of students however during the pandemic, they taught the bare minimum.

Theme 6: Challenges and Support for Justice-Centered Practices

Enacting social justice with an independent school community presents different challenges to success. Power, privilege, institutional policies, and societal class create tensions that conflict with the critical perspectives of those who would work toward reform. Responses from interviews with teachers and observations of institutional activities further highlighted these barriers.

The history of PTS and its location in Florida has made it challenging to expand specific initiatives. Ms. Amanda feels there is no opportunity for teachers to understand students' identities and understand that in the school history and community. "We need to know who our kids are. We need to know our community, and communities need to know our history… So that we know where the holes are, so we know where the best action is to be taken." She discusses students of color having difficulty bringing their identities to school and teachers not understanding the tensions students may face. Specifically, she highlights that PTS is not affiliated with any religion; there is no space for students to be comfortable being open about their faith. She says it is not a "non-

secular school. It is an “a-religious” school.” She then highlights how the community struggles with providing a space for its community to be inclusive of all religions but allows specific values to interrupt progress towards more justice-centered policies.

Isn’t that very interesting about how we're a nonreligious school, but then like we allow … perspectives or conservatism or whatever… to seep into, like, how we make decisions. And I think that's very interesting because we're not supposedly the non-religious school. Right…So it's like, do you not allow it, or do you allow everything? And if you allow everything, then allow everything. Where is the line? Yeah.

Next, Ms. Amanda makes the critical connection between the way values and religion are manifested in the school community to the influence and financial privilege of families, challenging the forward motion of her school community.

> “And what stinks about it, too, was the influence of money on the school's ability to stand up and be whom we want to be. And the like, one of the reasons I perceive that we are. Kowtowing to this certain group of conservative parents is because, especially now...In Covid. Financially, the school is in a rough place, and losing people is not something that the institution of the school can afford to do; we’re compromising what we say are some of our values to keep the people, to keep the money…Until we, the school, are in a place financially where we can say, "oh, we have a waiting list, so you just, you know, this is not the place for you." But it takes money. To be in that position. And what do you have to do to

get money, and who do you get money from?

This indicates the convergence of power within private institutions and money's role as a subset of that power. Critical Pedagogy asks educators to be cognizant of power structures within the communities as we hope to disrupt the status quo. PTS must navigate the challenges of being an institution that relies on donor funding and tuition to operate while managing the personal power of those who wish specific perspectives to be upheld. Ms. Amanda recognizes that her school is making positive gains in the development of social justice and points out that PTS is still figuring out its own institutional identity.

Ms. Amanda's identification of an unclear identity could stem from a vague understanding of how her school would like to enact social justice and use its vision and mission to support that. Both teachers shared that they feel supported to work towards justice-centered practices in their classrooms. However, it is not explicit, and not every teacher is focused on this. Ms. Amanda shares,

> "I feel like very much we have an okay from admin, but we don't have the like, "Hey, this is part of our mission, and I want you to do this." sentiment. Just like "here are some PD offerings," but actually having like "this is what we are going to do, and this is a focus of the year or the next ten years."

Ms. Amanda recognizes that with something that can be polarizing and challenge a dominant perspective, the goal needs to be clear so that all community members

understand. “You have to get everybody on board because when it's just you. It's harder to get going…you don't have people to bounce ideas off, and it's harder.” Ms. Erica shares similarly that she has the support of her division head in her division, but other teachers do not want to make the shift.

Chapter Summary

This chapter discussed six themes that emerged from the qualitative data collected in this study. These themes were developed from interpreting and analyzing identified codes, subsequently mapped to the conceptual framework guiding this study, Teaching science for social justice (Figure 2).

This study explored how independent school students understand science within a classroom using teaching science for social justice (research question 1a). Based on the artifacts, observations students in this study demonstrated growth in their scientific literacy. The mastered content for their grade level, performed well on tests and demonstrated their learning in various formats (tests, projects etc.). This was from the impact of their teacher’s application of a critical curriculum and their critical science pedagogy. Students developed some aspects of critical science agency through the understanding of critical topics and showed an inclination toward social action.

Table 10 summarizes how well the findings provide evidence for critical science curriculum and justice-centered pedagogy developing students' critical science agency (research question 2b).

Table 10 *Mapping Teaching Science for Social Justice Conceptual Framework Characteristics to Code Emergence*

Critical Science Literacy	Justice Centered Pedagogy	Critical Science Agency
• **Connections between curricular standards and real-world social justice topics** • **Students understand and critique multiple sources and perspectives of scientific information.** • **Students evaluate and develop moral and ethical decision-making skills.** • Curriculum reflects students' personal and cultural identities, • Includes explicit instruction about oppression, and inequity, • Develop and understand nature of science skills and scientific inquiry.	• **Facilitates growth in awareness of social oppression.** • **Disrupts power imbalances.** • **Emphasizes critical thinking and inquiry-based instruction that promotes students' academic, civic, and personal growth.** • **Develops student's critical science literacy and critical consciousness.** • **Use of social justice standards** • Commitment to anti-racist teaching and **student empowerment** • Science content is politically and culturally determined, value-laden and influenced by systems of oppression. • Creates equitable and supportive classroom climate that embraces multiple perspectives.	• Students' sense of themselves as social activists • Students' awareness of inequity and injustice • Students carrying out individual and or collective action. • Students' civic participation and social action • Develop expertise in science within community context. • Students express empathy. • Students stand against bias and injustice in their everyday lives.

Note: Characteristics that are in **bold** face were **s**upported by several overlapping data sources. Characteristics highlighted in gray, were present based on researcher notes and observations but not salient in participant conversations.

There is strong evidence from identified codes and thematic analysis supporting critical science literacy and justice-centered pedagogy being present within the two classes observed. Meaning each type of data source collected (interviews, observations, and artifacts) triangulated support for the individual characteristics of Critical Science Literacy and Justice-Centered Pedagogy. However, evidence supporting students' development of Critical Science Agency was not consistently identified in each data source, specifically, the interview data. Chapter 6 will discuss the possibilities for this lack of evidence and secondly provide possible methodological and changes to example this framework in the future.

CHAPTER SIX: DISCUSSION

This chapter will begin with a summary of the study, including an overview of the problem, the purpose of the study, the research questions, and a summary of the methodology. Next, the discussion will examine the findings and implications for practice and science education. The chapter with close with a discussion of future research and the study's limitations.

While research continues to conduct studies in the classroom with pre-service and in-service teachers and students that focus on the merger of justice-centered pedagogies with science education (Morales-Doyle, 2018) and exploration of CSA (Schenkel et al., 2019), these studies are enacted in culturally and racially diverse public schools. Private schools make up 25% of the schools in the United States and remain places where little research is conducted (Swalwell, 2011) in a science context. Further, 80% of private schools in the United States are predominantly White in their student demographic (Snyder et al., 2019), which provides a unique context to examine types of teaching and learning that develop students' critical consciousness and challenge the status quo.

This multiple case study aimed to examine and understand the enactment of justice-centered pedagogy in a predominantly White private school. A critical pedagogy

lens was used to address the need for future studies to observe the "relationship across teachers' social justice intentions, classroom practices, and students' outcomes" (Dover, 2012, p. 10) in a science classroom and in a community that views justice-centered learning as optional. The participants in this study were teachers and students at an independent school in the southwest region of Florida. The conceptual framework, discussed in chapter 1 and figure 2, examined the enactment of teaching science for social justice in the two classrooms at PTS.

