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Culturally Responsive Science Education and Teaching: Current Literature, Preservice Elementary Science Teachers and Lesson Planning

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Culturally Responsive Science Education and Teaching: Current Literature, Preservice Elementary Science Teachers and Lesson Planning

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by

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Abstract

First, a meta-analysis of Culturally Responsive (CR) science teaching characteristics and practices was conducted. Findings revealed that there are a limited number of CR teaching studies at the elementary science level. When studies conducted at the middle, secondary and postsecondary level were included, six themes which encompassed the characteristics and pedagogical practices of effective CR science teachers and teacher development emerged. These themes were academics, cultural competency, social inequities, CR learning environment, rejection of the deficit lens and pedagogical strategies.

Next, the impact of curriculum and practices designed to reflect these six themes on preservice elementary science teachers was explored. I used the six themes to build and implement the science methods course for preservice elementary teachers. Findings revealed that although the preservice elementary teachers acknowledged all six themes, full implementation within the field may require the methods course to be closely aligned with the field experience. This study also provided insight into the preservice elementary science teachers' discomfort with the science content as an obstacle and the limitations of class discussions to drive change within practices.

When the findings in the meta-analysis and preservice science methods course were combined, Chapter 4 was written to provide practicing elementary science teachers with a procedural guide to create and implement CR science lessons in their classrooms. The chapter included an explanation of each step along with an example and resources. A sample sixth-grade science lesson plan, which demonstrated the use of current events as the connection to the science content, was also included.

Acknowledgments

I have been fortunate to have been working as an education instructor while writing my dissertation. This experience allowed me to discuss current literature with my preservice teachers while also connecting with them on a personal level. We were all balancing school, work and family lives. I also greatly appreciate the encouragement and companionship of my colleagues along the way. Having been through the dissertation process as well, they pushed me to continue. My peers within the Ph.D. program at the University of Arkansas were also a huge support. During moments of frustration and isolation, we encouraged one another through long phone conversations and lengthy group text messages. I am especially thankful to my committee chair and two committee members.

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Chapter 1

Introduction

This research seeks to inform culturally responsive (CR) teaching in science education. One study was conducted and are disseminated into discrete chapters. In the second chapter, a meta-analysis gives an overview of the current literature on CR science teaching. The aim is to find common themes across the studies using the method described by Timulak (2009) to create a more cohesive picture of culturally responsive (CR) science teaching. Using that more complete picture, the third chapter further explores the six themes that emerged in the meta-analysis. These six themes encompassed the effective CR science teachers' characteristics and pedagogical practices and were then used to shape to my elementary preservice science methods course. Data from my course assignments was collected to analyze the impact of the application of the themes on preservice elementary teachers' CR science lessons. Findings from this study will inform future CR science teacher development. The fourth chapter is intended for in-service elementary teachers to create effective CR science lessons within their classroom. It combines the findings from the meta-analysis and the CR development study on preservice elementary teachers into a step-by-step process. The effective pedagogical practices are included, in addition to a sample CR science lesson plan. This introduction contains a brief history of CR teaching and pedagogy, an overview of the following chapters and the significance of this study.

CR Teaching and Pedagogy and Prominent Theorists

Ladson-Billings and Tate (1995) argued the need for critical race theory to be applied to education because, "(1) race continues to be significant in the United States; (2) U.S. society is based on property rights rather than human rights; and (3) the intersection of race and property creates an analytical tool for understanding inequity." (Ladson-Billings & Tate, p. 47). Using the theoretical framework of Harris (1993), they make direct parallels between Harris's "property function of whiteness" and US school systems (Ladson-Billings & Tate, 1995). By tying school-specific examples to Harris' (1993) functions of white property, Ladson-Billings & Tate (1995) made a strong argument for a need for a critical race lens with the sole purpose of analyzing our school systems.

That same year, Ladson-Billings' three-year study, which labeled her theory "Culturally Relevant Pedagogy" (CRP), was also published. Here, she identified three areas of "Culturally Relevant Pedagogy" as exhibited by eight elementary teachers (Ladson-Billings, 1995). Unlike the article published with Tate, Ladson-Billings' study did not argue the need for CRP but instead developed three areas of successful CRP as exhibited by these eight elementary teachers. Her findings suggest that elementary students must maintain their cultural heritage, recognize and critique sociopolitical concepts while achieving academic success (Ladson-Billings, 1995).

Parallel to the work of Ladson-Billings (1995), Geneva Gay summarized what she terms "Culturally Responsive Teaching (CRT)" in her 2002 article. Similar to Ladson-Billings (1995) in concept, the title replaced "relevant" with "responsive" and "pedagogy" with "teaching". Gay (2002) stated, "Culturally responsive teaching is defined as using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (p 106).

As Ladson-Billings continued to seek out and study teachers who were successful with African-American students, she began to characterize them as "culturally relevant, (CR)" teachers. Ladson-Billings and Milner (2011) added to the literature on CR teachers and teaching in their independent articles in the same book. Ladson-Billings (2011) added to her original criteria of effective CR teachers while Milner (2011) pushes the expectations of teachers more towards Paulo Freire's argument in *Pedagogy of the Oppressed*. Here, Milner cites Freire's belief that in order to shift the traditional power from the teacher to the students, teachers must pose questions that encourage students to think for themselves while still understanding the social structure (2011).

Milner's case study (2016) offers a more in-depth look into one teacher's teaching characteristics. The participant, Mr. Jackson, is a Black male math and science middle school teacher. Many of the characteristics identified in this case study fall under the categories set forth by Ladson-Billings (1995 & 2011), Gay (2002) and Milner's own 2011 article. This snapshot of one successful CR teacher provides images of what CR teaching looks like in a science and math classroom, giving context for the parameters of CRP/T.

The focus of this dissertation is CR planning and instruction specifically within science teaching and education. For the meta-analysis, the current studies by Byrd, C.M. (2016), Lanier and Glosson (2014), Wallace and Brand (2012) and Xu et al. (2012) were used due to their focus on CR teaching characteristics within science. Like Milner (2011), they contributed to the knowledge regarding effective CR science teacher characteristics and pedagogical practices. Others, Burgess et al. (2018), Brown and Crippen (2016a) Hernandez (2013) and Mensah, F.M. (2011) conducted studies on the development of effective CR preservice science teachers. Brown and Crippen (2016b) also conducted a study with in-service teacher participants. Studies with in-service science teacher participants were also conducted by Goldston and Nichols (2009), Johnson and Fargo (2014), Johnson, C.C. (2011) and Nam et al. (2012). Collectively, these studies further the information of effective CR teacher characteristics and pedagogical practices within science specifically. What is needed is a clear understanding of what CR science teaching looks like in an elementary setting and how to develop preservice elementary teachers' CR lesson plans and pedagogical practices.

Through this work, a more complete image of effective CR science teacher characteristics and practices emerged. Effective CR science teachers take the time to get to know their students as individuals and actively reject any preconceived perceptions. They do this by being involved with their students' lives inside and outside of the classroom. Bridges which connect the science content with students' interests and experiences are intentionally made by the teacher. Simultaneously, students are encouraged to make their own connections to the content. Effective CR science teachers take every opportunity to learn from their students, creating an environment in which learning is authentic and reciprocal. Furthermore, effective CR science teaching requires the teacher and students to make direct connection between specific social injustices and relevant science content. Through these connections, students are encouraged by their teachers to develop strategies in which science content and or procedures can be used to address the social injustices experienced by the students and their community.

Chapter Overview

The first second chapter describes the meta-analysis and its findings on current CR teaching studies within the field of science. Across these studies, participants include preservice and in-service science teachers from elementary through post-secondary settings. Although they cover a diverse range of study participants, commonalities emerge, resulting in six themes. These six themes encompass the characteristics and pedagogical practices exhibited by the effective CR science teachers and within the development studies.

Chapter 3 used the findings from the meta-analysis to shape my preservice elementary science methods course at the post-secondary level. First, Milner's (2010) article was used as reading and discussion outline for the course. Every other week, students discussed one of his "conceptual repertoires of diversity" (Milner, 2010). On discussion days, the instructor facilitated an elementary science lesson using a modified 5E format by Bybee, R. (2014) to structure the student-centered, inquiry lesson. The instructor also implemented demonstrations, student exploration and hands-on activities all with guiding questions to force the students to discuss observations which led them to the current science explanation of the relevant phenomenon. Lessons addressed standards relating to light waves, sound waves, moon phases, seasons, states of matter and human evolution.

The university is in an urban setting within a larger southern city in the United States and the course is required within the Bachelor of Science in Education (B.S.E.) degree that is tied to initial K-6 teacher licensure. It was a traditional course which met once a week for two to three hours over an entire semester. I was the instructor of the elementary science methods course in which the CR themes were applied, and the participants' products were collects. I began my career in education as a high school biology teacher. As a non-traditional student, I worked as a full-time teacher while completing my Master of Education degree that was needed for my initial, standard teaching license. While teaching in the high school, I found a need to connect the science content to the personal interests of the students. When I explicitly stated how the content could be applied to their own lives, they were more engaged and excited. For example, rather than using the textbook's analogy of a cell as a factory, I had my students teach me all the parts about football while I made connections between the organelles and their functions. The playbook became the "DNA" and the touchdown represented the synthesized protein. This experience was how I learned about the point after. Prior, I had always thought a touchdown was worth seven points. I was learning from the students about a game they loved while they were learning about the structure and function of the cell. We both took on the role as the learner. But it was not until working on my current PhD in science curriculum and instruction that I learned about CR teaching. Finally, I had a theory to explain some of my pedagogical practices and a lens for my research.

The findings from this study reveal the importance of intentional modeling by the instructor of all aspects of the effective CR science teacher pedagogical practices. Pedagogical practices that are omitted by the instructor are rarely translated into the lesson plan and facilitation of the preservice teachers. Also, the impact of the application of the themes to an elementary preservice science course would be strengthen by closely aligning the course to the field experience.

Unlike the other two chapters, the fourth chapter does not add to the body of knowledge on CR science teacher characteristics and pedagogical practices. Instead, is a practical guide for current elementary science. It seeks to assist elementary science teachers through developing effective CR science lesson plans for their classroom. A six-step procedure along with explanations of each, walk teachers through the process of planning and provide a CR lesson plan they can use in their classrooms. By applying the findings of the first and second studies, the third study provides practical applications for current elementary teachers to develop their own CR science lessons.

Significance of the Study

The election of Kamala Harris as our next vice president of the United States, embodies the importance of racial/ethnic diversity within all societal constructs. In her acceptance speech, she directed attention to the young girls, especially those of color, to set aim high as she did, knowing that it is possible. For young girls of color, they can more easily picture themselves in that same position of power now that they have Vice President Elect Harris to as an example of success for someone that looks like them.

In relation to science, students also need to feel as though they belong regardless of racial/ethnic backgrounds. Current science teaching practices, when they do not align with the beliefs and practices of the students, are hard to relate to and decrease interest. In contrast, effective CR science teaching appeals to all students by making direct connections to students' backgrounds and experiences outside of the classroom. Effective CR teachers value their students, their students' experiences and their residential community. Not only do they make direct connections between the science content and the students' backgrounds, they also use the curriculum to empower the students to make changes through the application of the scientific process.

Through the process of the meta-analysis, there are limited studies on CR science teachers and development, especially at the elementary level. These studies seek to fill that gap in the current literature by providing insight into current effective CR science elementary teachers and the development of CR science teachers at the post-secondary level. Filling this gap provides practical information for in-service elementary science teachers to implement CR science lessons and insight into a preservice elementary science methods course. This insight, building on effective pedagogical strategies, will reveal the impact of additional strategies.

Chapter 2

Culturally responsive elementary science teaching:

A meta-analysis of current science teaching studies and implications

Abstract

This study utilizes the meta-analysis method described by Timulak (2009) in order to create a more cohesive understanding of culturally responsive (CR) science teaching. This phenomenon will be explored by defining the characteristics of CR teaching from the extant literature and then comparing those characteristics to current CR science teaching studies with a focus on the elementary level. From those, six themes were created to represent both the extant literature and the current CR science teaching studies. As this study demonstrates, there are additional themes of CR science teaching not represented in the extant literature. Additionally, no one study addresses all six themes. This paper will make the argument to include these six themes in future study which will result in more cohesive findings and lead to evidence-based strategies for implementing CR teaching in elementary preservice teacher settings.

Keywords: culturally responsive teaching, meta-analysis, science, elementary, education

Meta-analysis: Culturally responsive elementary science teaching

Forty years after the landmark case in which the Supreme Court declared segregated schools unconstitutional in Brown V. Board of Education (1954), Ladson-Billings & Tate's 1995 article argued inequalities due to race were still evident within society. Thus, there was a need for the theorization of race within education. Critical Race Theory (CRT) acknowledges that social constructs impact citizens differently based on race/ethnicity which limits changes in social systems such as education (Bell, 1954). From a law perspective, Bell (1954) discussed specific legal cases which grew from the desegregation of American schools. But the CRT lens was not applied to the examination of school systems itself (Ladson-Billings & Tate, 1995). This was necessary, as Lason-Billings and Tate (1995) argued because, "(1) race continues to be significant in the United States; (2) U.S. society is based on property rights rather than human rights; and (3) the intersection of race and property creates an analytical tool for understanding inequity." (p. 47).

With these understandings in place, Ladson-Billings & Tate strengthened their argument for a school-specific theory in which to explore inequalities due to race. Using the theoretical framework of Cheryl I. Harris (1993), they make direct parallels between Harris's "property function of whiteness" and US school systems (Ladson-Billings and Tate, 1995). The four functions are, 1. "rights of disposition", 2. "rights to use and enjoyment", 3. "reputation and status property", and 4. "the absolute right to exclude" (Harris, 1993). Ladson-Billings and Tate give examples of each in relation to these functions (1995). In brief, 1. our school system rewards those who conform to the hegemonic norms of the school; 2. whites have greater access to school facilities; 3. schools associated with minority students or located in urban neighborhoods have poor reputations; and 4. school choice permits privileged White students to opt out of schools with minority populations or urban settings. By tying school-specific examples to Harris' (1993) functions of white property, Ladson-Billings and Tate (1995) made a strong argument for a need for a CRT lens with the sole purpose of analyzing our school systems. Yet their article did not propose clear parameters or even a title for such a theory.