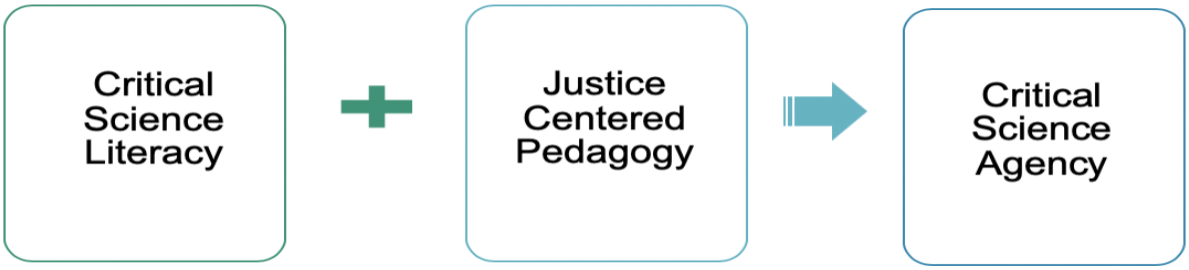


Figure 2. Teaching Science for Social Justice: Critical Science Literacy, Justice-Centered Pedagogy Leads to Critical Science Agency

Using a critical pedagogy lens and individual and cross-case analysis serval themes emerged that highlighted the complexity of enacting a justice-oriented science class at an independent school. These emerging themes overlapped with the conceptual framework of teaching science for social justice.

Summary of the Methods

I used an embedded case study design to answer the research questions that guided this study. The data collected for the study came from two classrooms, a middle and elementary class in a Florida K-12 independent school. The first classroom was a

7th-grade teacher's classroom with two students, and the second was a 3rd-grade elementary-level teacher's class with nine students. The data sources included observational memos, artifacts, and interview data generated from recordings of teacher interviews and student focus groups conducted during the duration of the study. Data analysis included thematizing all data sources using Dedoose qualitative software. First, I analyzed each classroom separately followed by a cross-case analysis approach. Analytic codes emerged from current literature and open coding of participants' words and phrases. Other potential themes were further fine-tuned during weekly discussions with a critical colleague (Merriam, 1998).

Discussion

Chapter four and chapter five presented the findings of this study and the six emerging themes relative to the research questions. What follows is a discussion of the findings through the lens of the three components of the conceptual framework, teaching science for social Justice - critical science literacy, justice-centered science pedagogy and student critical science agency. Figure 4 shows how the 6 themes that emerged from the findings overlap with the three components of the conceptual framework. Since critical science literacy and justice-centered science pedagogy were so intertwined and overlapped with all six themes they will be discussed together.

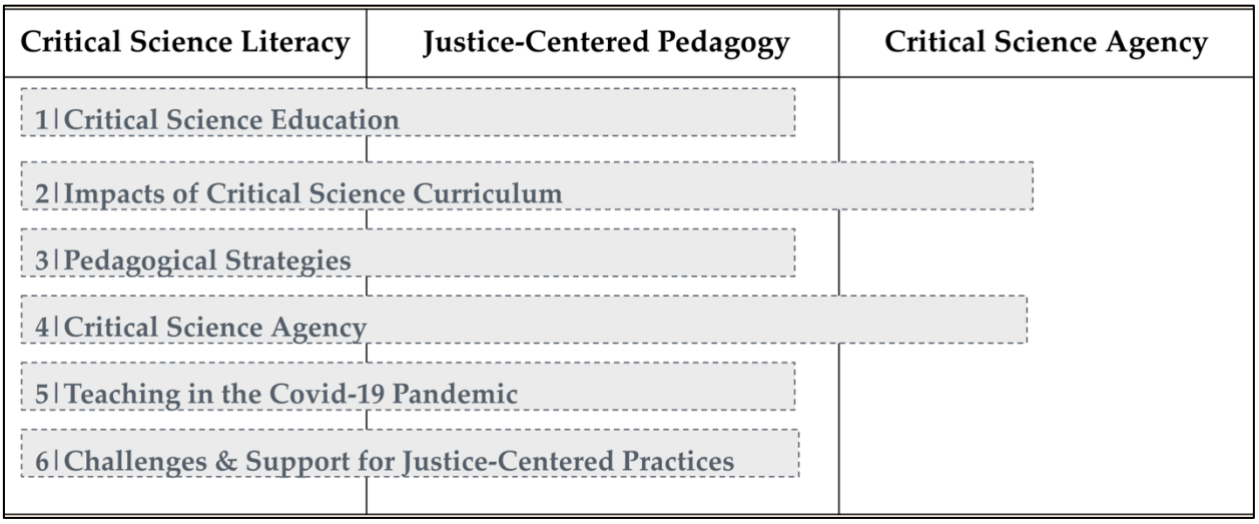


Figure 4. *Mapping Six Emerging Themes to Teaching Science for Social Justice Conceptual Framework*

Students' Critical Science Literacy and Critical Science Agency

The findings of this study suggest that students experienced limited growth in critical science agency. Critical science agency (CSA) provides opportunities to merge scientific and other forms of knowledge and practice to address instances of injustice (Vossoughi & Shea, 2019). Through this process, youth: 1) develop expertise in science content and the science in their community contexts, 2) use that expertise to identify and take actions collectively on problems within their community, and 3) understand that such actions are justice–oriented (Vossoughi & Shea, 2019). Making these tenets the goal of any science classroom asserts the critical components of justice-centered science learning. It emphasizes how science education can lead to epistemological

transformations within and beyond the classroom (Philip et al., 2018; Vossoughi & Shea, 2019).

Students' perception of learning critical science in the classroom connects to their sense of themselves as social activists, their awareness of inequity and injustice, and their desire to carry out individual or collective action. Some students could connect real-world scientific problems to their own lives and use science class as a resource to grow their understanding of those connections. Some students demonstrated robust knowledge of social justice-related issues but needed more awareness of oppression or sociopolitical consciousness. Overall, the outcomes of this study suggest that students could embrace more justice-focused topics but could not connect that awareness to any specific science content. Therefore, critical agency could be developed in the classroom without the respective science component, improving their critical consciousness, not critical science consciousness.

Lack of evidence of student CSA may raise concerns over the effectiveness of the teacher's pedagogy. However, we must acknowledge that disrupting engrained students' social perspectives, student identities, and scientific hegemony using a critical framework cannot be done with certainty in one academic year. Learning science for social justice is a gradual process that can incrementally develop the skills and tools (Chubbuck, 2010) students need to grow their critical consciousness. However, experiences in one year could contribute to epistemological breakthroughs in student

CSA in later years. In the case of PTS's organizational goals, students' justice-centered experiences and critical consciousness are a continuum that starts in younger grades and is developed throughout students' academic experiences through 12th grade.

There is a cyclic dependence on curriculum and pedagogy when teaching science for social justice. Teachers develop curricula to meet content-related standards but make pedagogical decisions that support critical science practices and tasks that develop students' CSA. Ms. Amanda and Ms. Erica used science content exemplars to foster social justice in their classrooms by encouraging the inclusion of all racial identities and teaching with a focus on human well-being and a clear connection to culturally responsive teaching. The discussions combined science content with justice-focused practices by developing problem-solving skills and helping students connect school experiences with their lives and related science content. Teacher participants used pedagogical strategies that facilitated growth in awareness of social oppression, developed student empowerment, discussed how to disrupt power imbalances, and used critical thinking and inquiry-based instruction to promote personal growth to impact students' critical science literacy. Teachers discussed challenging topics with students that drew from science content and students' real-life experiences and identified age-appropriate examples of how and why power and privilege exist in science. Overall, both teachers desired to help students recognize a responsibility to be "critical" and be "even more determined to do this for other people, kids or even adults"

(Interview 2, Ms. Amanda). When teachers modeled how to grapple with conflicting opinions by making deliberate choices like asking critical and ethically driven questions and supporting respective dialogue, this facilitated students developing an appreciation for multiple perspectives and diversity of thought. While the study found less evidence of students making a direct connection between science and social justice-inspired content, they collectively spoke about empowerment through the lens of activism, moral choices, and awareness of current events, which are all precursors to the components of CSA (see table 10).

Making Social Justice and Science Explicit in Curriculum and Pedagogy

Critical science curriculum attends to students' scientific literacy, providing opportunities to question, challenge, and reconstruct student knowledge and offer possibilities for transformation, not only of the learner but also of the social and political contexts in which learning and social action occur (Moje, 2007). There was a gap between teachers' perceptions of justice-centered pedagogy and students' respective development of their critical science literacy and critical science agency. Even with their success in teaching science content, teacher participants shared several challenges of making justice-centered science explicit to students.

To implement critical science curricula, teachers must work against hegemonic ways of teaching science in their classroom communities, within curricula, and in their pedagogical practices. Implementing justice-centered lessons proved more difficult for

teachers despite their expectations and critical development. When students were asked to reflect on justice-focused lessons, they did not identify justice-related components. When the link between science and social justice was unclear, Ms. Erica focused more on equitable teaching practices and modeling justice-focused thinking, acceptance of multiple perspectives, and diversity of thought elsewhere, like in history and English, and advisory. Ms. Amanda admitted that when the year became challenging due to the pandemic, she switched to a more traditional science class without the pre-planned justice-related components. Evidence shows that teachers with a developed understanding of the intersection of social justice and science may not guarantee the development of that link for students, creating a gap between theory, practice, and student outcomes.

There are a few reasons why this gap may continue to persist. As discussed in the literature review of this study, hegemony makes it challenging to dismantle systems that support the status quo. Educational research has long supported a focus on culturally relevant and sustaining practice. However, teachers, schools, and other related systems find it challenging to keep these practices at the forefront of their decision-making and school development. When challenges arise, like a global pandemic, difficulty identifying connections between science and social justice in content, or unclear messages about commitments from school leadership, teachers, especially elementary, choose to return to traditional ways of teaching. Teachers see

critical ways of teaching science as optional. These invisible factors slow the progress teachers hope to make as they move away from more essentialist practices towards more justice-centered ones.

Science is a human endeavor, and relegating science learning to certain pedagogical practices or topics ignores that *all* science content is essential and relevant and needs to be taught from a justice-oriented lens (Seriki and Lewis (2022). both teachers in this study struggled with this perspective. While they desired to teach topics in science through a critical science lens, they both needed more confidence and other resources to feel capable of full implementation. Vossoughi and Shea (2019) and Schenkel et al. (2019) caution us as researchers and educators to consider what is identified as student learning. As scientific knowledge and authority hierarchies are reshaped, more attention should be paid to what is hidden or made hidden in teaching science to combat the status quo. Questions arise, how do teachers carefully navigate students constructing their application of science in their lived contexts and its ability to change the future narratives of science education? "Imagining more just futures in STEM is critical for developing forms of science… that contribute to ethical inquiry, invention, and change" (Vossoughi & Shea, 2019, p. 332).

Impact of Students Privilege

Privilege was a factor that PTS highlighted as an area to understand on its journey to becoming more focused on social justice. Teachers mentioned privilege

several times in their pre- and post-interview sessions and in observational conversations with members of the PTS community. Teachers hoped to help students address their privilege through science curricula by showing examples of multiple perspectives, asking specific questions, and helping them identify types of privilege (economic, class) and connect this privileged to their power and agency to create change. However, students did not bring up their privilege or any interpretation of privilege as deemed by the researcher in their class discussions, during social justice time or otherwise. If students were asked more directly in the interview about privilege, they might have shared more of their thoughts. It could also mean that in future studies developing intentional ways to capture information about students understanding of their privilege will be necessary to determining if and how privilege plays a role in the development of critical science consciousness and students' critical science agency.

During Students' time at PTS, external factors could impact their general critical consciousness development. Unfortunately, that variability could be said for any factor a school hopes to foster and grow in students' time in their community. What research does tell us, however, is that systems within schools can and do make impacts on students and their perceptions of the world in both negative and positive ways.

Therefore, it is not hyperbole to suggest that impact students' ability to improve their justice-oriented ways of thinking is impossible. With PTS continuing to implement more justice-focused practices within and outside the classroom, interactions among

students will help develop dignity, confidence, and healthy self-esteem without undermining the worth and dignity of others. Students will be able to identify characteristics of the dominant culture, their privilege, and their culture and understand how others negotiate their identity in multiple contexts and cultures. With the consistent implementation of justice-oriented practices, more substantial evidence of CSA could be present in PTS's science classes. Further, this proposed development of CSA could change students' and teachers' perspectives, building empathy for others and their ability to contribute to future systemic change.

Justice-oriented Professional Development

Teachers need opportunities to experience justice-oriented professional development. These opportunities go beyond professional development that shares what others have done at their schools or sharing a tested curriculum template but provides time for teachers to gather resources, customize units to their school context and community, and identify gaps in their critical consciousness (Crabtree & Stephan, 2022; McGee & Wiley, In Press) given the over prevalence of studies that examine informal or out-of-school time settings (Seriki & Lewis, 2022) one unique aspect of this study is examining seasoned in-service classroom teachers that are developing their justice-focused pedagogical skills. These teachers had access to professional development, time in their schedules to plan units, and autonomy to implement them.

Teaching science for social justice should be customized and unique to the school community and the students; it could be difficult for teachers to translate other experiences and exemplars from another teacher's classroom. With limited empirical studies on teaching science for social justice in the independent school context, this study shares implications for K-12 science education and students' critical science consciousness development in privileged educational spaces. Some evidence of the ability for justice-centered pedagogy and to facilitate the development of students' critical consciousness and critical science consciousness is an important finding. However, there is not enough support from students and scholarly research to support that these together can consistently help grow students' critical science agency.

Teachers Life Experience and their Justice-Orientation

The impact of teachers' life experiences before becoming educators had perceived effects on teachers' development of their current desire to be justice-centered science teachers. Teachers described social justice as a central theme in developing lesson plans for their classes or as a part of their educational goals. They recognized their role as agents of change. They facilitated students' connection to science through their justice-oriented lens by using specific experiences that set students on the path of empowerment and critical consciousness development. However, teachers consistently returned to the impact of their life experiences before becoming educators, which contributed to why they hope to continue to work toward teaching students how to be

more justice-oriented in their perspectives. They sometimes felt it was more important than the science content.

Implications for Teaching Science for Social Justice

Challenges and Support for Justice-Centered Practices at Palm Tree School

As explained in chapters 4 and 5, PTS has several initiatives that continue to bring the community closer to a more accepting and inclusive space. However, how those goals are supported across its divisions and community needs to be more consistent. These inconsistencies allowed some teachers and administrators to refrain from the robust implementation of justice-centered practices allowing dominant pedagogy and curricula to persist.

Given PTS's history, location in the country, and an accepted understanding of challenges encountered during organizational shifts towards inclusivity, this is not an unexpected or novel observation. Philosophy and changes in science experience similar barriers when shifts in knowledge paradigms occur (Kuhn, 1970). However, there are steps that PTS and other independent schools could take to make the shift toward a justice-centered community more intentional. For example, making social justice and inclusivity required parts of the curriculum in every grade and subject and including it in the teacher evaluation and professional development process. PTS should document and examine its progress more intentionally through school evaluation of its practices. These changes allow teachers to co-construct a shared vision for social justice with the

school and provide accountability. PTS deciding to be more justice-centered but making it an optional component of the curriculum allows some teachers to continue teaching science in traditional ways and from dominant perspectives. Moreover, such a model requires careful crafting of evaluative tools so that incorporating social justice into the curriculum is not an add-on but an asset to learning that drives instruction, fulfills the school mission, and develops teachers' pedagogical skills simultaneously.