Another drawback to the extant literature was a lack of focus within the field of science. From 2008 to 2018, degrees within science, technology, engineering, and mathematics (STEM) fields comprised 18 percent of the total 331,000 bachelor's degrees awarded in the U.S. When compared to the national average, each race/ethnicity is unique. The percentage of White students with a bachelor's degree in STEM was the same at 18 percent while Asian/Pacific Islander (15%), Hispanic (15%), American Indian/Alaska Native (14%), and Black (12%) all had lower percentages than the national average (NCES, 2019). In contrast, Asian students had a higher than average rate with 33% as did students with Two or more races at 20% of bachelor's degrees within STEM (NCES, 2019). White, Asian, and students with Two or more races obtained bachelor's degrees in STEM at higher percentage rates than the national average of overall STEM bachelor's degrees. Table 1 contains the total percentage based on race/ethnicity within all levels of degrees/certificates within STEM college degrees as reported by the National Center for Education Statistics (NCES, 2019).

Table 1: NCES (2019) Race/Ethnicity Percentages of Awarded Degrees/Certificates at the Postsecondary Level within STEM Fields for 2008-09 and 2017-18

	Percentages based on Race/Ethnicity					
Year	White	Black	Hispanic	Asian/Pacific Islander	American Indian/Alaska Native	Two or more races
2008-09	70.0	9.3	8.6	11.3	0.8	---
2017-18	61.5	8.4	13.3	12.6	0.5	3.7

The Next Generation Science Standards (NGSS) were published by the National Research Council (NRC) in 2013. Shortly after, twenty states adopted NGSS while twenty-four developed their own state standards based on NGSS guidelines (National Science Teaching Association NSTA, 2014). With a "focus on issues of student diversity and equity in relation to the NGSS specifically as the NGSS present both learning opportunities and challenges to all students, particularly non-dominant student groups" NGSS strive to decrease the achievement gap (NGSS, 2013, Appendix p. 26). But as discussed above, diversity within STEM fields are still limited in regard to specific races/ethnicities.

Rather than looking at the standards as a solution to increase diversity in STEM degrees, Maltese and Tai (2010) noted that student interest in science must occur prior to selecting high school courses. They found that students who took more science courses in high school and valued the long-term outcomes of science on a future career were more likely to pursue a STEM degree (Maltese and Tai, 2010). Thus, it is important to focus on increasing student interest in lower grades, especially those in underrepresented race/ethnicity groups, for an increase in the diversity of STEM degree/certificate earners. For that reason, this study's primary focus was on CR science in elementary classrooms. By increasing CR science strategies in elementary grades, students will experience science content as it relates to them, making the overall experience more meaningful. First, an overview of Culturally Relevant/Responsive Pedagogy/Teaching (CRP/T) is necessary to compare the extant literature with current CR science elementary teacher characteristics and practices.

Parameters of Culturally Relevant/Responsive Pedagogy/Teaching (CRP/T)

Ladson-Billings' three-year study, which labeled her theory "Culturally Relevant Pedagogy" (CRP), identified three areas of "Culturally Relevant Pedagogy" as exhibited by eight elementary teachers (Ladson-Billings, 1995). Unlike the article published with Tate, Ladson-Billings' study did not argue the need for CRP but instead developed three areas of successful

CRP as exhibited by these eight elementary teachers. This three-year study included an ethnographic interview, weekly classroom observations and participant review and analysis of the videos (Ladson-Billings, 1995). Although each teacher participant was unique, Ladson-Billings identified areas in which their successful implementation of CRP practices overlapped. These three areas are "…helping their students to be academically successful, culturally competent, and socio-politically critical" (Ladson-Billings, 1995, p. 477-8). In other words, students must maintain their cultural heritage, recognize and critique sociopolitical concepts while achieving academic success (Ladson-Billings, 1995). The eight elementary teacher participants did so by viewing their students' through an asset lens, encouraging individual differences and placing students in leadership roles (Ladson-Billings, 1995). They also avoided the "right-answer approach" to academics, guiding students to think critically.

Parallel to the work of Ladson-Billings (1995), Geneva Gay published a book titled *Culturally Responsive Teaching: Theory, Research, and Practice* (2001). In her book, Gay summarizes what she terms "Culturally Responsive Teaching (CRT)" (2002). Similar to Ladson-Billings (1995) in concept, the title replaces "relevant" with "responsive" and "pedagogy" with "teaching". Here, the two are used interchangeably with the acronym "CRP/T" in which the "R" represents both "relevant" and "responsive" while the "P" denotes "pedagogy" and the "T" denotes "teaching" (Ladson-Billings, 1995; Gay, 2002). Gay (2002) states, "Culturally responsive teaching is defined as using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (p 106). She outlines five "specific components" of CRT that she has compiled through her research (Gay, 2002). These five components can be viewed on Table 1. In contrast to Ladson-Billings (1995), Gay does not explicitly express "academic achievement" as one of her components (2002).

Instead, her components outline what a teacher must learn in order to implement CRT in their classrooms (2002). First, teachers must develop their own knowledge base of cultural diversity that goes beyond traditional multicultural training and instead focuses on knowledge about the specific, ethnically diverse students the teacher will be working with (2002). This includes the ability to design curricula that is culturally relevant by being critically aware of the three types of curricula: “formal”, “symbolic”, and “societal” (Gay, 2002, p. 108). Once aware, teachers must address the issues within each (2002). The third component, also unique from Ladson-Billings’ (1995) three areas, requires teachers “demonstrating cultural caring and building a learning community” (Gay, 2002, p. 109). Here, Gay stresses the importance of incorporating the students’ prior knowledge and experiences within the classroom, validating their students’ assets and creating a learning environment built on caring (2002). This is similar to Ladson-Billings (1995) “cultural competency” area since Gay states that students should be made aware of the cultural context of the content (2002). Related to the caring learning environment, Gay (2002) posits effective “cross-cultural communications” as a necessary component of CRT (p. 110). Effective instruction is reliant upon effective communication (Gay, 2002). Teachers must listen to their students and also know how to connect to ethnically diverse students in a way that is familiar to them (Gay, 2002). The fifth and final component addresses “cultural congruity in classroom instruction” (Gay, 2002, p. 112). Here, she stresses the importance of matching instructional strategies to the learning strategies of the ethnically diverse students (Gay, 2002).

As Ladson-Billings continued to seek out and document teachers who were successful with African American students, she began to characterize these “culturally relevant, (CR)” teachers. By 2011, she added an additional area, “teacher thinking” to her three original (Ladson-Billings, p. 34). The “teacher thinking” area is broken down into three further subcategories, “social contexts”, “the students”, “the curriculum” and “instruction” (Ladson-Billings, 2011, p. 34-37). First, she states that CR teachers must recognize there is an inherent difference within the school system and beyond between minority students and the hegemonic society, (Ladson-Billings, 2011). CR teachers must encourage appreciation of personal culture within students while also exposing them to different cultures. (Ladson-Billings, 2011). In addition, she argues that CR teachers must learn to feel with their students rather than pity them (2011). This would require teachers to get to know students and their situations at the individual level, including aspects within their personal lives. Ladson-Billings (2011) states that CR teachers recognize what she calls “school-dependence” of disadvantaged students (p. 35). She explains that students with resources outside of schools do not rely solely on their school for growth and success (Ladson-Billings, 2011). The final characteristic is in regards to curriculum. CR teachers recognize that curriculum is a societal artifact and should not be treated as stagnant (Ladson-Billings, 2011). Instead, CR teachers challenge students to develop personal meaning within the curriculum (Ladson-Billings, 2011). CR teachers should focus on long-term success of their students by helping them to know how the content and skills apply to their lives (Ladson-Billings, 2011).

Milner’s article in the same book as Ladson-Billings’ (2010) article, shares one “principle beyond good intentions” with her work (p. 71). They both assert that CR teachers know what deficit thinking is and reject it (Ladon-Billings, 2011; Milner, 2010). But this is where the “teacher thinking” or “principles” as Milner (2010) calls them, ceases being the same. He instead speaks on three additional and unique values. Milner’s second principle states that CT teachers must understand the difference between ‘equity’ and ‘equality’ and apply this practice within the classroom (Milner, 2010). Expanding on Ladson-Billings’ characteristic of realizing a system of inequality, Milner suggests that different students need different things (2010). His third principle, "understand and negotiate power structures", pushes the expectations of teachers more towards Paulo Freire's argument in *Pedagogy of the Oppressed* (Milner, 2010, p. 71). Here, Milner cites Freire's belief that in order to shift the traditional power from the teacher to the students, teachers must pose questions that encourage students to think for themselves while still understanding the social structure (2010). Milner's fourth and final principle encourages teachers to not only recognize cultural differences but instead, navigate through any conflicts these differences may cause while encouraging students to do the same (2011).

Milner's case study (2016) offers a more in-depth look into one teacher's teaching characteristics. The participant, Mr. Jackson, is a Black male math and science middle school teacher. Many of the characteristics identified in this case study fall under the categories set forth by Ladson-Billings (1995 & 2011), Gay (2002) and Milner's own 2010 article. This snapshot of one successful CR teacher provides images of what CR teaching looks like, giving context for the parameters of CRP/T. Whether teaching math or science, Mr. Jackson validated his students' prior knowledge and personal interests in several ways (Milner, 2016). First, he listened to them and got to know each student as an individual (Milner, 2016). This aligns with both Gay's (2001) and Milner's (2011) CRP/T parameters of a caring and inclusive learning environment. He then applied what he learned about his students to the classroom environment and his instruction (Milner, 2016). One example was how Mr. Jackson incorporated situations that were occurring at the school into his math lessons (Milner, 2016). Realizing he shared music interests with his students, songs that were familiar to his students were often played in his classroom (Milner, 2016). These two strategies incorporate parameters from Ladson-Billings, (1995), Gay (2001) and Milner (2011). Another key component was his view of both teachers and students. Mr.

Jackson recognized the assets he brought, such as shared music tastes, and those of his students by giving them opportunities to teach him (Milner, 2016). Although music was his major connection with his students, teachers need to identify their own individual assets rather than mimic Mr. Jackson's (Milner, 2016). What all teachers can borrow from this case study was how Mr. Jackson situated himself as a "community member" rather than a "spectator" by building relationships with his students, valuing them as individuals and creating opportunities for his students to demonstrate their own assets within the classroom. (Milner, 2016, p. 425).

The findings of Ladson-Billings (1995, 2011), Gay (2002) and Milner (2010) provide the characteristics of effective CRT teachers which are summarized on Table 2 below.

Table 2: Summary of CRP/T Parameters

Ladson-Billings, 1995	Geneva Gay, 2002	Milner, 2010
1. Aids in academic student achievement (1995) 2. Gives students cultural competency by being aware of personal view, views of others and positive interactions across differing cultures 3. Critical awareness of sociopolitical climate **Ladson-Billings, 2011** 4. Teacher thinking a) Social contexts: assume social inequalities based on race and poverty b) The students: reject deficit lens and feels with rather for students by advocating and holding high standards c) The curriculum: recognizes that it is a societal document and modifies as needed d) Instruction: know and use a variety of strategies to engage ALL students	1. Develop a cultural diversity knowledgebase 2. Include cultural diversity in the curriculum 3. Establish a caring community of culturally responsive learning 4. Communicate with ethnically diverse students 5. Respond to cultural diversity through instruction	1. Ensure students find meaning in the classroom 2. Help students feel a sense of belonging within the classroom 3. Facilitate building of skills and knowledge needed for academic success

Methodology

This purpose of this study is to compare the CR teacher characteristics from the extant research to the current CR science teacher research in elementary. By doing so, the strategies and outcomes of the current CR science teacher research can be evaluated through the lens of the CRT characteristics. A meta-analysis was also conducted with the current CR science teacher research in elementary. This will reveal if there are characteristics and/or strategies unique to CR elementary science teaching.

To locate CR science teaching in elementary, a university search engine was utilized to locate articles in peer-reviewed journals. A complete list of the search words and the total results Table 3. Initially, the search was narrowed by restricting the dates from 2014 to the present. This yielded 429 total articles. These articles contained a variety of language outside of "culturally responsive teaching in science". For example, if the terms "integrating indigenous knowledge", "social justice" "language barriers" "minorities" and "equitable" occurred in the title, the abstract or both without the mention of CRT then the article was omitted. Since CRT within science is the focus of this review, the date restriction was removed from the search and specific words within the title were applied instead. Within the search, only one study focused on elementary science. Thus, the search was extended to include middle and secondary grades. A total of forty-three journals were represented in the search. Table 4 provides a list of all the journals along with which journals were represented in the four selected articles for the meta-analysis.

Table 3: Key Title Words, Number Total Results and Number of Selected Articles

Key Title Words	# of Total Results
culturally *responsive* teaching in elementary science	10
culturally *relevant* teaching in elementary science	5
culturally *responsive* pedagogy in elementary science	3
culturally *relevant* pedagogy in elementary science	2
culturally *responsive* teaching in middle school science	4
culturally *relevant* teaching in middle school science	17
culturally *responsive* pedagogy in middle school science	5 (2 previously represented)
culturally *relevant* pedagogy in middle school science	10 (2 previously represented)
culturally responsive teaching and science (title)	17 (1 previously represented)
culturally *responsive* teaching (title) and science (title) and elementary	4 (1 previously represented)
culturally *relevant* teaching (title) and science (title) and elementary	8 (2 previously represented)

Only research articles were selected for further analysis and synthesis. From the research articles revealed in the eleven searches, four articles examined the characteristics of effective CRT science teachers. Xu et al. (2012) focused on elementary teachers, Byrd (2016) surveyed 315 middle school and high school students across the United States, Lanier & Glasson (2014) studied one middle school science teacher and eleven of her students while Wallace & Brand's (2012) study participants are two middles school science teachers. Table 4 provides an overview of the four selected studies. They were selected because of their focus on CR science teacher characteristics at the elementary, middle school and high school level.

Table 4: Overview of Four CR Science Teaching Studies

Author, Year	Theoretical Lens	Participants
Wallace & Brand 2012	Critical Race Theory	Two middle school science teachers One White female, one Black female, both over 22 years of teaching experience
xXu et al. 2012	Sociocultural perspective	8 African American elementary teachers
Lanier & Glasson 2014	Third space theory & Critical Race Pedagogy	One middle-school teacher, selected based on research requirements (total of 9), two of which were success with AA students in an urban middle school 11 students from the participating teachers' class
Byrd, C.M. 2016	Critical Race Theory	315 MS and HS students (6-12) across US

In addition to the four articles selected for their research on effective CR science teaching characteristics, seven additional articles were selected from the original eleven searches. These articles, unlike the previous four, focused on the development of CR science practices with either preservice or in-service teachers. These studies provide additional insight on the current studies seeking to increase CR science teaching practices by revealing similar and unique methods. Table 6 provides an overview of the seven studies focused on the development of CR science practices.