Layered within PTS's inconsistent commitment to shifts toward teaching science for social justice, teachers have mixed confidence in addressing the needs of a growing multicultural student body. Doing an equity audit of their staff to understand teacher gaps would help create a long-term plan to address teacher pedagogy. Since PTS is not a public school, it is incumbent on teachers to know the changes in science education. However, without professional development and the required connection to current changes in science education research, these changes may not happen. For example, culturally relevant and responsive teaching, socio-scientific issues, and place-based learning are educational theories implemented in research for over 20 years. It is unclear if every science teacher, newer or older at PTS, knows what each of those theories entails and how they serve students and support more substantial outcomes of critical scientific literacy, critical consciousness, and a more inclusive classroom.
PTS is not starting its journey from infancy; some teachers, like those who filled out the preliminary interest survey, want to learn more about changing their curriculum and

supporting their critical consciousness development. Ms. Erica talks about this in her interviews, describing wanting to continue her development by taking courses at the local university. She realizes she might be one of the teachers more experienced in justice-oriented teaching and has been elevated as an expert by her colleagues. She says she wants to continue to grow so that she can support the mission of the school. When PTS does conduct school-wide professional development, some sessions focus on developing a justice-oriented curriculum and individual critical consciousness; these sessions always include several teachers, but incorporating their learning is optional, and there is no tracking of how or what teachers learn is consistently incorporated into pedagogy and curriculum development.

PTS is a non-religious independent school; it provides a community that respects all religious practices, sexual orientations, and cultural backgrounds. Ms. Amanda, who grew up in a very religious community, realizes that students struggle to be openly comfortable about their religious and cultural beliefs. She connects this to the prevalence of new conservative societal perspectives and the lack of institutional practices that foster students' ability to bring their whole selves to school safely daily. Educationally, schools teach students skills to debate one another and how to present points that support their perspectives. Less prevalent skills teach students how to hold space for their views of knowledge without diminishing the thoughts of others. For example, implementing critical thinking skills like social justice science issues teaches

content and provides skills to see multiple perspectives within scientific knowledge. These skills could directly impact supporting inclusivity if other content areas and social-emotional learning practices used at PTS followed similar patterns.

Moving a school community towards inclusive and justice-centered practices is not an overnight transformation. There are several opportunities for PTS to continue to shift within its community toward its mission of more acceptance and social responsibility. With limited accountability and the permeation of ideals contradictory to their mission, the path forward will continue to present challenges.

Limitations of the Study

There are several notable limitations in this study. First, this study took place at a specific independent school. It is possible that interview responses would be different if the study were conducted at a public school or even an independent school with different demographics (e.g., not predominantly white) where the learning contexts may differ. Next, in the elementary school division, there are no stand-alone science courses like in the middle school division. Flexibility regarding lesson time is approached differently within either division.

Additionally, PTS's elementary school science classes are less structured; activities are fluidly designed to take up smaller or larger periods during the day and create more natural interdisciplinary links. However, in middle school, an activity can be completed in one or multiple class periods. In either case, this affected the time to

complete the study's observations. Additionally, accommodating the schedule of two different divisions and sporadic school activities (e.g., field trips, presentations, guidance lessons) challenged the timeline, the implementation of science lessons, and data collection. While the principal researcher had a previous professional relationship with the school's community, scheduling class visits were challenging, limiting the time to observe classes. Individual interviews were planned with all student participants; however, because of condensed timelines and availability, these were changed to focus groups—this limited time to interview each student and gather their thoughts about their experiences within classe**s.** There were many unforeseen challenges related to implementing a research study while schools navigated the constraints of a national pandemic. Several of Ms. Amanda's classes had to be combined as students in her grade level were quarantined due to the school's Covid-19 policies making her virtual class impossible to follow the proposed schedule.

Implications for Future Research

This study has implications for future research in the field of science education. First, this study confirms that students can develop critical agency and even begin to develop critical science agency when taught using a justice-centered curriculum and pedagogy. However, more research is needed to detail the instructional practices needed to support the more robust development of students' CSA.

Teachers' Critical Science Agency Development

The first step to understanding how to grow students' CSA consistently is addressing teachers' critical science consciousness and critical science agency by developing equitable systems within a school. Past studies have focused heavily on the redistributive aspect of social justice, equally distributing resources for equal access and opportunity for participation in science for all students (Chen & Moore Mensah, 2022; Chubbuck, 2010; Nieto, 1992). However, as we tackle those relational dimensions of social justice, understanding and researching solutions that directly impact empowering teachers and students to disrupt science requires more attention and is equally as critical to challenge the narratives of the backgrounds, experiences, and identities in the science classroom (Chen & Mensah, 2022).

A teacher's historical background significantly impacts their identity as a justice-oriented teacher. This study confirms other research on the relationship between teachers' social justice beliefs and students' identity development and, thus, students' development of critical science agency. However, understanding the process of changing specific pedagogical practices that impact lasting change on students' critical scientific literacy and critical science agency requires more understanding.

Research should address supporting veteran and in-service teachers beyond their early years to reimagine their pedagogical practices to include social justice themes. Several research studies examine the outcomes of novice and pre-service teachers in

undergraduate and graduate method courses. Examining questions that navigate the epistemological and ontological dissonance of a teacher revising their current practices could determine other frameworks for understanding how to impact teachers who have been in their classrooms longer than five years. When private, independent, or public schools require a focus on teaching for social justice, what changes need to occur for the teacher and the school's systems, and how do professional development models need to change to facilitate that growth?

Teachers of color often recognize opportunities to disrupt dominant ideologies in their classroom and quickly switch to dismantling systems of oppression traditional science teaching can support. Chen and Mensah (2018) used a social justice lens to explore how science teacher professional development supports science teacher identity development and agency of teachers of color by scaffolding and building on their cultural backgrounds and personal experiences with science.

Two teacher participants drew on their justice-oriented science teacher identities to challenge the dominant narrative of science and use inclusive science teaching methods that welcomed students of color into science. Ms. Erica, a woman of color, employed a similar strategy paying particular attention to her student's color by highlighting her stories and experiences. Vossoughi and Gutiérrez (2016) encourage attention to the possibilities for nondominant communities presented by the creative practice of pedagogy toward liberatory ends, building on Freirean perspectives where

students develop critical consciousness about inequities and injustices and become agentic trans-formers of those worlds. What is an extension of Chen, Mensah, Vossoughi, and Gutiérrez's work is that Ms. Erica has added a goal to re-direct and impact the perspectives of the student from dominant cultures through her stories as well. Culturally informed pedagogies benefit underrepresented students but provide pathways for dominant cultured students "to develop the skills that will allow them to critique the very basis of their privilege and advantage"(Ladson-Billings, 2014, p. 83). This supports Freire's critical pedagogical goals. Therefore, research exploring similarities and differences between teachers of color teaching in predominantly white classrooms like the PTS provides tools to support all students' critical science agency.

In order to empower all students to dismantle hegemonic forces in society, science teachers' professional development must understand critical aspects (Crabtree & Stephan, 2022) of teaching science for social justice. However, research on teaching science for social justice and similar frameworks have primarily emphasized school-university partnerships (Lee & Buxton, 2010) and preparing pre-service teachers (Ball & Tyson, 2011). According to the literature review, discussions about teaching science for social justice in specific K-12 classroom contexts have focused on social justice science issues (Morales-Doyle, 2017, 2018), anti-racism, and sociopolitical consciousness in indigenous science classrooms (Upadhyay et al., 2020, 2021) and environmental justice (Dimick,

2012; Herman et al., 2018). Nevertheless, only some studies are about preparing in-service teachers who are seasoned practitioners in specific content areas, especially science, and examining these frameworks at independent schools.

Frameworks in science education that emphasize the importance of teachers' self-awareness and critical consciousness must be developed (Crabtree & Stephan, 2022; Patterson & Gray, 2019). A particular course or professional development workshop will do little to achieve the desired change; instead, a guiding framework for pedagogical and curricular change must be used to ensure success in impacting students' critical consciousness Crabtree and Stephan (2022) ask an interesting question that also arises from this study: can the development of teacher critical *science* consciousness happen before "an awareness of the systems that create social inequities" in science is achieved, and if "critical consciousness is a necessary antecedent to critical *science* consciousness " future research should unpack this hypothesis. Therefore, implications from this study agree with Crabtree and Stephan and call for research that includes a new model for professional development to support science teachers' critical awareness and, potentially, the sociopolitical consciousness necessary to enact justice-oriented pedagogies. Components of this model include collaborative inquiry and place-based approaches to investigate inequities in a scientific context. Exploring how teachers might be supported to recognize racism and other forms of oppression *within* science and guide students to apply science tools to

dismantle oppressive systems is a crucial area for future research.