Table 5: CR Science Teacher Development Studies

Chronological Level: K-12 students; Preservice teachers first followed by in-service teachers

Author, Year	Participants & Grade level	Strategies	Outcomes
	Preservice		
Bottoms et al. 2017	53 PSETs, UG, over two semesters	PSETs worked with diverse families in FMSNs while enrolled in science methods course Intentional course assignments, materials and structures. Intentional instructional design (methods) information.	FMSN: 1. Creates more opportunities for interaction and reflection 2. Integrates emotions to re-conceptualize practice 3. Builds partnerships in community 4. Teaches content through culture and community resources
Burgess et al. 2018	15 non-traditionally licensed elementary para-educators, 11 bilingual and 10 Lainx	Used outdoor spaces in conjunction with classroom experiences Co-learning: instructors learned how candidates learned and used that knowledge to shape instruction (this is the CRT component)	Two perspectives for implications: those of PSTs and those of TEs PSTs: 1. Use learner-centered strategies and previous experiences 2. utilize specific cultural ties within the science content 3. support the cultural and community wealth of students 4. emphasize asset over deficit views TEs: 1. listen to PSTs 2. meet their needs 3. view them as collaborators with assets 4. value family/community connections 4. reported higher CRT awareness
Mensah, F. M. 2011	3 graduate-level PSETs in 4/5th grade science within a science methods course for an ILP	Microteaching Discussions in science methods course Groups of 3 PSET Intentional FP in urban setting	PSETs need: 1. opportunities to collaborate 2. diverse urban settings 3. time to incorporate and reflect on CRT strategies 4. microteaching opportunities 5. time to research the particular students and community

Table 5: CR Science Teacher Development Studies Cont.

Author, Year	Participants & Grade level	Strategies	Outcomes
Brown & Crippen 2016a	14secondary math PSTs & 5 science PSTs Third year UGs majoring in math/science with a minor in secondary education	PSTs math/science methods course and FE of their program-intentionally complementary Two GAIn observations by the PSTs and then designed and taught three lessons using the 5E Lesson Template (Bybee et al. 2006)	GAIn alone cannot cultivate CR practices in PSTs More explicit lesson planning based on GAIn observations needed
Hernandez et al. 2013	12, non-traditional Latinx students in an UG ILP for secondary science	TE's approach 1. Review of literature 2. Synthesis of literature for major themes 3. Application of major themes to PST course	Use the developed model to guide course/curriculum development for TE. However, to fully comprehend PSTs ability to implement CRT, a variety of data collection is needed as well as an intentionally designed FE, such as the Professional Development School model in conjunction with post-lesson debriefings.
	In-service		
Johnson & Fargo 2014	4-6 grade Hispanic students in two elementary schools, one with the PD and one without the PD	2-year professional development program	Effective PD components: 1. Clear content (science) connection 2. Significant if not whole school, number of participants and align with school/district/teacher beliefs 3. Must occur over a long period of time and be ongoing
Johnson, C.C. 2011	Two middle-school science teachers in a district with a growing Hispanic population	Transformative professional development (TPD) for 3 consecutive years Year 1: building relationships; inquiry, positive expectations, and cooperative learning Year 2: new lessons/units, teaching strategies, teacher empowerment, and incorporation of Hispanic students' lives within science content Year 3: additional teaching strategies, CRP study and common discipline plan development	TPD may be effective model with the use of Ladsen-Billings (1995) CPD areas, but it is time consuming (<300 hours), expensive and requires district/school-wide participation and school/district support Shed light on the continued institutional inequalities within district/school, of which, teachers need to be aware of

Table 5: CR Science Teacher Development Studies Cont.

Author, Year	Participants & Grade level	Strategies	Outcomes
Goldston & Nichols 2009	Six middle school teachers Both science teachers were White The other four teachers were Black and one taught LA	Two university professors developed a PLC with a total of 6 middle school teachers within a predominantly black and low income school Within the PLC, participants read books, discussed, took photos, then used the photos to create a photonarrative which was further discussed	Photonarratives are an alternative method for science teachers to develop and grow cultural knowledge of their students and school community Three Luminaries emerged: 1. Church and Sunday schooling 2. Daily sustenance 3. Community
Nam et al. 2012	35 teachers of AI students, 29 of which taught middle or high school science, participated in the CYCLES and ICE-Net Climate Change PD	Teachers participated in a 3-year long PD and were asked directly about their view of CR science teaching They were also given content knowledge specific to climate change	Teachers' perceptions of CR science teaching strategies grouped into three subcategories: 1. providing hands-on experiences 2. place-based teaching 3. integrating traditional teaching styles Challenges grouped into two main subcategories: 1. external (science standards, parents, community, and student attitude) 2. internal (lack of knowledge about the AI culture, low awareness, and less connection with the AI community) To implement CR, teachers need: 1. know their AI students' knowledge and beliefs 2. incorporate specific student knowledge and beliefs into content 3. view learning as reciprocal 4. value community resources/input Clear need for specific PD
Brown & Crippen 2016b	Six life science teachers from the Five participating high schools 2 to 22 years of teaching experience All women	Ongoing, 6-month PD with a focus on both science content and pedagogy Six major activities: 1. Lesson study 2. GAIn observation 3. Curriculum topic study 4. Professional growth tasks 5. Saturday collaboration sessions 6.Culturally responsive science units	Four themes exhibited by CR science knowledge and practices which cannot stand alone: 1. views of students 2. repositioning 3. community building 4. utilizing a CRP toolbox Additional research needed on how to develop sociocultural and critical consciousness in science teachers and their lesson designs

Key for Table 5

AA: African American	LA: Language Arts
AI: American Indian	PD: professional development
CRIOP: Culturally Responsive Instruction Observation Protocol (Powel & Rightmyer, 2011)	PLC: personal learning community
	PSSTP: preservice secondary science teacher preparation
CR: culturally responsive/relevant	PST: preservice teacher
CRP: culturally responsive/relevant pedagogy	PSET: preservice elementary teacher
CRT: culturally responsive/relevant teaching	STARS: Science Teachers Are Responsive To Students program
EST: elementary science teacher	
FE: field experience (K-12 school setting)	STEM: Science, Technology, Engineering, Mathematics
FMSN: family math and science night	TE: teacher educator
FP: field placement	TEK: traditional ecological knowledge
GAIn: Growing Awareness Inventory (Brown & Crippen, 2016a)	UG: undergraduate
ILP: initial license program	US: United States
	Wk: week

Meta-Analysis

As Timulak explains, "the basic idea of qualitative meta-analysis is to provide a concise and comprehensive picture of findings across qualitative studies that investigate the same general research topic (2009, p 591). Meta-analysis serves two purposes. First, by conducting a meta-analysis, more information about the phenomena is revealed (Timulak, 2009). The first phenomenon being explored here is the comprehensive list of CR science teacher characteristics. The second phenomenon are the methods used to build CR science teaching awareness and strategies in preservice and in-service teachers. To compare the extant data with the new science-specific studies, five themes where created. These themes encompass the specific characteristics that overlap in one or more of the studies. The themes and specific characteristics are found below in Table 6.

Table 6: Five Characteristics of Effective CR Science Teachers

	Characteristics				
	Academics	Cultural competency	Social inequities	CR learning environment	Rejection of deficit lens
Characteristics (Author/s, Date)	*Aides in academic student achievement (Ladson-Billings, 1995) *Facilitate building of skills and knowledge needed for academic success (Milner, 2010) Provide a challenging curriculum which incorporates scaffolding opportunities to ensure all students meet the high expectations (Byrd, 2016; Lanier & Glosson, 2014; Xu et al., 2012) Develop students' life-long skills through achievement and by removing barriers (Wallace & Brand, 2012) Expect all students to learn the science content and contribute to discussions about	*Gives students cultural competency by being aware of personal view, views of others and positive interactions across differing cultures (Ladson-Billings, 1995) *Develop a cultural diversity knowledgebase (Gay, 2002) Examine their own biases, stereotypes, analyze privileges and share personal experiences, perspectives and privileges with students (Lanier & Glosson, 2014; Wallace & Brand, 2012) Develop skills to talk about race and ethnicity (Lanier & Glosson, 2014; Wallace & Brand, 2012) Learn and respond to students' sociocultural realities while also helping students to do the same with their peers (Byrd, 2016) Remain involved in students' community from which students reside (Lanier & Glosson, 2014) Get to know each student as an individual, your students' communities and avoid stereotyping, relating to students on a personal level	*Critical awareness of sociopolitical climate; social contexts: assume social inequalities based on race and poverty; the curriculum recognizes that it is a social document and modifies as needed (Ladson-Billings, 1995, 2011) Develop students' sense of empowerment, self-efficacy and self-confidence in the science content (Lanier & Glosson, 2014) Develop a critical view of teaching situated within the sociocultural context (Wallace & Brand, 2012) Use class time to acknowledge and address issues of social inequities (Byrd, 2016; Lanier & Glosson, 2014) Will advocate for individual students (Wallace & Brand, 2012)	*Establish a caring community of culturally responsive learning; communicate with ethnically diverse students (Gay, 2002) *Include cultural diversity in the curriculum (Gay, 2002) *Help students feel a sense of belonging within the classroom (Milner 2010) Foster collaborative learning relationships and incorporate healthy classroom competition (Lanier & Glosson, 2014; Wallace & Brand, 2012) Develop a sense of community, trust, positivity, respect and safety in the classroom where all feel included (Lanier & Glosson, 2014; Wallace & Brand, 2012) Demonstrate care and respect for all students while being patient and tolerant (Lanier & Glosson, 2014; Wallace & Brand, 2012; Xu et al., 2012) Value and affirm what students have to say and the products they produce (Lanier & Glosson, 2014) Valuing of students' experiences outside of the classroom and encourage opportunities to	*The students reject deficit lens and feels with rather for student by advocating and holding high standards (Ladson-Billings, 2011) Value the resources, intellectual and practical, students bring to class and build from them (Byrd, 2016) Believe in the abilities of all students (Lanier & Glosson, 2014; Wallace & Brand, 2012)

Table 6: Five Characteristics of Effective CR Science Teachers Cont.

	Characteristics				
	Academics	Cultural competency	Social inequities	CR learning environment	Rejection of deficit lens
	learning (Lanier & Glosson, 2014; Wallace & Brand, 2012)	instead (Byrd, 2016; Lanier & Glosson, 2014) Demonstrate an awareness of cultural differences within the classroom (Lanier & Glosson, 2014; Wallace & Brand, 2012) Recognize that culture impacts a student's learning (Lanier & Glosson, 2014; Wallace & Brand, 2012) Awareness and concern for the students' preparation and skill acquisition for the real world (Wallace & Brand, 2012)		students to share (Byrd, 2016; Lanier & Glosson, 2014) Have conversations with individual students beyond just the science content to build connections and carve out time before/after school to spend with students (Lanier & Glosson, 2014; Wallace and Brand, 2012) All students always engaged in the learning activities (Lanier & Glosson, 2014) Effective planning, classroom management and communication skills (Lanier & Glosson, 2014; Xu et al., 2012) Physical classroom is organized and displays science content relevant to current instruction (Lanier & Glosson, 2014; Xu et al., 2012)	

*Denotes extant literature that is not specific to science education

As Table 6 demonstrates, there are a significant amount of effective CR science teacher characteristics that align with the work of Ladson-Billings (1995), Gay (2002) and Milner's (2010)'s general effective CR teacher characteristics. There are also characteristics unique to the effective CR science teachers. For example, under the theme of cultural competency, Lanier and Glosson (2014) and Wallace and Brand (2012) stress the importance to recognize that culture impacts the student's learning. As science teachers, it is important to plan according to those cultural impacts while designing lessons to create an effective CR science learning environment (Lanier and Glosson, 2014; Xu et al., 2012). Under the theme of social inequities, another unique effective CR science characteristic is to use class time to acknowledge and address issues of social inequities especially as they relate to the science content (Byrd, 2016; Lanier and Glosson, 2014). Three out of the four science-specific studies argue that effective CR science teachers provide a challenging curriculum which incorporates scaffolding opportunities to ensure all students meet the high expectations (Byrd, 2016; Lanier and Glosson, 2014; Xu et al., 2012). This aligns with the belief in the abilities of all students as expressed by Lanier and Glosson (2014) and Wallace and Brand (2012) under the theme rejection of the deficit lens. Each of the themes will be discussed in greater detail under findings.

Through this comparison, one unique characteristic emerged within the science-specific studies. Both Xu et al. (2012) and Lanier and Glasson (2014) stress the importance of an additional characteristic that best fits under the theme of "effective pedagogical strategies" of effective CR science teachers. Lanier and Glasson (2014) tout having a genuine interest in the science content and offering multiple standpoints as a characteristic of a science CR teacher. This is mirrored by Lanier and Glasson's (2014) inclusion of using a variety of teaching strategies. By demonstrating excitement for the content, teachers are generating interest within their students as well. In addition, presenting content more than once and in a variety of ways gives students the opportunity to interact with the content frequently and in ways they may better connect. Lanier and Glasson (2014) also explicitly link effective classroom management to the characteristics of CR teachers. A detailed list of effective CR science teacher strategies across the four studies is found on Table 7.

Table 7: Pedagogical Strategies of Effective CR Science Teachers

Pedagogical strategies (Author, date)
Offer multiple standpoints on the same science concept (Xu et al., 2012)
Make direct connections between students' life outside of the classroom, personal interests and the science content while planning and facilitating (Byrd, 2016; Lanier & Glosson, 2014)
Incorporate peer discussions, inquiry-based, exploration activities, hands-on experiments, making authentic connections, providing new exposures, song, technology, physical/virtual field trips, science content readings, group projects, referencing previous experiences, evidence-gathering activities, story-telling, comics, trial-and-error opportunities, drawings, writings, and whole-class discussions (Lanier & Glosson, 2014; Wallace & Brand, 2012; Xu et al., 2012)
Personalize the content by connecting science to relevant or real-world phenomenon students can relate to and include examples from the students' culture (Lanier & Glosson, 2014; Wallace & Brand, 2012; Xu et al., 2012)
Develop reciprocal learning experiences through inquiry activities and by giving up some authority (Lanier & Glasson, 2014; Xu et al., 2012)
Incorporate the "funds of knowledge" from the community and students into instruction while harnessing a constructivist view of by building from what students already know (Byrd, 2016; Lanier & Glosson, 2014)
Utilize a variety of authentic assessment opportunities and tools; provide specific feedback and positive reinforcement (Lanier & Glosson, 2014; Wallace & Brand, 2012)
Science learning should be fun and incorporate laughter (Lanier & Glosson, 2014)
Encourage students to make sense of the science content by making their own connections from prior experiences (Lanier & Glosson, 2014)
Incorporate opportunities for students to be involved in decision making, specifically in science content, forms of expression and grouping (Byrd, 2012; Lanier & Glosson, 2014; Xu et al., 2012)
Include opportunities to teach about different cultures regardless of the demographic makeup of the classroom (Byrd, 2012)
Inviting community members/parents/guardians into the classroom and encourage students to share science content with their families (Lanier & Glosson, 2014; Xu et al., 2012)
Address students' science misconceptions by redirecting rather than correcting (Lanier & Glosson, 2014)
Exhibit and possess personal interest in science (Xu et al., 2012)
Encourage students to make sense of science ideas/ vocabulary with their own words and use student-friendly wording when introducing science vocabular (Lanier & Glosson, 2014; Xu et al., 2012)
Encourage students to share what they learn with their families (Lanier & Glosson, 2014; Xu et al., 2012)

Table 6 adds to the extant literature on effective CR teacher characteristics by adding effective CR science teacher characteristics. All characteristics fit under the five themes of academics, cultural competency, social inequities, CR learning environment and the rejections a deficit lens. A new theme also emerged that stands outside of the effective CR science teacher characteristics since it contains pedagogical strategies, Table 7, effective CR science teachers implement. Both these tables provide detailed insight into effective CR science teachers' characteristics and the pedagogical strategies they employ. This information provides researchers with themes, substantiated by examples, for future evaluation of science teachers. But there is a need to analyze the CR science teacher development studies found in Table 5 as well.

Rather than uncovering the effective CR science teacher characteristics and strategies, the ten CR science teacher development studies on Table 5 sought to increase CR science teaching in either preservice or in-service teachers. These studies shared one major similarity, intentional planning and teaching of CR science lessons. But they went about their studies in unique ways, giving future researchers a large sample of methodologies. Johnson and Fargo (2012) compared the state science assessments of 4^{th} through 6^{th} graders, half in the test school and half in the control school. For the students in the test school, the ten elementary teachers received professional development over the two years. Four other studies, Johnson (2011), Goldson and Nichols (2009), Nam et al. (2012) and Brown and Crippen (2016b) also utilized professional development of in-service teachers, but they did not use student academic achievement in science as an indicator. The remaining five studies, Bottoms et al. (2017), Brown and Crippen (2016a), Hernandez et al. (2013), Burgess et al. (2018) and Mensah (2011) focused on preservice teachers. In summary, six focused on preservice science teachers and four focused on in-service science teachers. Of the preservice teacher participant studies, four were elementary science teachers.

An additional unique theme of science-specific CR teachers emerged through the seven CR science teacher development studies utilized in the second meta-analysis. Bottoms et al. (2017), Hernandez et al. (2013) and Mensah (2011) describe the need for reflection in their outcomes. For Bottoms et al. (2017), the Family Math and Science Night provided time for the preservice science elementary teachers (PSETs) to reflect on their lessons. This strengthened their conceptualization of CR teaching. The need for reflection was listed as an outcome for Hernandez et al. (2013), stating a need for the professional development to include post-lesson debriefing for the participating teachers. This need was also expressed in Mensah's (2011) outcomes in relation to PSETs. Through this meta-analysis, a new list of six themes of CR science teacher characteristics, effective CR science teacher pedagogical strategies and the various methods for the development of CR science teacher studies provide a cohesive overview of current CR science teaching studies.

Findings

During the literature review, several holes emerged. First, there were a limited number of elementary science teacher studies, one in the effective characteristics of CR science teachers and four in the development of effective CR science teachers for a total of five out of the grand sum of fourteen. As an elementary science methods instructor, the lack of studies regarding preservice elementary teachers is problematic. The lack of a cohesive language within CR science teacher and teaching research proved to be another hurdle. As demonstrated in the article selection, most of the research does not explicitly address cultural relevance nor responsiveness. A larger number of articles instead referenced "equity, diversity, migrants, English Language

Learners (ELL) and urban or indigenous populations". Though these studies are grounded in the complexities of culture in education, they were not conducted through the CR lens. Thus, they do not address the standards set out in the CR teacher characteristics. The remaining science-specific CR studies lack one evaluation model and how to explicitly address the development of these characteristics and strategies. To address the holes revealed during the meta-analysis of the fourteen CR science studies, examples from the studies will be linked to the six themes of CR teacher characteristics in addition to the science-specific themes of pedagogy and reflection.

Academics

Academically, Ladson-Billings (1995) and Milner (2010) state the importance of CR teachers addressing the academic needs of their students. This was mirrored by the science-specific studies seeking effective CR characteristics since all four articles stressed the importance of high expectations for all students (Byrd, 2016; Lanier and Glosson, 2014; Xu et al., 2012). Though Wallace and Brand (2012) did not explicitly address high expectations, they discussed preparing students with real-world skills and holding every student accountable for learning the science content. Yet, only one of the eleven current CR science studies addressed student academic success as one of the research goals. Johnson and Fargo's (2014) study found that 50% of students in the test school with teachers receiving the professional development scored proficient in science while only 31% reached a level of proficient in the control school. By the end of the second year, students in the 67% at the test school were proficient compared to only 29% at the control school (Johnson and Fargo, 2014). Five other CR science teacher development studies stressed the importance of teachers to have high expectations for all students (Bottoms et al., 2017; Brown & Crippen, 2016a; Hernandez et al., 2013; Mensah, F.M., 2011 and Johnson C.C., 2010). Related to academics is the science content itself. Johnson and Fargo (2014) argue that for successful CR professional development to occur, there must be a clear science content connection. The importance of science content was also addressed in the outcomes by Nam et al. (2012). Specifically, that the teacher participants in the three-year professional development were challenged by the connection of CR to the science content. The other nine studies do not address academics in the strategy nor the outcomes.

Cultural competency

In contrast to the academic theme, cultural competency theme emerged in all but one of the eleven CR science teacher development studies. These are directly linked to Gay's (2002) characteristic of CR teachers developing a knowledgebase of their students' culture. For the CR science teacher characteristic studies, three discussed topics which fall under the theme of cultural competency. Specifically, effective CR science teachers must get to know each student as an individual, learn about students' communities and avoid stereotyping by relating to students on a personal level instead (Byrd, 2016; Lanier and Glosson, 2014). Within the CR science teacher development studies, Goldston and Nichols (2009) required six middle school teachers to create a photonarrative of their students' community. This resulted in an increase in teachers' cultural knowledge of their students and their students' communities. Bottoms et al. (2017) focused a great deal on topics under the cultural competency theme. Explicitly, that preservice teachers need time and support to deal with the emotions associated with identifying current beliefs about differing cultures, (Bottoms et al., 2017). Preservice teachers need to, according to Bottoms et al. (2017), take the time to learn about the students' culture and how to include specific cultural references into the science content. The importance of involving the students' families and communities was also stressed by several of the studies (Bottoms et al., 2017; Hernandez et al., 2013 and Burgess et al., 2018). Building K-12 students' social competency, awareness of other cultures and valuing these cultural differences in the classroom were evident in the studies by Mensah, F.M. (2011), Johnson, C.C. (2010) and Brown and Crippen (2016b). Nam et al. (2012) pointed to the direct implications of the lack of cultural knowledge and the need for current teachers to learn their students' knowledge and beliefs in order to implement CR strategies. In agreeance with this need, Mensah's (2011) research outcomes states that preservice elementary science teachers need time to research the particular students and community.

Social inequities

Both Ladson-Billings (1995, 2011) and Gay (2002) determine that CR teachers must be aware of social inequalities outside and within the classroom. These inequalities then need to be addressed within the curriculum (Gay, 2002; Ladson-Billings, 1995, 2011). Agreeing with the extant literature, Wallace and Brand (2012) discussed the importance of effective CR science teachers to develop a critical view of teaching situated within the sociocultural context. Byrd (2016) and Lanier and Glosson (2014) took it a step further by stating effective CR science teachers use class time to acknowledge and address issues of social inequities. Six of the eleven CR science teacher development studies aligns with this theme. Johnson's (2011) conducted a three-year professional development with two middle school science teachers. As a result, the teachers were made more aware of the continued institutional inequities within the district and school. Johnson states the importance of this awareness in teachers (2011). Brown and Crippen (2016a) stress the importance for teachers to not only acknowledge social inequities but to teach within the current sociocultural climate. The remaining four CR science teacher development studies encourage teachers to help develop critical awareness of social inequities their students may encounter and then address these experiences within the context of the science content, pushing students to develop solutions and focus on community assets rather than deficits (Brown and Crippen, 2016b; Goldson and Nichols, 2009; Hernandez et al., 2013; Johnson, 2011; Mensah, 2011).

CR learning environment

A learning environment that is culturally inclusive, encourages students to feel a sense of belonging and seeks to build relationships on trust, are all characteristics of a CR learning environment (Gay, 2002; Milner, 2010; Wallace and Brand, 2012). All four of the effective CR science teacher characteristic studies echo the extant literature, stating CR science teachers demonstrate care and respect for all students while being patient and tolerant (Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012). Byrd (2016) stresses the importance of valuing students' experiences outside of the classroom and encouraging opportunities for students to share. Of the ten CR science teacher development studies, eight addressed the CR learning environment in either their strategy or their outcomes. Johnson and Fargo (2014) were the least specific, stating there is a need to focus on the learning environment but without specific guidelines. Bottoms et al. (2017), Brown and Crippen (2016b), and Johnson (2010) found that the community needs to be connected through active partnerships as well. Furthermore, the classroom must function as a community as well (Brown & Crippen, 2016b). Brown and Crippen (2016a) were more specific in regard to the learning environment, expressing that CR learning environments encourage student communication, collaboration, respect for all and with the teacher expressing care for every student. Uniquely, Hernandez et al. (2013) encouraged the use of K-12 students' native language in the classroom. Burges et al. (2018) presented their outcomes from two different perspectives, those of the PSTs and those of the TEs. For the PSTs, they stressed the importance of supporting the culture and community of the students within the classroom (Burges et al., 2018). For TE's, they discovered the need to listen to PSTs, meet their needs and view them as collaborators in addition to valuing their cultural and community wealth in the classroom. Mirroring this sentiment, Nam et al. (2012) found that CR teachers must view learning as reciprocal, and they must value the students' community resources and input. All these studies demonstrate a need to focus on the learning environment and not just the science teacher characteristics and strategies when evaluating effective CR examples.

Rejection of deficit lens

Ladson-Billings (2011) expressed the need for students to reject the societal deficit lens. Connected to this goal is the perspectives of teachers. Although the deficit lens is not explicitly addressed in the four effective CR teacher characteristic studies, three express sentiments reflecting an asset-based approach to teaching. Byrd (2016) found that CR science teachers value their students' practical and intellectual resources while Lanier & Gloss (2014) and Wallace and Brand (2012) state that all CR science teachers have a belief that their students have valuable abilities. Three of the ten CR science teacher development studies explicitly addressed the deficit lens. Bottoms et al. (2017) and Burgess et al. (2018) stated that PSTs need to emphasize asset over deficit views. Brown and Crippen's (2016b) outcomes were grouped into four themes. One of these themes specifically addresses the preservice teachers' views by focusing on the resources from their K-12 students' backgrounds (Brown and Crippen, 2016b). The CR science teacher must adopt and model an asset lens.

Pedagogical Strategies

The first discovered theme unique to science-specific CR studies is pedagogy. This becomes apparent since, out of the ten CR science teacher development studies, all address pedagogy. Many of the effective CR strategies exemplified in the effective CR science teacher characteristic studies are also present. For instance, CR science teachers must build from what their K-12 students already know, engage students in inquiry and/or experiential learning experiences and connect the science content to real-world concepts students can relate to (Brown and Crippen, 2016b; Hernandez et al., 2013; Johnson & Fargo, 2014; Mensah, F.M., 2011). Goldson and Nichols (2009) stress the importance of bridging students' culture and the science content, specifically by utilizing the K-12's community. Uniquely, Johnson and Fargo (2011) stress the importance of including opportunities for argumentation in science. While Hernandez et al. (2013) discuss promoting critical thinking in K-12 students with the incorporation of on hands-on activities, teacher modeling and visual aids. Critical and creative thinking were topics within Johnson's (2010) study, specifically with a focus on literacy and language strategies. Collaboration between K-12 students and the use of open-ended questions were other prominent CR science teaching strategies in the CR science teacher development studies (Bottoms et al., 2017; Burgess et al., 2018; Mensah F.M., 2011). Teacher flexibility and duel learning (teacher and K-12 students) were exemplified by Bottoms et al. (2017), Burgess et al., 2018 and Brown and Crippen (2016b). Two studies, Burgess et al. (2018) and Nam et al. (2012) discussed the success of utilizing local spaces outside of the classroom to bridge experiences outside of the community with the science content. Their place-based science inquiry promoted reciprocal learning between the teachers and K-12 students while making the science content more meaningful to all (Burgess et al., 2018 & Nam et al., 2012). Based on these exemplified pedagogical strategies, the teacher must have knowledge of the students. That includes the students' culture. Thus, there exists a bit of an overlap between cultural competency and individualized instruction.

Reflection

Another unique aspect to the CR science teacher development studies was the time preservice science teachers need to reflect on current and future practices, especially in relation to effective CR science teaching. Four CR science teacher development studies expressed the need for the participants to have time to reflect on their lessons. In the case of the Family Math and Science Nights, PSTs used their reflections to adapt their lessons for following events (Bottoms et al., 2016a). This is similar to the discussion by Burgess et al. (2018) and Mensah (2011) who stated that the preservice science teachers needed time to reflect on their current CR strategies in order to plan for future lessons. Goldson and Nichols' (2009) use of photonarratives made reflection crucial to the professional development process. Missing from their study, the need for the inclusion of post-teaching debriefing, or reflection, was stated by Hernandez et al. (2013). In addition, Brown and Crippen's (2016a) study with PST participants indicated a need for more explicit lesson planning based on the field observations. Though reflection is not explicitly stated here, the importance is evident in the reflective nature of effective lesson planning.