Justice-centered Science in Independent Schools

Given the discussion about the unique context of independent school classrooms in the literature review, there is limited research about the pedagogical strategies teachers in independent schools use when examining the outcomes of justice-centered science pedagogy and curriculum in support of students' critical science literacy critical science agency development. As researchers, we often search for the patterns and threads that lead to generalizability and transferability to develop a theory that can be applied in several contexts. The longer I encounter frameworks that address justice-oriented practices in science education, the more I ponder the need to create uniformity in science education reform. How PTS changes its community and science curriculum towards more just practices is unique to its characteristics and needs. This study sought to describe what it looks like to teach science for social justice in two specific classrooms. However, while this type of pedagogy should have similar conceptual underpinnings, how teachers execute it in their school's context and how students respond could differ.

PTS's desire to be a more inclusive community that incorporates equitable practices throughout its decision-making, teaching practices, and development within students opens a conversation for all independent schools. Before this study, several conversations were conducted between the researcher, teachers, the head of the school,

and the diversity coordinator. PTS's willingness to examine their school's community created an opportunity to learn and improve. Through collaborative discussion, leadership supported the goals and purpose of this study despite its unknown outcomes. There was invested interest by the researcher and the school in the value that the findings could provide to their community and its potential to support future growth. Identifying strengths and areas for improvement allows PTS to keep charting the path forward for its community.

The potential for this study to guide similar progress at other schools is an important endeavor. How can we create frameworks that provide a general framework that is clear and useful to teachers and schools that outlines only why this work is needed but "how" to do this work and allow an element of customizability? Bell (2019) “we need to resist uniformity in educational systems and practices—a common logic centered on sameness in educational improvement efforts—since it tends to reinforce socially dominant perspectives in how uniform structures” (p. 688).

The Covid-19 Pandemic had a significant impact on the results of this study. In conjunction with current events, our analysis suggests that several revisions to the instructional sequence are warranted. Researchers could extend this study by duplicating this study at Palm Tree School with more elementary, middle, and high school classes. Performing similar work at groups of independent schools across the region and the United States could also provide great insight into how the landscape of

independent schools of various types committed to implementing teaching science for social justice impacts student critical science agency. Additionally, students and teachers could be administered a questionnaire to understand how the critical science agency of teachers and students changed over several years with larger data sets and mixed methods. One could then study the myriad of similarities and differences at these institutions based on race, ethnicity, class, gender, gender identity, sexual orientation, religion, and the like. In any case, it is essential that the study be longitudinal to allow for more time to study participants.

A critical pedagogy lens was used to address the need for future studies to observe the "relationship across teachers' social justice intentions, classroom practices, and students' outcomes" (Dover, 2012, p. 10) in a science classroom and in a community that views justice-centered learning as optional. The study hoped to answer these research questions: How do independent school students understand science within a classroom using teaching science for social justice? And In what ways do independent school students demonstrate, use, and apply scientific content in a justice-centered science classroom? To what extent, if any, does critical science curriculum and justice-centered pedagogy develop critical science agency, including the ability for students to take social action?

This study provided a detailed description of teaching science for social justice in an elementary and middle school science classroom at the Palm Tree School. In

conclusion, while the intention was to find evidence of the teaching science for social justice conceptual framework and its ability to support critical science agency, more work is needed to understand how to support critical science literacy. Justice-oriented pedagogy together drives the development of critical science agency of students. Additionally, the study uncovered the importance of teachers' critical agency and its connection to their desire to become justice-oriented educators. Lastly, the findings identified that if the desire to implement justice orientations is not an explicit goal communicated to students in the science classroom, the ability for science to serve as a tool to develop students' critical science consciousness is difficult to detect.

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APPENDIX A: UNIVERSITY OF SOUTH FLORIDA IRB APPROVAL

UNIVERSITY of SOUTH FLORIDA

APPROVAL

December 18, 2020

Selene Willis
[redacted]

Dear Ms. Selene Willis:

On 12/18/2020, the IRB reviewed and approved the following protocol:

Application Type:	Initial Study
IRB ID:	STUDY001813
Review Type:	Expedited 5, 6, 7
Title:	Teaching Science for Social Responsibility: Curriculum, Pedagogy, and critical Science Agency in Independent School Classrooms
Approved Protocol and Consent(s)/Assent(s):	• IRB Protocol - Study001813 Science for SR 12.15.20.docx; • Parental Consent - Study001813 Science for SR 12.12.20.pdf; • Student Assent - Study001813 Science for SR 12.12.20.pdf; • Teacher Consent - Study001813 Science for SR 12.12.20.pdf; Approved study documents can be found under the 'Documents' tab in the main study workspace. Use the stamped consent found under the 'Last Finalized' column under the 'Documents' tab.

Within 30 days of the anniversary date of study approval, confirm your research is ongoing by clicking Confirm Ongoing Research in BullsIRB, or if your research is complete, submit a study closure request in BullsIRB by clicking Create Modification/CR.

This study involving child participants falls under the minimal risk category 45 CFR 46.404: Research not involving greater than minimal risk.

Requirements for Assent and/or Permission by Parents or Guardians: 45 CFR 46.408 Permission of one parent is sufficient. Assent will be obtained as outlined in the IRB application.

UNIVERSITY of SOUTH FLORIDA

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

Jennifer Walker
IRB Research Compliance Administrator

APPENDIX B: INFORMED ASSENT AND CONSENT FORMS

Teacher Informed Consent to Participate in Research Involving Minimal Risk

Title: Teaching Science for Social Responsibility: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

Information to Consider Before Taking Part in this Research Study

Study # 001813

Overview: You are being asked to take part in a research study. The information in this document should help you to decide if you would like to participate. The sections in this Overview provide the basic information about the study. More detailed information is provided in the remainder of the document.

Study Staff: This study is being led by Selene Willis who is a Doctoral Candidate at The University of South Florida. This person is called the Principal Investigator. Selene Willis is being guided in this research by Dr. Dana Zeidler as her faculty advisor.

Study Details: This study is being conducted at independent (private) middle and elementary schools in the Tampa Bay area. The purpose of the study is to is to understand the perceptions of students in the science elementary and middle school classrooms and the impact of a social responsibility focused pedagogy and curriculum on students' development of science expertise and critical science agency. The research will be carried out by observing classrooms, collecting artifacts and conducting two hour long interviews with classroom teachers.

Subjects: You are being asked to take part because you are a teacher at an independent school in the Tampa Bay area.

Voluntary Participation: Your participation is voluntary. You do not have to participate and may stop your participation at any time. There will be no penalties or loss of benefits or opportunities if you do not participate or decide to stop once you start. Your decision to participate or not to participate will not affect your job status, employment record, employee evaluations, or advancement opportunities

Benefits, Compensation, and Risk: We do not know if you will receive any benefit from your participation. There is no cost to participate and you will not be compensated for your participation. This research is considered minimal risk. Minimal risk means that study risks are the same as the risks you face in daily life.

Confidentiality: Even if we publish the findings from this study, we will keep your study information private and confidential. Anyone with the authority to look at your records must keep them confidential.

WHY ARE YOU BEING ASKED TO TAKE PART?
We are asking you to take part in this research study because you self-identify as a middle school science teacher or and elementary teacher at an independent school in the Tampa Bay area.

STUDY PROCEDURES
You will be asked to:
Complete a 20-minute open-ended online questionnaire.
Participate in two individual 45 to 60-minute interviews where you will be asked to discuss your experiences as a classroom teacher and your implementation of science curriculum that promotes social responsibility. These interviews will be audio and video recorded.