Implications for Further Studies

Effective CR elementary science teachers are necessary for increasing all students', regardless of culture and ethnicity, interest in science in order to promote student enrollment in additional science courses at the postsecondary level (Maltese and Tai, 2010). This requires teacher preparation institutions, especially within preservice elementary teacher programs, to include effective CR science teaching characteristic and pedagogical practice building within the curriculum. But, as this meta-analysis demonstrates, there are limited studies on effective elementary science teacher characteristics and practices. This meta-analysis included studies from middle level and high school level schools in addition to CR science teacher development studies to address this gap in the literature. From which, explicit characteristics which are unified under five cohesive themes and specific CR science teacher pedagogical practices became apparent. The findings from each meta-analysis can be utilized independently or in unison to further future CR elementary science teacher studies.

First, by defining a clear picture of effective CR science teacher characteristics, future studies will not only be more cohesive but will also offer a clear methodological path. The five cohesive themes with the examples from the four effective CR science teacher studies offers a snapshot of characteristics future researchers can look for. In addition, the effective CR science teacher pedagogical practices exemplified within these four studies gives practical examples current teachers can utilize to build CR elementary science teaching within their own classrooms. They also provide researchers with a practical list for classroom observations.

For the development of CR elementary science teachers, each of the five themes and the pedagogical practices of effective CR elementary science teachers need to be explicitly addressed in the research method. By doing so the outcomes should reflect a positive increase in these desired characteristics. Additionally, by connecting the desired characteristics to practical strategies, the teachers become the basis for evaluation rather than the student outcome, which, as Aronson and Laughter (2016) point out, may be inherently bias when student scores are used since the testing instruments themselves are often bias. Thus, with a clear evaluation model and CR elementary science teacher methodology, teacher educators (TEs) can develop strategies to systematically address each of the CR science teacher themes and CR pedagogical practices. Through the unification of an evaluation system and methodology, evidence-based strategies will also be discovered, giving all TEs the specific tools needed to cultivate CR elementary science teachers.

Chapter 3

The Impact of Evidence-Based Strategies for Culturally Responsive Science Teaching on Preservice Elementary Teachers

Abstract

In this study, the findings from a previous meta-analysis on effective culturally responsive elementary science teacher characteristics and practices, are applied to a preservice elementary science methods course (Pinneo, 2020). The elementary science course practices were shaped around the extant literature on effective Culturally Responsive (CR) teacher characteristics and practices in addition to the strategies implemented by current CR science teacher development studies. Through the findings, it is argued that although preservice elementary science teachers acknowledge these characteristics and practices, full implementation of these practices require the method course to be closely connected to the field experience community in order for explicit connections to the science content and opportunities to address local issues through science.

Keywords: Culturally Responsive Teaching, preservice elementary teachers, science

The Impact of Evidence-Based Strategies for Culturally Responsive Science Teaching on Preservice Elementary Teachers

In the fall of 2020, Kamala Harris, was the first female and non-White individual elected vice president of the United States. Vice President Elect Harris identifies as both Black and Indian American. In her acceptance speech, she acknowledged this historical moment and the impact it will have on young women, especially young women of color. Because young women of color can now see someone who looks like them in this position of power, they can imagine themselves in a similar position. Representation of diverse members are important within all fields.

Diverse members bring new perspectives to their fields as well. For example, scientists, mostly male, focused on the competitive nature of male apes (Rutherford, 1990). It was not until women scientists like Jane Goodall, Diane Fossey and Biruté Galdikas joined the field and began studying apes that the important role female primates played vital to community building was studied and explained (Rutherford, 1990). These women scientists, with different experiences and backgrounds than their male counterparts, contributed to their field by adding a different perspective within their studies. As a female science teacher educator and mother to a pre-teen daughter, that is important. Women scientists like Goodall Fossey and Galdikas continue to demonstrate the contribution women make to the field of science.

But science education is not solely for representation within science. As Rutherford (1990) explains, "scientists can bring information, insights, and analytical skills to bear on matters of public concern" which requires citizens to have an understanding of the scientific process in order to comprehend and evaluate the information (p 11). Citizens of the US are diverse, and as citizens, are expected to participate in democratic decision making, sometimes involving scientific information. As the Biden-Harris administration has discussed, a plan that is science-based is necessary to defeat the current pandemic. Thus, there is a need to increase science interests for all, regardless of gender or ethnic background. Since Maltese and Tai (2010) demonstrated the need for an early interest in science, preservice elementary teacher preparation becomes especially important. Within preservice elementary teacher education courses, effective culturally responsive (CR) science teaching pedagogical practices needs to be included and explicitly addressed. Culturally responsive (CR) science teaching connects the cultural knowledge, perspectives, and experiences of all students to the science content, making science relevant through the students' experiences and backgrounds. If preservice elementary teachers can learn to plan an implement effective CR science lessons, perhaps interest in science will increase in their future classrooms.

As a preservice elementary science instructor, I am in the position to implement this positive change. I am particularly interested in the impact a semester-long elementary methods science course has on the students' planning and implementation of CR science lessons. For methods course in the fall of 2019, I structured the content around Milner's "conceptual repertoires of diversity" (2010, p. 121). Using the structure of inquiry, I examined my own practices to influence future instruction by conducting what Ferrance defines as "action research" (2000). My action research addressed the following two questions:

Research Questions

1. How do preservice elementary teachers' abilities to enact CR science teaching relate to discussions of Milner's (2010) "conceptual repertoires of diversity" throughout the elementary science methods course?

2. How does the instructor's use of modeling, group discussions, authentic assessments and Hawkins and Rogers (2016) "Video-Based Reflection Questions", impact preservice science elementary teachers' ability to enact CR science teaching?

Effective Culturally Responsive Science Teacher Characteristics and Practices

Characteristics

CR science studies, especially at the elementary level, are limited (Pinneo, 2020). Through my process of a meta-analysis of recent CR science teacher characteristic and CR science teacher development studies, only four articles from the total of fourteen relevant articles were at the elementary level (Pinneo, 2020). However, when I included studies conducted at settings other than the elementary level, a more conclusive picture of CR science teacher characteristics and practices emerge. Effective CR science teachers provided a challenging curriculum which incorporated scaffolding opportunities to ensure all students met the high expectations (Byrd, 2016; Lanier and Glosson, 2014; Xu et al., 2012). This was demonstrated by expecting all students to learn the science content and contribute to discussions about learning (Lanier and Glosson, 2014; Wallace and Brand, 2012). Effective CR science teachers do not just focus on the science content. Instead, they intentionally planned instructional opportunities to develop students' life-long skills, such as the ability to critically assess the information community scientists provide for the public (Wallace and Brand, 2012). To do so, the teachers had to reject their deficit lens, or their instinct to view students with the assumption that they are lacking in experience and or skills. Instead, they valued the intellectual and practical resources, students brought to class and then built from those assets (Byrd, 2016). For example, the Lanier and Glasson's (2014) interviews with elementary students revealed their view that their academic success was directly related to their teacher's ability to relate with them on a personal and academic level.

To reject the deficit lens, teachers had to examine their own biases, stereotypes and they analyzed their own privilege (Lanier and Glosson, 2014; Wallace and Brand, 2012). They then shared their personal experiences, perspectives, and privileges with students (Lanier and Glosson, 2014; Wallace and Brand, 2012). To share personal experiences, the teachers developed skills to talk about race and ethnicity (Lanier and Glosson, 2014; Wallace and Brand, 2012). The process of addressing one's own biases and personal experiences were encouraged within the students as well. Teachers demonstrated an awareness of cultural differences within the classroom and responded to students' sociocultural realities while also helping students to respond to their peers' sociocultural realities as well (Byrd, 2016; Lanier and Glosson, 2014; Wallace and Brand, 2012). One way these goals were accomplished, was that the teachers either remained or became involved in students' residential communities (Lanier and Glosson, 2014). Simply put, effective CR science teachers got to know each student as an individual, their students' communities, avoided stereotyping and related to students on a personal level (Byrd, 2016; Lanier and Glosson, 2014).

Relating to students on a personal level, required the teachers developed a critical view of teaching situated within the sociocultural context (Wallace and Brand, 2012). Effective CR science teachers used class time to acknowledge and address issues of social inequities (Byrd, 2016; Lanier and Glosson, 2014). Teachers did not focus on personal obstacles students had but instead developed students' sense of empowerment, self-efficacy, and self-confidence in the science content (Lanier and Glosson, 2014). By doing so, students learned life-long skills they could apply to future obstacles. This required candid conversations in which the teacher directly connected the science content to real-world, relevant situations within the students' community and the students' personal interests (Byrd, 2016; Lanier and Glosson, 2014). For example, one effective CR science teacher preserved a deceased snake in a jar and took it to class to show her students (Xu et al., 2012). After this exciting event, many of her students started to do the same thing. Like their teacher, they brought organisms they found in their community to share in class as well (Xu et al., 2012).

Having open and honest interactions with students and between students required effective CR teachers to have focused on the learning environment as well. They cultivated a sense of community, trust, positivity, respect, and safety in the classroom where all students felt included (Lanier and Glosson, 2014; Wallace and Brand, 2012). This was done by their demonstration of care and respect for all students through their consistent patience and tolerance (Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012). Teachers also had conversations with individual students beyond just the science content and carved out time before/after school to spend with students to build connections (Lanier and Glosson, 2014; Wallace and Brand, 2012). They affirmed what their students had to say and valued their students' experiences outside of the classroom and encouraged students to share (Byrd, 2016; Lanier and Glosson, 2014).

Practices

Since effective CR science teachers recognized that culture impacts a student's learning, pedagogical practices that meet diverse students' needs were selected (Lanier and Glosson, 2014; Wallace and Brand, 2012). In addition to the use of evidence-based teaching strategies, effective CR science teachers included opportunities to teach about different cultures regardless of the demographic makeup of the classroom (Byrd, 2012). They also incorporated the "funds of knowledge" from the community and students into instruction and developed reciprocal learning experiences through inquiry activities and through relinquished authority when possible (Byrd, 2016; Lanier and Glosson, 2014; Xu et al., 2012). This helped to provide multiple standpoints on the same science concept (Xu et al., 2012). Effective CR science teachers were also excited about the science content and had fun (Lanier and Glosson, 2014; Xu et al., 2012).

Conceptualizing these effective CR science teachers revealed a mental image of an elementary science classroom that was rigorous, respectful, student-centered, well organized, and energetic. Student work was on display and representations from a variety of ethnic/racial backgrounds were visible. The students were involved in high level thinking activities at all times and encouraged to connect their personal experiences and background to the science content. The teacher got to know each student as an individual and their personal interests. This community of learners developed through consistent procedures, acknowledgement, and celebration of differences. The of students' racial/ethnic backgrounds were intentionally connected to the content and the teacher demonstrated enthusiasm for these connections and the science content.

Considering the previous discussion, I was inspired to explore my own instructional practices, specifically the addition of Milner's (2010) article and use of reflection questions developed by Hawkins and Rogers (2016). My elementary science methods course had always implemented inquiry and exploration, both effective CR pedagogical practices, but my new focus were these additions and their impact on my students' CR planning and implementation of lessons. I wanted to gain insight into the two research questions, above, to modify my curriculum and instruction within the science methods course. These questions were investigated through a deductive analysis of the lesson plans, post-teaching reflections and their summative reflection.

Since I had previously recognized six major themes (Table 5) of effective CR characteristics and practices, I used the themes as my initial codes. Through this process, a story emerged from the twelve, preservice elementary teachers' course assignments.

Positioning

As mentioned previously, my elementary science methods course contained some of the elements found in the development of CR science teacher studies. I modeled inquiry and exploratory-based instruction, guided students through the use of the 5E model (Bybee, R.W., 2014) and used performance-based assessments. It is difficult to assess my own CR teacher characteristics and I have admittedly not attempted to do so. I am a white female, originally from the Midwest, now living in a Southern metropolitan city. For my high school experience, I attended a science focus program. It was a part of our public-school system but unlike the other high schools, it required an application process. Students who wanted to attend had to gain references and write an essay which, as it was intended to do, increased the number of students who wanted to attend a school focused on science. It was a much smaller environment than I was used to from my elementary and middle school experiences. We averaged about sixty students within grades ten through twelve. The courses were also mixed, rather than adhering to a strict schedule, we were able to take the courses we wanted regardless of what grade we were in. We also had several doctoral students from our local university teach at our school as part of their graduate work. For one such project, we helped develop an underwater rover for exploration in our school's pond. We also had the opportunity to work with bees and collect trash from the early 1900s from the bottom of Firestone River in Yellowstone National Park. Simply said, my high school experience was grounded in scientific inquiry and problem-solving opportunities. I, with my peers, got to work with scientists and did what scientists do.

I began my career as a high school biology teacher in a school that, from the outside, looked completely different from my own high school experience. I walked into class with the assumption that everyone loved science as much as I did. I quickly learned that not all my high school students had been given the opportunity to love science. Many of my high school students told me that science, in their experiences, never left the classroom and was often textbook based. I wanted to change this. So, I started planning our first field trip my second semester as a teacher. I also brought in guest speakers, took my class outside as often as possible and encouraged students to connect the science content to their own interests and experiences.

One of my favorite examples comes from one of my most memorable students. She, we will call her Marie, loved to bring up shocking content to cause a commotion in the classroom. So, I had no choice but to roll with her verbal punches. During our project on adaptations, I always let students select their own organism for their presentation on the structural, behavior and physiological adaptations specific to their chosen lifeform. When asked which organism Marie was interested in, she loudly declared, “pubic lice”. I, without breaking my steady expression, recorded her organism on my roster and asked her to get started on her research. There were a few chuckles but as we kept moving, her classmates became interested in their own work and quickly forgot about hers. I will always remember Marie’s presentation. Not only was she professional, but she also led an interesting discussion on the impact of “deforestation” of pubic lice’s natural habitat due to many North American women’s grooming practices on the extinction of some species.

I did not know this at the time, but I was using the tools of effective CR science teachers in my high school biology class. I worked to get to know my students as individuals, incorporated this knowledge into the content, embraced their opinions and questions and guided students through discovery rather than presenting rote facts. By connecting the science content to my students' experiences outside the class and promoting their own interests, they began to value the strategies used by scientists to gather knowledge. This was exemplified by another one of my past students, Marcia (pseudonym). She had failed her first semester of biology during tenth grade, so she had to complete the first semester during her eleventh-grade year. During our first lab I overheard her leading her peers in the use of the scientific method by guiding them through a similar story to the one I like to use. To paraphrase, she asked her peers, "have you ever wondered what would happen if you only ate hot Cheetos, would you get tired of them?" She followed up by saying, "well, we could make a prediction, test our prediction and then see what happened. That is the scientific method." I was so overjoyed! I contained myself in the moment, not wanting to spoil it, but I could not wait to verbally gush to her about my pride in between classes. The last time I saw Marcia, she was successfully completing nursing school.

When the opportunity arose, I moved into teacher education at my current university. I still miss my high school students, but I found that my calling is working with preservice teachers. I also begin my doctoral work towards a PhD in Curriculum and Instruction in science education. Through my classes, I discovered CR science teaching. Finally, I had a name to the theoretical framework I adhered to within my instruction design and facilitation.

Currently I teach the science methods courses, in addition to others, for the elementary, middle, and secondary preservice teachers. With a specific interest in inspiring love of science at the elementary level, this researched was conducted within my preservice elementary methods course during the fall of 2019. The course is only offered at the undergraduate level and is required as part of the Bachelor of Science in Education (B.S.E.) degree that is tied to initial K-6 teacher licensure. My university is in an urban setting within a larger southern city in the United

States. It was a traditional course which met once a week for two to three hours over an entire semester. Most of the students took the course their junior year of college. Although the students were also required to complete a field course within the K-5 setting, the methods course was not aligned with the field experience.

Field Experience

Students in the B.S.E. program complete three field courses and two internships throughout the program. Placements were conducted throughout a wide range of school districts in and around the University area. Students were placed in different schools for each semester, with the intent of providing experiences with diverse K-6 racial/ethnicity and socioeconomic demographics. Specific projects were linked throughout the experiences with the addition of specific classes during the two internships. During the internships, students took an internship seminar course. During the semester of their science methods course, they were in their third field placement. During these placements, they were required to write and submit a weekly reflection to their field supervisor. Although it would be ideal to have students teach their CR science lesson in the field, the instructor and students received a lot of push back from the cooperating teachers (CTs) in the K-6 classrooms. CTs were the current K-6 teachers who hosted the preservice elementary teacher within their classroom. All the CTs had a minimum of three years of classroom teaching experience. Students were carefully placed with CTs based on personalities. Since the CTs were expected to meet state-wide standardized testing goals, science was often omitted from the curriculum. The preservice elementary teachers were rarely permitted to teach their CR science lessons which made it difficult to tie to the science methods course.

Participants

Participants were selected from the students taking the course in the fall of 2019. Although all students were required to complete the course requirements, twelve out of the eighteen students completed the participant consent form. Table 2 lists the total race/ethnicity of the participants.

Table 2: Participant Name, Gender and Ethnicity/Race

Name (Pseudonym)	Gender	Ethnicity/Race
Amanda	Female	White
Ashley	Female	White
Charlotte	Female	White
Emiri	Female	White
Imani	Female	African American or Black
Jessica	Female	White
Kim	Female	Asian
Olivia	Female	White
Rosa	Female	Other, Hispanic, Latino, or Latin American
Shanice	Female	African American or Black
Sophia	Female	White
Stephanie	Female	White

The Methods Course

I was the instructor for the course and I taught according to an outline (Table 3) in which Milner's (2010) "conceptual repertoires of diversity" were used to organize class readings and as a guide for discussion topics. My students read each, starting with "color-blindness" and continued throughout the semester with the others, "cultural conflicts, myth of meritocracy, deficit conceptions and expectations" (Milner, 2010).

Course Content

The course outline, Table 3, was given to students on the first day of the semester. It was a graphic organizer I intended my students record their thoughts, ideas questions, etc. throughout the semester. They were expected to take notes during classroom discussions, discussions with their group members and while reading the assigned section from Milner (2010). My students used the notes to submit an overall reflection on our discussions and applications of Milner's (2010) article over the semester after the final topic "low expectations" was discussed. After the final discussion, students participated in a gallery walk in which all five "repertoires" were listed on five separate large pieces of paper around the room. Students worked in teams of three or four to address each "repertoire" and provided a practical pedagogical strategy for effective CR science teaching under each. Students were encouraged to take pictures of the results and use the images and their notes when they wrote their reflections on Milner (2010).

Table 3: Course Outline/Notes

Week	Milner's (2010) "Repertoires"/Lesson Standard	Assignments	Post Discussion/Lesson Reflection
1.	Color-blindness	Milner, H. R. (2010). -Introduction and "Color-blindness" section (p 118-122)	Characteristics/Strategies?
2	Selected scientist:	Lesson Planning: What CRT strategy did you add to the lesson?	What evidence of the CRT strategy did you see in your facilitation of your lesson?
3	Cultural conflicts	Milner, H. R. (2010). -"Cultural conflicts" section (p 122-123)	Characteristics/Strategies?
4	NGSS 4-6 Science Standard	Lesson Planning: What CRT strategy did you add to the lesson?	What evidence of the CRT strategy did you see in your facilitation of your lesson?
5	Myth of meritocracy	Milner, H. R. (2010). -"Myth of meritocracy" section (p 123-124)	Characteristics/Strategies?
6	NGSS 4-6 Science Standard	Lesson Planning: What CRT strategy did you add to the lesson?	What evidence of the CRT strategy did you see in your facilitation of your lesson?
7	Professional Development: Project Learning Tree training		
8	Deficit conceptions	Milner, H. R. (2010). -"Deficit conceptions" section (p 124-125)	Characteristics/Strategies?
9	(Low) Expectations	Milner, H. R. (2010). -"(Low) Expectations" section to the end (p 126-131)	Characteristics/Strategies?

The reading sections alternated weeks with student-facilitated lessons. This provided time for the me to model CR science elementary lessons on the weeks the students were not facilitating. The lesson objectives and thematic connections I identified in the meta-analysis are on Table 5 (Pinneo, 2020). The lessons I facilitated were on the days in which a Milner (2010) was discussed. Then, students formed groups of two to three and selected an elementary grade NGSS to drive their lesson planning. Most students planned outside of class time. Students were encouraged to plan CR effective science pedagogical strategies with the use of a modified 5E lesson plan (Bybee, R.W., 2014) and by explicitly connecting our Milner (2010) discussions to the lesson I had facilitated. The lesson plan template provided for students can be found in Appendix A. Student groups facilitated their lessons with their classmates the following class. I used class time to address both the science content and the pedagogical practices, with a focus on positive examples and ideas to go deeper. I provided more explicit feedback through Blackboard where students were expected to submit their lessons.

One week, the I modeled the facilitation of an effective CR science lesson and then students discussed the specific section of Milner (2010). The following week, the students facilitated their CR science lesson. This pattern occurred for eleven weeks. During week seven, a guest speaker was invited into the classroom for training on the Project Learning Tree (Sustainable Forestry Initiative, 2019) which resulted in three hours of state-approved professional development for my students. They also received the curriculum and were encouraged to use it to develop their final CR elementary science lesson plan. Whole-group classroom discussions utilized the Socratic circle method. As Brown, A.C. (2016) explains, “Socratic circles are designed to discuss open-ended questions in order for participants to further their understanding of a topic” (p A82). Students were divided into two groups, the inner circle and the outer circle. While the inner circle spoke, the outer center could only take notes. A three-minute timer was set, and groups rotated in and out of the circle until the discussion reached a point in my students no longer had additional points or questions. I used notes taken during the student discussion to create a whole-class list of students' ideas. Instead of inserting my own opinions, I initially encouraged students to respond to their peers' questions and interjected when the question could not be addressed by peers.

Table 4: Weekly Lesson objectives and CR Theme Connection

Week	Lesson Objective	CR Theme Connection
1	Students will use the scientific method to predict, observe and test the average weight needed to pop the popper while correctly applying the method, associated vocabulary (hypothesis, dependent variable, independent variable, control, trials, line vs bar graph, etc.) and accurately graph the results.	**Academics**-All students expected to demonstrate correct application of vocabulary and procedural steps of the scientific method. **CR Learning environment**-every student was involved in the activity. Alternating volunteers placed the weights, one student collected data on the board, several students cleaned up the popper materials, and all students used their observations and group discussion to create a graph. **Rejection of deficit lens**-The instructor asked questions to encourage the students use prior knowledge for the test design, how to record and graph data.
2	Students will facilitate lessons on their scientist with a focus on a hands-on activity that connects with the scientists' field of study. Socratic circle on Milner (2010) "color-blindness"	**Social inequities-** We discussed how each scientists' gender and/or ethnicity impacted their career. **Cultural competency**-The scientists the students selected from were female and/or ethnically diverse (Marie Curie, George Washington Carver, Grace Hopper, Katherine Johnson, Ada Lovelace, Anna Mani, Neil deGrasse Tyson and Chien-Shiung Wu).
3	Students will draw a simple phylogenic tree depicting how they think gorillas, chimpanzees and humans are related; they will build a model of the same gene, compare and modify their phylogenic tree to accurately reflect the relationship. Socratic circle on Milner (2010) "cultural conflicts"	**Social inequities**-As a class, we used this activity to discuss shared ancestors, the students' misconceptions regarding skin color, eugenics movement in the US and using misconceptions about race to justify slavery in US history.
4	Students will facilitate their first CR Lesson Plan and then meet with their group members for their post-lesson discussion (modified Brookfield's () questionnaire).	**Pedagogical strategies**-The students used a 5E approach with a variety of strategies. Specific examples used are group work, hands-on activities, incorporation of local landmarks, student-friendly videos, formative assessments, an article about fossils in Africa, demonstrations, written records of student observations and mining resources from specific locations based on their field students' ethnicity.
5	Students will break into two large groups, predict whether ice will melt faster in fresh water or salt water, test their predictions and then explain their observations. Socratic circle on Miner (2010) "myth of meritocracy"	**Social inequities**-this activity specifically related to "myth of meritocracy" by giving only one of the two groups blue food coloring. The group with the food coloring were able to see the melting ice floating on the salt water rather than mixing with the fresh water, causing the ice to melt faster. The
6	Half of the students will facilitate their second CR lesson plan.	**Pedagogical strategies**- The students used a 5E approach with a variety of strategies. Specific examples used are providing models, guiding questions for whole-group discussions, student drawings, problem-solving activities, making direct connections to content in other areas such as social studies and football (students' interests), learning stations and incorporation of animals in the local environment.
7	**Professional Development:** Project Learning Tree training	
8	Remaining half of students will facilitate their second CR lesson plan. Socratic circle on Milner (2010) "deficit lens"	**Pedagogical strategies**- The students used a 5E approach with a variety of strategies. Specific examples used are real-world connections, exploration activities, use of graphic organizers during whole-class discussions, incorporation of myths from other cultures, and authentic assessments.

Table 4: Weekly Lesson objectives and CR Theme Connection Cont.

Week	Lesson Objective	CR Theme Connection
9	Students will record the "lava" (baking soda and vinegar) on the cardboard surface with Play-Doh, creating layers with multiple trials and then collect "core samples" using a clear straw and discuss how this activity connects to the work of geologists and volcanologists. Socratic circle on Milner (2010) "expectations"	**CR learning environment**- The students worked in groups of their choosing to complete the activity. While students were working, the instructor spent time with each group to discuss how their field placements were going, how their families/jobs were going, and any other topics students wanted to share.

Note: Questions below are adapted from Hawkins and Rogers (2016)

Student Name:____________________ Partner/s Names:______________________ Date:______

As a group, watch each of your video lessons and then address each question. Responses to these reflection questions in regards to your lesson video should be addressed in your written reflection. In your reflection, you only need to discuss your recorded lesson but be sure to include ideas shared by your peers during the video viewing.

- What concepts from class discussions/readings/assignments helped you prepare for this lesson?
- What did you intend students to learn about this idea?
- Why is it important for students to know this?
- What difficulties/limitations are connected with teaching this idea?
- What is your knowledge about students' *thinking* which influences your teaching of this idea?
- What is your knowledge about your students' *backgrounds* which influences your teaching of this idea?
- What other factors influence your teaching of this idea?
- In what ways, if any, did your perception of Milner's (2010) "conceptual repertoires of diversity" change during this process?

Figure 1: Post-Teaching Reflection

My students also completed a post-lesson reflection with open-ended questions adapted from Hawkins and Rogers (2016) "Video-Based Reflection Questions" (Figure 1). Although the lesson facilitations were not recorded, I took detailed notes and provided them to each group. If class time permitted after the facilitation of all the preservice teacher CR elementary science lessons, students would meet with their groups to discuss each of the questions. If time did not permit, they discussed via phone, text, email, etc. out of class time. They would then complete and submit the questionnaire individually.

Data Collection and Analysis

Student lesson plans, post-lesson reflections and a final reflection on Milner (2010) were collected. I analyzed the data using the software program Nvivo 12. Through my meta-analysis of current CR science teaching and development studies, the six themes on Table 5 emerged (Pinneo, 2020). Five of the themes organized the characteristics of effective CR science teachers. The final theme, "pedagogical strategies" displayed the effective CR science teacher practices within classrooms. I used these six themes in my typological analysis as described by Hatch (2002). "In typological analysis, an early step is to read through the data set and divide it into elements (i.e., disaggregate it from the whole) based on predetermined categories" (Hatch, 2002, p 152). This deductive approach is especially helpful when the initial categories for analysis have been identified and easily justified (Hatch, 2002). In the initial stages of coding, the themes were divided into a total of seven. The "pedagogical theme" was originally under two different categories, "individualized instruction" and "pedagogy". When nearly one third of the initial data was coded, I discussed with my mentor the problematic use of two separate columns. After our discussion, I combined the two themes into "pedagogical strategies". The final six themes were academics, cultural competency, social inequities, CR learning environment, rejection of the deficit lens and pedagogical strategies. These themes and their descriptions are on Table 5.