- Allow the principal investigator to observe your classroom during 10 science lessons.
- Share Artifacts your students generate through during their regular classroom activities.
- The interview will take place during regular school hours during non-content related class time.
- The interviews will be in-person with the researcher, who is also a certified classroom teacher. All COVID-19 and social distance guidelines required by the school will be observed.
- Should your go into quarantine and classes are still in session, the interviews will be scheduled using video conferencing software.

All data collected will be stored electronically in the researcher's password protected Microsoft One Drive. Paper copies of any collected data and artifacts will be scanned and stored electronically. Non-paper generated artifacts will be captured electronically through the use of digital photography and stored electronically.

All collected information and data will be kept confidential by removing any identifying information right after data has been collected. Numerical identifiers and/or pseudonyms (fake names) will be used to record the data and to protect your identity. The legend that relates your identification to the numerical codes will stored on a separate file, on a password restricted computer. Data shared on a public domain, will be aggregated so that your anonymity is preserved. Any collected materials will be stored up to 5 years after the final report is submitted to the USF Institutional Review Board then afterwards the all materials will be destroyed.

TOTAL NUMBER OF SUBJECTS

About 10 to 30 individuals will take part in this study at your school.

ALTERNATIVES / VOLUNTARY PARTICIPATION / WITHDRAWAL
You do not have to participate in this research study. You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study. You are free to participate in this research or withdraw at any time. There will be no penalty or loss of benefits you are entitled to receive if you stop taking part in this study. Your decision to participate or not to participate will not affect your or job status.

BENEFITS

The potential benefits of participating in this research study include:
- Developing your experience teaching curriculum that centers student social responsibility and social action.

RISKS OR DISCOMFORT

This research is considered to be minimal risk which means that the risks associated with this study are the same as what you face during your daily activities every day. Your participation in this study does not increase your risk of exposure to COVID-19 anymore that the normal risk you face every day while teaching at your school. The researcher will adhere to the school's COVID-19 safety procedures by remaining in their mask at all times and remain at least 6 feet away from you. While the above precautions will be taken, the researcher cannot guarantee that your child will not be exposed to the virus. There are no known additional risks to your participation in this study.

COMPENSATION

You will receive no payment or other compensation for taking part in this study.

COSTS

It will not cost you anything to take part in the study.

PRIVACY AND CONFIDENTIALITY

We will do our best to keep your records private and confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Certain people may need to see your study records. These individuals include:
The research team, including the Principal Investigator and their faculty advisor.
Certain government and university people who need to know more about the study. For example, individuals who provide oversight on this study may need to look at your records. This is done to make sure that we are doing the study in the right way. They also need to make sure that we are protecting your rights and your safety.

- The USF Institutional Review Board (IRB) and its related staff who have oversight responsibilities for this study, and staff in USF Research Integrity and Compliance.

We may publish what we learn from this study. If we do, we will not include your name. We will not publish anything that would let people know who you are.

While participating in an online study and completing an online survey, it is possible, although unlikely, that unauthorized individuals could gain access to your responses. Confidentiality will be maintained to the degree permitted by the technology used. No guarantees can be made regarding the interception of data sent via the Internet. However, your participation in this online survey involves risks similar to a person's everyday use of the Internet. If you complete and submit an anonymous survey and later request your data be withdrawn, this may or may not be possible as the researcher may be unable to extract anonymous data from the database.
What if new information becomes available about the study?

During the course of this study, we may find more information that could be important to you. This includes information that, once learned, might cause you to change your mind about being in this study. We will notify you as soon as possible if such information becomes available.

You can get the answers to your questions, concerns, or complaints.

If you have any questions, concerns or complaints about this study, contact Selene Willis at SeleneWillis@usf.edu . If you have questions about your rights, complaints, or issues as a person taking part in this study, call the USF IRB at (813) 974-5638 or contact by email at RSCH-IRB@usf.edu.

CONSENT TO TAKE PART IN RESEARCH

I freely give my consent to take part in this study. I understand that by signing this form I am agreeing to take part in research. I have received a copy of this form to take with me.

_____ _____

Signature of Person Taking Part in Study Date

_____

Printed Name of Person Taking Part in Study

STATEMENT OF PERSON OBTAINING INFORMED CONSENT AND RESEARCH AUTHORIZATION

I have carefully explained to the person taking part in the study what he or she can expect from their participation. I confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in their primary language. This research subject has provided legally effective informed consent.

_____ _____

Signature of Person Obtaining Informed Consent Date

_____

Printed Name of Person Obtaining Informed Consent

Assent of Children to Participate in Research

Study #001813

Title of Study: Teaching Science for Social Responsibility: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

WHY AM I BEING ASKED TO TAKE PART IN THIS RESEARCH?

You are being asked to take part in a research study about learning science in your classroom. You are being asked to take part in this research study because your teacher is participating in this study and you are in their class. If you take part in this study, you will be one of about 10 to 30 people at your school.

WHO IS DOING THIS RESEARCH STUDY?

The person in charge of this study is Selene Willis who is being guided in this research by Dr. Dana Zeidler, her faculty advisor.

WHAT IS THE PURPOSE OF THIS RESEARCH STUDY?

By doing this study, we hope to learn about how you learn about science and social responsibility in your classroom.

WHERE IS THE RESEARCH STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The study will be taking place at your school. The total amount of time you will be asked to volunteer for this study is 2 to 3 hours over the next 6 months.

WHAT WILL YOU BE ASKED TO DO?

You will be asked to participate in the regular activities and lessons in your class every day. During those activities, the researcher will observe what you do. You will be asked to volunteer to take part in 2 interviews that will take about 20 to 30 minutes each. The interviews will happen right at the beginning of the study and at the end of the study. You do not have to do the interviews to be in the study. If you like you can agree to only being observed.

WHAT THINGS MIGHT HAPPEN IF YOU PARTICIPATE?

To the best of the researcher's knowledge, your participation in this study will not harm you. Since this study is happening during COVID-19, the researcher will follow your school's safety procedures to keep you safe to the best of their ability. The researcher will keep their mask at all times and stay at least 6 feet away from you when possible.

IS THERE BENEFIT TO ME FOR PARTICIPATING?

We cannot promise that you will receive benefits from taking part in this research study. However, some people may experience joy when learning about science and how it connects to real world challenges.

WHAT OTHER CHOICES DO I HAVE IF I DO NOT PARTICIPATE?

You do not have to participate in this research study if you do not wish to do so.

DO I HAVE TO TAKE PART IN THIS STUDY?

You should talk with your parents or guardian and others about taking part in this research study. If you do not want to take part in the study, that is your decision. You should only take part in this study if you want to volunteer.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY?

You will not receive any compensation for taking part in this study.

WHO WILL SEE THE INFORMATION ABOUT ME?

Your information will be added to the information from other people taking part in the study so no one will know who you are.

CAN I CHANGE MY MIND AND QUIT?

If you decide to take part in the study you still have the right to change your mind later. No one will think badly of you if you decide to stop participating. Also, the people who are running this study may need you to stop. If this happens, they will tell you when to stop and why.

WHAT IF I HAVE QUESTIONS?

You can ask questions about this study at any time. You can talk with your parents, guardian or other adults about this study. You can talk with the person who is asking you to volunteer by contacting Selene Willis at SeleneWillis@usf.edu. If you think of other questions later, you can ask them. If you have questions about your rights as a research participant you can also call the USF IRB at (813) 974-5638 or contact the IRB by email at RSCH-IRB@usf.edu.

ASSENT TO PARTICIPATE

I understand what the person conducting this study is asking me to do. I have thought about this and agree to take part in this study. I have been given a copy of this form.

_____ _____

Name of person agreeing to take part in the study Date

_____

Signature of child agreeing to take part in the study:

_____ _____

Printed name & Signature of person providing Information (assent) to subject Date

Parental Permission for Child to Participate in Research

Information for parents to consider before agreeing to participate and allowing your child to participate in this research study

Title: Teaching Science for Social Responsibility: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

Study # STUDY001813

The following information is being presented to help you and your child decide whether you would like them to be a part of a research study. The sections in this Overview provide the basic information about the study. More detailed information may be provided in the remainder of the document.

Study Staff: This study is being led by Selene Willis who is a Doctoral Candidate at The University of South Florida (USF). This person is called the Principal Investigator. Selene Willis is being guided in this research by Dr. Dana Zeidler as her faculty advisor.

Study Details: This study is being conducted at independent (private) middle and elementary schools in the Tampa Bay Area. The purpose of the study is to understand the perceptions of students in the science elementary and middle school classrooms and the impact of a social responsibility focused pedagogy and curriculum on students' development of science expertise and their own agency. The research will be carried out by observing classrooms, collecting artifacts and conducting two 20 to 30-minute-long interviews with students.

Participants: You are being asked to allow your child to take part because they are a student at an independent school in the Tampa Bay area.

Voluntary Participation: Your child's participation is voluntary and your child does not have to participate and may stop their participation at any time. There will be no penalties or loss of benefits or opportunities if your child does not participate or decides to stop once they start. Their decision to participate or not to participate will not affect your student's status, course grade, recommendations, or access to future course opportunities.

Benefits, Compensation, and Risk: We do not know if your child will receive any benefit from participation. There is no cost to participate and your child will not be compensated for their participation. This research is considered minimal risk. Minimal risk means that study risks are the same as the risks you face in daily life.

Confidentiality: Even if we publish the findings from this study, we will keep your child's study information private and confidential. Anyone with the authority to look at your child's records must keep them confidential.

WHY ARE YOU & YOUR CHILD BEING ASKED TO TAKE PART?

We are asking your child to take part in this research study because they are a middle or elementary grades student currently attending an independent school in the Tampa Bay area that is a part of this study.

STUDY PROCEDURES:

Only your child, not you the parent or guardian will be participating in this study. Your child will be asked to participate in all research activities for this program. Specifically, we will collect the following data from your child:

- Audio and video recordings of their participation during their regular science classroom activities.
- Artifacts your child generates through during their regular classroom activities.
- If your child volunteers to do so, some students will be asked to provide verbal responses during no more than 2 audio and video recorded interviews that will last no longer than 30 minutes. The questions students that will be asked will seek to understand their science content knowledge and their understanding of social responsibility.
- The interviews will take place during regular school hours during non-content related class time.
- The interviews will be in-person with the researcher, who is also a certified classroom teacher. All COVID-19 and social distance guidelines required by the school will be observed.
- Should your child's school go into quarantine and classes are still in session, the interviews will be scheduled using video conferencing software.

All data collected will be stored electronically in the principal investigator's password protected Microsoft One Drive. Paper copies of any collected data and artifacts will be scanned and stored electronically. Non-paper generated artifacts will be captured electronically through the use of digital photography and stored electronically.
All collected information and data will be kept confidential by removing any identifying information right after data has been collected. Numerical identifiers and/or pseudonyms (fake names) will be used to record the data and to protect your child's identity. The legend that relates the identification of your child to their numerical codes will stored on a separate file, on a password restricted computer. The collected data, if shared in the public domain, will be reported in aggregated forms, so that all participant's anonymity is preserved. All collected materials will be stored up to 5 years after the final report is submitted to the USF Institutional Review Board then afterwards the all materials will be destroyed.

TOTAL NUMBER OF PARTICIPANTS

About 10 to 30 individuals will take part in this study that will be conducted at your child's school during their science classes.

PARTICIPATION / WITHDRAWAL

Your child does not have to participate in this research study. You should only let your child take part in this study if both of you want to. You or your child should not feel that there is any pressure for them to take part in the study. Your child is free to participate in this research or withdraw at any time. There will be no penalty or loss of benefits to your child if they stop taking part in this study.

BENEFITS

The potential benefits of participating in this research study include:
- Gaining increased competency in scientific content knowledge.
- Developing an increased level of social responsibility.

RISKS OR DISCOMFORT

This research is considered to be minimal risk which means that the risks associated with this study are the same as what your child will face every day. Your child's participation in this study does not increase their risk of exposure to COVID-19 anymore that the normal risk your child faces everyday while attending their school. The researcher will adhere to the school's COVID-19 safety procedures by remaining in their mask at all times and remain at least 6 feet away from your child. While the above precautions will be taken, the researcher cannot guarantee that your child will not be exposed to the virus. There are no known additional risks to those who take part **IN THIS STUDY.**

COMPENSATION

You and your child will receive no payment or other compensation for your child's participating in this study.

COST

It will not cost you anything to let your child take part in the study.

PRIVACY AND CONFIDENTIALITY

We will do our best to keep your child's records private and confidential. We cannot guarantee absolute confidentiality. Your child's personal information may be disclosed if required by law. Certain people may need to see your child's study records. These individuals include:

- The Principal Investigator and their faculty advisor.
- Certain government and university people who need to know more about the study. For example, individuals who provide oversight on this study may need to look at your child's records. This is done to make sure that we are doing the study in the right way. They also need to make sure that we are protecting your rights and your safety.
- The USF Institutional Review Board (IRB) and its related staff who have oversight responsibilities for this study, and staff in USF Research Integrity and Compliance.

We may publish what we learn from this study. If we do, we will not include your child's name. We will not publish anything that would let people know the identity of your child.

If your child's school goes onto distance learning, students may need to complete an online survey, of do a virtual interview, it is possible, although unlikely, that unauthorized individuals could gain access to their responses. Confidentiality will be maintained to the degree permitted

by the technology used. No guarantees can be made regarding the interception of data sent via the Internet. However, your child's participation in an online survey (only in the case of distance learning) involves risks similar to a person's everyday use of the Internet. If they complete and submit an anonymous survey and later request your data be withdrawn, this may or may not be possible as the researcher may be unable to extract anonymous data from the database.

What if new information becomes available about the study?
During the course of this study, we may find more information that could be important to you or your child. This includes information that, once learned, might cause you to change your mind about your child's participation in this study. We will notify you as soon as possible if such information becomes available.

You can get the answers to your questions, concerns, or complaints.
If you have any questions, concerns or complaints about this study, contact Selene Willis at SeleneWillis@usf.edu. If you have questions about your rights, complaints, or issues as a person taking part in this study, call the USF IRB at (813) 974-5638 or contact by email at RSCH-IRB@usf.edu.

Consent to Participate and Parental Permission for My Child to Participate in this Research Study
I freely give my consent to let my child take part in this study. I understand that by signing this form I am agreeing to take part and to let my child take part in research. I have received a copy of this form to take with me.

_____ _____
Signature of Parent of Child Taking Part in Study Date

_____
Printed Name of Parent of the Child Taking Part in Study

_____
Printed Name of the Child Taking Part in Study

STATEMENT OF PERSON OBTAINING INFORMED CONSENT
I have carefully explained to the person taking part in the study what he or she can expect from their participation. I confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in their primary language. This research subject has provided legally effective informed consent.

_____ _____
Signature of Person Obtaining Informed Consent Date

_____
Printed Name of Person Obtaining Informed Consent

APPENDIX C: RECRUITMENT EMAILS

Email Correspondence to Teachers at PTS

Subject: Teaching Science for Social Responsibility: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms

My name is Selene Willis, and I am a 5th grade middle school science teacher and a graduate student in the Science Curriculum and Instruction Doctoral Program at the University of South Florida. I am conducting a case study on Science curriculum and Social Responsibility in independent school science classrooms. I am currently recruiting teachers who will be teaching elementary or middle school science in the 2020/2021 academic school year to participate in my study.

This study will span approximately 4 months, from January 2021 to April 2021. The study will consist of one survey, two follow up interviews and classroom observations. The initial survey will take 15-20 minutes and each interview will take 45 to 60-minutes, one at the start of the study and one at the end. There will be 10 observations of your classroom and the regular functions of your science classroom while you teach. While many should be in person, if your class should switch to virtual learning, observations may be completed using videotaping. The results of this study will inform other science teachers and science curriculum development for teachers and school administrators in the area of science education.