Table 5: Description of Thematic Codes and References

Thematic Codes	Description
Academics	Aides in academic student achievement; Provide a challenging curriculum which incorporates scaffolding opportunities to ensure all students meet the high expectations; Develop students' life-long skills by removing barriers; Expect all students to learn the science content and contribute to discussions about learning;
Cultural competency	Develop a cultural diversity knowledgebase; Analyze privileges and share personal experiences with students; Develop skills to talk about race and ethnicity; Learn and respond to students' sociocultural realities while also helping students to do the same with their peers; Be involved in students' community; Get to know each student as an individual; Demonstrate awareness; Recognize that culture impacts a student's learning; Focus on skill acquisition for the real world;
Social inequities	Critical awareness of sociopolitical climate; social contexts: assume social inequalities based on race and poverty; modify the curriculum as needed; Include cultural diversity in the curriculum; Develop students' sense of empowerment, self-efficacy and self-confidence within science content; Develop a critical view of teaching situated within the sociocultural context; Use class time to acknowledge and address issues of social inequities; Advocate for individual students;
CR learning environment	Communicate with diverse students; Foster students' sense of belonging; Foster collaborative learning relationships; Develop trust, positivity, respect and safety in which all feel included; Demonstrate care for all students while being patient and tolerant; Value and affirm what students have to say and produce; Value students' experiences outside of the classroom; All students engaged at all times; Effective planning, classroom management and communication skills; Organized classroom and science displays;
Rejection of deficit lens	Reject deficit lens and feels with rather for students by advocating and holding high; Value the resources, intellectual and practical, students bring to class and build from them; Believe in the abilities of all students;
Pedagogical strategies	Multiple standpoints; connect students' life and interests in the science content; Peer discussions, inquiry, exploration, hands-on, song, technology, field trips, science readings, group projects, previous experiences, evidence-gathering, story-telling, comics, trial-and-error, drawings, writings, relevant and real-world connections, "funds of knowledge", authentic assessment, feedback, positive reinforcement, student-friendly words, student choice and enthusiasm; Teach about cultures; Invite community in;

References (Byrd, 2016; Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012)

I read the data by each typological theme, looking for themes within (Hatch, 2002). Within the themes, a pattern of "example" and "non examples" emerged in several. Academics, cultural competency, social inequities and rejection of the deficit lens each contained student ideas that did not reflect the concepts exhibited by the CR science teacher studies. Examples are displayed on Table 6.

Results

Data analysis revealed that the preservice elementary teachers were consistent in two of the six themes, CR learning environment and CR science pedagogical practice. For both, none of the participants exhibited non-examples. The CR learning environment and CR science pedagogical practices were also the most frequently represented theme. Table 6 provides participant examples and non-examples for each theme. The frequencies of code by participant are on Table 7.

Table 6: Participant Examples and Non-Examples for Each Theme

Themes	**Example** (Participant and Source)	**Non-Example** (Participant and Source)
Academics	I also like the idea of challenging students regardless of what stereotypes say that African or Honduran students can and can't do. (Jessica, Milner Reflection) Real life circumstances call for collaboration all the time and students must know how to work together to achieve a goal! (Sophia and Ashley, Lesson Plan 2).	I immediately go to the simple fact that space is totally confusing and should be approached in a simple and very concreate form. (Ashley, Post-teaching Reflection 1)
Cultural competency	The class will learn about mining and the different resources in certain parts of the world and will be able to correctly identify the country they mined, as well as, the learning portion of KWL (Shanice, Kim and Stephanie, Lesson Plan 1) Students using their knowledge of animals/plants in Arkansas that are common (Charlotte and Imani, Lesson Plan 3) Not acknowledging culture differences is not doing anyone any good. "Not seeing color" or not seeing students for individuals and treating them as if they are all the exact same student with the exact same experiences and backgrounds not only doesn't do anyone any favors, but actually hurts the concept for creating a classroom environment that is culturally diverse and accepting. (Olivia, Post-teaching Reflection 3)	Some students of color don't go through "horrors" at home (Imani, Milner Reflection) Most of my students will probably have a similar background to mine as far as this lesson is concerned (Olivia, Post-teaching Reflection 1)
Social inequities	No matter where they go in the world though, there will be a system of power in place, so it's not unreasonable for students to learn how they work and where they fit in. Challenge students of color to question systems that oppress them. (Jessica, Milner Reflection) By allowing the students to create their own strategies to complete the problem at hand allowed then to take the power from my hands and create their own (Ashley, Post-teaching Reflection 2)	There is no denying that there is a power issue that definitely plays a part in just about every aspect of life. While this is the case, I don't think race is where the issue lies (for the most part – it does play it's part) but I think it's just the fact that someone, anyone, is in a position of power and some students feel the need to challenge that power, no matter the culture or race that's behind it. Again, not saying that doesn't play a role at all, because it most certainly does. (Olivia, Milner Reflection)

Table 6: Participant Examples and Non-Examples for Each Theme Cont.

Themes	**Example** (Participant and Source)	**Non-Example** (Participant and Source)
CR learning environment	(Using a) KWL Chart together as class, have students write down what they thought was the most interesting thing they learned (Emiri and Olivia, Lesson Plan 2) We need to incorporate all cultures throughout curriculum (Sophia, Milner Reflection) I think it's opened my mind to being explicit with students to help solve some of the differences in the classroom and build mutual respect (Amanda, Post-teaching Reflection 3)	
Rejection of deficit lens	Use a student's assets to the learning opportunity/build on the knowledge brought to the classroom (Stephanie, Milner Reflection)	Depending on their home lives, they may not be exposed to a rich environment that allows them to witness many different things. (Jessica, Post-teaching Reflection 3)
CR Science pedagogical practice	The class will learn about mining and the different resources in certain parts of the world and will be able to correctly identify the country they mined, as well as, the learning portion of KWL. Each group will have a different area of popular mining resources from that part of the world. Africa - mostly cobalt; Russia - mostly nickel; Arkansas - mostly diamonds; California - mostly gold (Shanice, Stephanie and Kim, CR Lesson Plan 1). Fifth graders will graph shadow direction and write how it compares to the placement of the sun (Imani, Lesson Plan 2) Then the students will split up into groups and be given 5 objects in a paper bag to feel (Sophie, Shanice and Amanda, Lesson Plan 3). Does everyone know what the five senses are? What do you do when you are hungry and want something to eat? What if you can't use your eyes? Could you still find your way? (Rosa, Lesson Plan 3)	

Within the theme of academics, my preservice teachers consistently expressed the importance of rigor and high expectations for all students. They acknowledged that all students are capable of learning the content regardless of race/ethnicity or culture. The non-examples were not related to their perceptions of students. Instead, they revealed a discomfort with some of the science content. When my preservice elementary teachers were not comfortable with the NGSS content, they admittedly simplified their lesson, and assumed their elementary students would have difficulties with the content as well. Ashley, in her first post-teaching reflection, stated that she was confused by space and that her elementary students probably would be too. So, she wanted to start with "concrete" facts that were simple and, for her, approachable.

My preservice elementary teachers were the most comfortable talking about creating CR learning environments and effective CR pedagogical strategies. This was evident in the lack of non-examples throughout the entire data. There was a high frequency in cultural competency, but several non-examples emerged, which demonstrated some inconsistency under this theme. Although my students acknowledged the desire to learn about other cultures, respect other cultures and incorporate a variety of cultures in their lessons and curriculum, some conflicting statements emerged.

Table 7: Frequency of Codes by Participant

	Academics		Cultural Competency		Social Inequities		CR Learning Environment	Rejections of deficit lens		Pedagogy
Name (Pseudonym)	Example	Non-	Example	Non-	Example	Non-		Example	Non-	
Amanda	2	1	16	0	4	0	10	2	0	25
Ashley	8	2	9	1	2	1	10	5	0	42
Charlotte	3	0	14	1	0	1	9	1	0	47
Emiri	0	0	10	0	3	0	10	0	0	33
Imani	2	1	12	2	2	1	6	2	1	30
Jessica	7	1	11	2	3	0	10	2	1	48
Kim	1	1	20	1	2	0	8	0	0	39
Olivia	4	0	24	1	4	1	13	3	1	41
Rosa	3	0	13	0	0	0	6	2	0	32
Shanice	3	0	11	1	3	0	15	1	0	38
Sophia	3	1	7	0	0	0	12	4	1	27
Stephanie	4	0	21	1	3	0	14	1	0	45
Total	**40**	**7**	**168**	**10**	**26**	**4**	**123**	**23**	**4**	**447**

Frequencies revealed a piece of the story which were supported by my preservice elementary students' statements (Table 7). For example, Olivia discussed cultural competency often in her reflections of Milner (2010), but she did not fully apply the concept to her lesson plans. Olivia agreed with Milner (2010) that "not seeing color" impacts the learning environment in a negative way. But during her first post-teaching reflection, she assumed her students, regardless of background, would have the same experiences as her. She placed her own experiences onto her students rather than taking the time to learn of her students' experiences.

While addressing social inequities, my students acknowledged this importance but only one lesson plan contained an opportunity for elementary science students to address a global issue related to social inequities. Emiri and Olivia worked together on their first CR elementary science lesson plan. They had the students discuss their thoughts on water before showing a video on the water crisis. But the video was dated, published in 2015, and was not specific. It did not specify what the crisis exactly was, what was causing the water crisis and the people affected by the water crisis. Emiri reflected that "In my lesson plan and in-class demonstration, my aim was to teach students that by using science we can solve the problem of purifying dirty water" (Post-teaching Reflection 1). Emiri and Olivia and a great idea, but the quality of science content was low. They also did not give their students the opportunity to address the problem using their own approaches. Instead, they showed a low-quality video and built a water purification model.

In contrast, Ashley and Sophia focused on their students' ability to problem solve for their second CR elementary science plan. They selected an engineering practice from NGSS which required the students to define a problem and create a testable solution. Ashley and Sophie opened the lesson with a simple relay challenge for small groups to complete while being mindful of time. Each small group competed with the other small groups to complete the task first. Sophia reflected that "it is important for students to know this so they can learn to work together as a class when completing anything really and to be able to solve problems they may run across and be able to and be able to solve the problem" (Post-teaching Reflection 2). Ashley shared this sentiment but neither took the lesson a step further by explicitly relating the activity to solving problems in the real-world. Like their peers, they were able to create a warm, engaging lesson but social inequities were not explicitly linked to the science content.

Regarding effective CR pedagogy, preservice elementary teachers utilized a variety of strategies to have their peers involved in the lesson. They worked in groups, completed hands-on activities, incorporated technology, and addressed science misconceptions by linking the content to real-world situations. Preservice elementary teachers also demonstrated the incorporation of student interests into the lessons. Three lessons used the preservice elementary teachers' knowledge of their students' racial/ethnicity. In her first lesson plan, Imani included an article on fossils in Africa, reflecting the identification of students in her elementary classroom as Black or African American. Olivia and Kim acknowledged their students with Japanese roots by incorporating a myth from Japan used to explain Earthquakes. Kim demonstrated her comfort with incorporating what she knew of her students' racial/ethnicity background within another lesson as well. In her first lesson she worked with Shanice and Stephanie. They incorporated all four specific locations that they either knew their students had lived or which reflected their students' racial/ethnic background. In four bins, they used birdseed and beads to represent mining activities. The beads represented the various natural resources, and each bin represented a different environment by containing the natural resource specific to that environment. Teams worked together to "mine" their bin and collect their resources. Then, they identified their "environment" based on the percentage of resources.

Discussion

Color-blindness

The most evident impact on my students' reflections were regarding Milner's (2010) argument against teachers' assertions of "color-blindness" as effective. For example, Rosa stated that teachers "cannot ignore students' background and cultures. It's like ignore(ing) who (the) student is" (Milner Reflection). My students also acknowledged the need to research their students' race/ethnic background and incorporate what they learned into the lessons. Olivia wrote that teachers need to, "Research specific student culture and socioeconomic status" (Milner Reflection). But only three out of the twenty total lessons reflected this practice. Those three lessons, described in the results section, explicitly linked my students' knowledge of their elementary students' racial/ethnicity background in their field schools demonstrated their commitment to disregard the notion of "color-blindness" and instead they recognized their elementary students' culture and intentionally built the lesson around their students' background.

Cultural conflicts

Incorporating and acknowledging students' racial/ethnic background is a necessary step for addressing cultural conflicts in the classroom. Milner (2010) cautioned teachers from teaching how they were taught and expecting all students, regardless of backgrounds, to conform to the classroom's social norms. Instead, teachers should learn their students' experiences and learning preferences to shape a classroom unique to the students. Since the teachers have the power in the classroom, they need to address this issue of power and provide opportunities for students to develop autonomy. This concept of power within the classroom was confusing for many of my students. Only half addressed power in their Milner Reflections, agreeing that the person in power, such as a teacher in a classroom, used this power to create expectations and procedures that reflect the teacher's background only. Jessica stated, "If a culture of power must exist, which it does in the real world, make sure that students know the rules and consequences of those that hold power" (Milner Reflection). Not only must students be aware of power differences, Rosa stated that teachers need to, "empower students to employ change" (Milner Reflection). Some confusion regarding the cause of power imbalance was expressed by one student, Olivia. She stated that although power differences occur, she does not "think race is where the issue lies" (Milner Reflection). Since only half of my students acknowledged power imbalance and less than that acknowledged race/ethnicity contributes to the imbalance, Milner's section on cultural conflicts had a weak relation to my preservice elementary teachers' ability to enact this piece of effective CR science teachers.

Myth of meritocracy

According to Milner (2010), "the meritocracy argument sometimes rejects institutionalized and systematic issues that permeate policies and practices such as racism, sexism, classism, and discrimination both in the classroom and society" (p 124). Of the twelve participants, only half discussed the concept of meritocracy as described by Milner (2010). But within these six participants, some confusion was evident. Imani only addressed the myth of meritocracy in regard to socioeconomic status. She omitted race and ethnicity from her notes completely (Milner Reflection). Ashley explicitly stated that she was confused about this topic and did not know what it had to do with teachers. One participant, Rosa, stated the exact opposite of Milner (2010) by writing that the, "system is not to blame for failure" and instead that "not succeeding is due to lack of effort" by the student (Milner Reflection). Due to the limited demonstrations of comprehension, needed to be address the myth of meritocracy further.