If you have any additional questions later about the study, please contact me, Selene Willis or Dr. Dana Zeidler my faculty advisor at SeleneWillis@usf.edu or Zeidler@usf.edu who will be happy to answer them. If you have further administrative questions, you may contact the USF IRB at (813) 974-5638 or contact by email at RSCH-IRB@usf.edu.

Please complete this introductory questionnaire if you are interested in participating in this study. CLICK HERE.

Sincerely,

Selene Willis

Email Correspondence to Parents and Guardians

Dear Parents and Guardians,

Happy new year! My name is Selene Willis, and I am the 5th-grade middle school science teacher and a graduate student in the Science Curriculum and Instruction Doctoral Program at the University of South Florida. To complete my program, I am required to complete an independent research study or a dissertation. You are receiving this email because your child's classroom teacher has been selected to be a part of my study titled: *Teaching Science for Social Responsibility: Curriculum, Pedagogy, and Critical Science Agency in Independent School Classrooms* and I would like to include students as part of my dissertation.

I have created a short informational video to explain the purpose of my project and to share the major components of my study. Please click or tap here to view the video.

After watching the video if you are interested in having your child participate or if you have more questions about my project, please complete this short interest form. Link to the interest form.

After filling out the form, I will be in touch with the next steps. If you would like to review the parent and student consent/assent forms mentioned in the video they are attached to this email. Should you need to ask me questions, please email me at selenewillis@usf.edu Additionally, there will be a virtual WebEx informational session at the following dates and times if you would like to speak with me directly.

1. During the day - Thursday 1/14 @ 9:30 - 10:00 am
2. After School - Tuesday 1/19 @ 3:30 - 4:00

Thank you so much for your time and I look forward to hearing from you.
With sincerest appreciation.
Selene Willis

APPENDIX D: INTERVIEW PROTOCOLS

Teacher Participant Semi-Structured Interview 1 Protocol

Hello, my name is Selene Willis, and I am graduate student at the USF and a teacher here at Sunnyside School. Thank you so much for agreeing to participate in this study. I am very interested in learning about what you think about Teaching for Social justice and how that connects to your current students' science learning.

We will have two one on one interviews, one now and one at the end of your science unit, during which I will ask you a series of questions that will help me answer my dissertation's research questions. This interview is a conversation between you and I so feel free to ask me to repeat a question at any time, ask me to explain anything you do not understand, or simply not answer if you do not want to, although I really hope you try to share your honest thoughts with me. There are no right or wrong answers and anything you tell me is welcomed.

This interview is being recorded. Recording is done to make sure that I accurately capture your response to the interview questions. A transcript of our session will be provided to you so that may review it for accuracy. Please keep in mind that everything you share today will be used only for the purposes of this study. Your name and other personally identifying information will be removed. Do you have any questions for me before we begin recording? Now I will begin the recording. This is Selene Willis on (Date) at (time) conducting Teacher interview 1 with _____.

Interview Questions	Aligned research questions and themes
1. What subject grades and levels do you currently teach?	Research question 1 - independent and elite school context
2. Explain the current school environment you work in today? What are the students, faculty and parent body like?	Research question 1 - independent and elite school context
3. How long have you been teaching? What other school(s) did you teach in before this one?	Research question 1 - independent and elite school context
4. How do you identify your ethnic/racial background?	Research question 1 - independent and elite school context
5. Did you grow up in this local community? Did you grow up in a similar community as your students?	Research question 1 - independent and elite school context
6. How would you describe your K-12 and college education?	Research question 1 - independent and elite school context
7. In your own words how would define teaching for social justice? How does your belief in social justice inform your practice?	Research question 1b – justice centered pedagogy
8. What impact do you hope your vision of teaching for social justice will have on your students?	Research question 1b – justice centered pedagogy & critical science agency
9. Why did you choose to start implementing social justice into your teaching? What has specifically influenced you to teach for social justice? (Was there an experience in your life that deeply connects you to your desire to include social justice in your classroom?	Research question 1b – justice centered pedagogy
10. Share any specific opportunities you have within your academic curriculum to integrate social justice concepts into the science curriculum? a. How are these concepts conveyed to students? b. How do you determine if students understand the concept social justice and science concepts? c. How do your student demographics influence how this comes together in your classroom? d. How comfortable do you think your students feel working on these topics? What makes you say this?	Research question 1 - independent and elite school context Research question 1a – critical science literacy Question 1b – justice centered pedagogy

e. How does you're your school support your desire to implement justice centered practices?	
11. How do you determine which important social justice ideas/concepts students should know and what is your process for creating the lessons?	Research question 1a – critical science literacy Question 1b – justice centered pedagogy
12. How do you navigate your multiple goals of developing students' sociopolitical consciousness? (Both Social justice and science based)	Research question 1a – critical science literacy Question 1b – justice centered pedagogy
13. Tell me what I will observe in your classroom when I visit or record? What will I see, hear, notice when I walk in? What will students be doing? What will you be doing?	Research question 1a – critical science literacy Question 1b – justice centered pedagogy & critical science agency

Student Participant Interview 1 Protocol

Introductory Script

Thank you for meeting with me. For this interview I'm interested in getting to know a little bit more about you, and who you are as a student. I have some interview questions that you and I will talk about.

Hello, my name is Selene Willis, and I am graduate student at the USF and a teacher here at Sunnyside School. Thank you so much for agreeing to participate in this study. I am very interested in learning about what you do in your science class with

_____

We will have two one on one interviews, one now and one at the end of your science unit. I will ask questions that will help me do my project. You can ask me to repeat a question at any time, or to explain anything you do not understand. There are no right or wrong answers and anything you tell me is welcomed. If you do not have an answer that's ok too.

This interview is being recorded. Recording is done to make sure that I can have exactly what you said for my project. Everything you share today will be used only for the purposes of this study

Do you have any questions for me before we begin recording? Now I will begin the recording.

This is Selene Willis on (Date) at (time) conducting Teacher interview 1 with _____.

Interview Questions	Aligned Research Questions and Themes
1. Pretend you have been selected to be a shadow to a new student. How would you describe this school to this student who has never been here before?	Research question 1 - independent and elite school context
2. What do you like best about school? What do you not like as much or would want to change about school?	Research question 1 - independent and elite school context
3. Looking at this picture, can you describe what is happening in the picture? a. How do you feel about this interaction? b. Is there anything that you will do now that you have seen this image?	Research question 1b – critical science agency
4. My project is all about science, why do we learn science in school?	Research question 1a - conceptual understanding of scientific content
5. Probe: What would the shadow from before see when they visit your science class? What are you doing? What are your classmates doing? What is your teacher doing?	Research question 1a - conceptual understanding of scientific content
6. In your opinion, is there anything in real life (or life outside of school) that science is related to?	Research question 1b – critical science literacy
7. Has your science class changed the way you view the world? What makes you say that? Can you explain a little more what you mean please?	Research question 1b – critical science literacy
8. Let's look at this activity [have a copy of the student's work from the activity] a. What were you asked to do? b. What did you learn from this activity? c. What do you think your teacher wanted you to learn? d. Did it relate to your life outside school or the real world? e. Have you had other science assignments that relate to your life outside school or the real world? f. Did you like this activity? Was it fun?	Research question 1a - conceptual understanding of scientific content

APPENDIX E: CLASSROOM OBSERVATION PROTOCOL

Teacher_____ Date: _____ Science Topic: _____

	Component	Notes
Independent School Context	justice components (RQ 1)	
	critical components (RQ 1)	
Critical Science Literacy	critical components (RQ 1b)	
	science components (RQ 1a)	
Justice Centered Science pedagogy	justice components (RQ 1b)	
	science components (RQ 1a)	
	pedagogical components (RQ 1b)	
Critical Science Agency	critical components (RQ 1b)	
	science components (RQ 1a)	
	agentic (praxis) based	