Deficit conceptions

According to Milner (2010), “deficit conceptions can shape teachers’ explicit and implicit curriculum, the null curriculum-what teachers refuse to cover and include in the curriculum-can also detrimentally shape student learning opportunities” (p 124). Unlike the reflections regarding the myth of meritocracy, more participants reflected Milner’s (2010) description and were also extended into their lesson planning. Seven participants acknowledged that their students’ racial/ethnic backgrounds and culture need to be addressed in the curriculum. Imani was the most explicit. She listed the “asset lens” as a characteristic of effective CR science teachers (Milner reflection). Stephanie, Kim, and Shanice did just that in their lesson on mining which included regions specific to their 4-6 grade field students’ backgrounds. Kim continued this strategy in her lesson on natural disasters by including a Japanese myth. In contrast, Rosa’s reflection demonstrated a deficit lens perspective stating, “low income students have bad home lives and need to be protected” (Milner Reflection). So, while some participants excelled in their discussions on Milner’s (2010) concept, others also changed their curriculum to reflect their understanding. My remaining four participants did not address the topic in either their reflections or their lessons.

(Low) Expectations

Olivia related Milner’s (2010) discussion on the rejection of the deficit lens with teacher expectations by stating teachers who give “particular students low expectations (is) not helping them”. And Milner (2010) agreed that “deficit lens” and “expectations” are linked. Milner argued, “some teachers believe that they are actually doing students a favor when they do not develop rigorous and challenging learning opportunities for them” (p 125). Most of my participants, eight, demonstrated agreement of Milner’s (2010) concept. But the high expectations were not reflected in the CR science elementary lesson plans. Every lesson demonstrated a lack of comfort with the science content. Thus, the science lessons contained surface-level expectations. Ashley, as discussed in the results, admittedly lowered her science content on Earth and its systems because she did not feel comfortable with the content. She was not the only one. Imani expressed that she "intended students to learn about the basic knowledge and facts about fossils" (Post-teaching Reflection 1). This did not reflect high expectations for her students regarding the science content. In Jessica's post-teaching reflection, she expressed her concern that it would be difficult to for sixth graders to understand how the eye works because the concept is too "complex" (Post-teaching Reflection 2). In all three of these examples, my participants placed their own discomfort with the science concepts onto their students and lowered the expectations of student science content acquisition as a result.

To address question two, I incorporated elements from preservice science teacher development studies within the science methods course. In the meta-analysis of current CR preservice elementary science teacher development studies, several strategies emerged (Pinneo, 2020). These four strategies were, modeling of CR science teacher characteristics and practices (Bottoms et al., 2017; Burgess et al., 2018. Mensah, F.M., 2011), classroom discussions (Mensah, F.M., 2011), authentic assessments opportunities (Bottoms et al., 2017; Mensah, F.M., 2011), and student reflections (Bottoms et al., 2017; Burgess et al., 2018). Two other current CR preservice elementary science teacher developments studies, Brown and Crippen (2016) and Hernandez et al., (2013) were also included in the meta-analysis but the strategies utilized in their studies required a close connection between the science methods course and the field experience which did not exist with my elementary science methods. An overview of these studies is on Table 8.

Table 8: Overview of CR Preservice Science Teacher Development Studies

Author, Year	Participants and Grade level	Strategies	Outcomes
Bottoms et al. 2017	53 PSETs, UG, over two semesters	PSETs worked with diverse families in FMSNs while enrolled in science methods course Intentional course assignments, materials and structures. Intentional instructional design (methods) information.	FMSN: 1. Creates more opportunities for interaction and reflection 2. Integrates emotions to re-conceptualize practice 3. Builds partnerships in community 4. Teaches content through culture and community resources
Burgess et al. 2018	15 non-traditionally licensed elementary para-educators, 11 bilingual and 10 Lainx	Used outdoor spaces in conjunction with classroom experiences Co-learning: instructors learned how candidates learned and used that knowledge to shape instruction (this is the CRT component)	Two perspectives for implications: those of PSTs and those of TEs PSTs: 1. Use learner-centered strategies and previous experiences 2. utilize specific cultural ties within the science content 3. support the cultural and community wealth of students 4. emphasize asset over deficit views TEs: 1. listen to PSTs 2. meet their needs 3. view them as collaborators with assets 4. value family/community connections 4. reported higher CRT awareness
Mensah, F. M. 2011	3 graduate-level PSETs in 4/5th grade science within a science methods course for an ILP	Microteaching Discussions in science methods course Groups of 3 PSET Intentional FP in urban setting	PSETs need: 1. opportunities to collaborate 2. diverse urban settings 3. time to incorporate and reflect on CRT strategies 4. microteaching opportunities 5. time to research the particular students and community
Brown and Crippen 2016	14secondary math PSTs and 5 science PSTs Third year UGs majoring in math/science with a minor in secondary education	PSTs math/science methods course and FE of their program-intentionally complementary Two GAIn observations by the PSTs and then designed and taught three lessons using the 5E Lesson Template (Bybee et al. 2006)	GAIn alone cannot cultivate CR practices in PSTs More explicit lesson planning based on GAIn observations needed
Hernandez et al. 2013	12, non-traditional Latinx students in an UG ILP for secondary science	TE's approach 1. Review of literature 2. Synthesis of literature for major themes 3. Application of major themes to PST course	Use the developed model to guide course/curriculum development for TE. However, to fully comprehend PSTs ability to implement CRT, a variety of data collection is needed as well as an intentionally designed FE, such as the Professional Development School model in conjunction with post-lesson debriefings.

Modeling

As the instructor, I, much like Burgess et., (2018), sought to reduce my role as a content expert and instead wanted to "create a place of co-inquiry where we learn together" (np). By using a modified 5E lesson plan (Bybee, R.W., 2014), I intentionally created inquiry-based activities for the students to make predictions, make observations, collect data and use their own experiences to explain the phenomenon. I also utilized guided questions to probe student understanding and drive student explanations rather than explaining the content from my perspective only. The participants clearly relied on my modeling of effective CR elementary science teacher lessons. Their lesson plans reflected a clear understanding and use of the 5E method. In addition, my students' use of guiding questions increased over the semester. The first lesson plans lacked specific guiding questions for each of the 5E sections but by the third lesson plan, all the lessons contained a minimum of five questions per section. Through modeling, I pushed my students to "ask, rather than tell" in order to shift the focus off the "teacher as expert" for answers onto the explanations of their students.

Group discussions

Mensah, F.M. (2011) stressed that "pre-service teachers need ample time to plan, research, discuss, and teach culturally relevant curriculum throughout their teacher education preparation" (307). For this study, I intended for in-class planning time and encouraged students to conduct independent research on their elementary students in their field experiences. Time, for better or worse, was more often spent with the facilitation of CR science elementary lesson by me or the students and our discussions around the Milner (2010) article. Although my preservice teachers expressed enjoyment in the Milner discussions, standing alone, they did not greatly impact the CR science lessons as a whole. As my first research question demonstrated, each of

Milner's repertoires were expressed differently although we spent an equal amount of discussion time on each. None of my classes or assignments required participants to research their field students' race/ethnic backgrounds and directly discuss ways to implement what they discovered into their lesson plans. Although several of my students did just this, perhaps more would have had our classroom discussions focused less on Milner (2010) and more on characteristics and strategies for specific racial/ethnic learners.

Authentic assessments

All five of the preservice CR science teacher development studies incorporated opportunities for participants to teach as much as possible. Bottoms et al., (2017) designed their methods course around the Family Math and Science Nights (FMSN) by requiring their students to design and teach one science lesson at the event. Burgess et al.'s, (2018) study required their preservice teachers to "prepare, teach and assess a one-week field immersion centered on schoolyard ecology" for the elementary students they were working with (np). Similarly, Mensah's F.M. (2011) study also incorporated lesson and instruction by the elementary preservice teachers but within the classroom instead. Brown and Crippen (2016) required preservice secondary teachers to conduct guided classroom observations and then teach their CR science lesson. Observations of preservice secondary science teachers were collected by Hernandez et al. (2013), further highlighting the need for teaching.

My study, unlike the five described above, did not incorporate the close connection between my preservice elementary teachers' science methods course and field experience. Instead, I built in a minimum of three class sessions in which my preservice teachers facilitated the CR science lessons they developed in their groups. This provided the opportunity for me to authentically assess the preservice teachers. The preservice teachers treated the science methods classroom as though it were filled with elementary student learners, thus practicing, and receiving feedback on practice rather than theory. Over the duration of the semester, students used the verbal and written assessments from the me to improve their CR science lessons. This is evident in the increase of CR strategies in their lesson plans and facilitations as demonstrated in the results section.

Student reflections

Both studies by Bottoms et al. (2017) and Burgess et al. (2018) stress the importance of preservice teachers' reflections. Incorporating several MSFN's events, Bottoms et al. (2017) recognized the need for their preservice elementary teachers to reflect on their experiences at one event to enact changes in their lesson for additional events. Burgess et al. (2017) built in opportunities for students to reflect on their field experiences at the end of the day in their daily meetings. Since my study did not incorporate field experiences, I utilized post-teaching reflections adapted from Hawkins and Rogers (2016). These reflections were also sources of data for my study. The richest form of reflections through the semester were during our classroom discussions and activities. As evident in their lesson plans and Milner reflections, my students referenced their experiences with the Socratic method and additional connections to culture and the science content. As demonstrated by Sophia in her second post-teaching reflection, "I believe the discussions in class about Millner and color blindness helped with our lesson".

Conclusion and Implications

My study revealed three main findings important to the development of these specific elementary science teachers. First, our classroom discussions alone did not have an impact on all the six total themes of effective CR teacher characteristics and practices. Our classroom discussions in my study were centered around Milner's (2010) five repertoires, for each of which, he explained the concept, teachers' assertions, and the consequences. But Milner (2010) did not offer explicit and practical advice to address each concept. Instead, the I would use guided questioning during the classroom discussions to draw out possible classroom strategies to combat the concept being described by Milner (2010). Evident in my preservice teachers lessons and reflection on Milner (2010), they often skipped the step of taking notes based on how to address each concept and instead summarized Milner's (2010) main points. The use of Milner's (2010) article to drive classroom limited the impact of our discussions. Instead, my preservice teachers needed a diversity of articles spanning the entity of the six themes of effective CR science teacher characteristics with explicit attention to effective CR practices.

Second, my preservice elementary teachers needed more support with the science content. Because they were not comfortable with the science content itself, the rigor of the lessons they developed was low. Even when the standard was for a higher elementary level, the lesson would focus on lower levels of thinking. On her lesson plan regarding the solar system, Ashley self-reported her lowered standards due to her lack of comfort with the content. I did not prioritize the assessment of preservice elementary students' science content acquisition. Instead, I assumed that my preservice elementary students received science content knowledge in the science courses required by the college prior to their admission to the program. Our university only required eight science hours to complete the core requirements. Therefore, my methods course, although not a science content course, utilized time for the inclusion of science content rather than a strict focus on science methods in order to increase my preservice elementary teachers' science content knowledge.

For example, my students did not understand the concepts being expressed in the movie, *A Private Universe* (Harvard-Smithsonian Center for Astrophysics, 1987) Typically, I have used this film to introduce the challenges teachers face with common science misconceptions. The movie follows one science teacher and several of her students. First, their misconceptions are revealed in one-on-one student interviews. Then they participate in a science lesson on the same concept. Following the lesson, they are again assessed through one-on-one interviews. Astonishingly, the post-assessments reveal that most of the students in the video hold on to their misconceptions. The misconceptions addressed within the movie are about the phases of the moon and the popular belief that seasons are caused by the proximity of the sun to Earth. Since most of the preservice teachers shared these misconceptions, the pedagogical importance of the video was lost, and we had to instead stop to learn about the moon phases and cause of seasons. By increasing preservice elementary teachers' comfort with science, I would be able to increase the amount of time to focus on pedagogical practices and rigor within my methods course. My students would have also had the science content background to increase the rigor of their elementary science lessons.

Finally, I needed to directly apply examples from each of the six main themes of effective science teacher characteristics and practices. The themes in which the I modeled consistently, (cultural competency, CR learning environment, rejection of the deficit lens and pedagogical strategies of effective CR science teachers) were reflected within my preservice teachers' lessons. The most evident impact was in the use of guiding questions by my students. Their first set of lesson plans contained a very limited amount of guiding questions and instead focused on what the teacher was going to say and do. As I continued to model student-focused lessons, in which the students' explanations rather than my own to explain the phenomenon, the amount of guiding questions within my preservice teachers lessons and facilitation increased greatly. What the I omitted from my lessons was also omitted by my preservice teachers. None of my lessons included a connection of a local, current event or problem within the science content. Not surprisingly, none of my preservice teachers' lessons did either. I needed to explicitly model every theme within the effective CR science teacher characteristics and practices. For example, only one of my preservice science teacher lesson plans, the one on mining, incorporated information on their elementary students in their field experience. Unlike these students, I did not use specific information about my preservice science teachers in the CR science lessons that I modeled. This revealed that classroom discussions were not enough to push my students to seek out pedagogical practices which differed from those that I modeled.

Explicitly, evidence of CR characteristics under the theme "social inequities" lacked from all of our lesson plans. Rather than simply discussing the concept through Milner's (2010) article, I needed to connect a specific social justice issue important to my preservice teachers to the science content. My preservice teachers also needed time to discuss social inequities in relation to science content. For example, Wallace and Brand (2012) explain that "the socially constructed myth of Black inferiority dates back to over 200 years ago as a justification for slave labor" (p 343). Their example of scientific racism, the non-scientific belief that evidence exists to support racism, is a natural connection between social inequities and the science content. Scientific racism, and other social justice issues, needed to be included in my methods course curriculum to increase my preservice elementary teachers' understanding of the connection between specific social inequities with particular science content.

My preservice elementary teachers should have also been required to conduct research regarding the elementary students' race/ethnicity in their field experiences. My methods course should have included information on the racial/ethnic backgrounds of their elementary students in their field experience, including cultural norms and learning styles, to discover practical ways to change their lesson plans and facilitations. This would have also increased their cultural competency by learning about race/ethnicities specific to their elementary students in their fields such as, cultural practices, languages, and values.

The area of strength within my study were effective CR pedagogical practices. I modeled a variety of teaching strategies, required the use of NGSS and the 5E structure and provided continuous, individual feedback and positive reinforcement. Thus, my preservice elementary teachers' lessons and facilitations contained similar CR pedagogical practices and contributed positively to the CR learning environment. Because my students felt accepted by our classroom community, my students felt free to made mistakes and used their mistakes as an opportunity to learn. They frequently asked questions and presented their own ideas, and I valued those questions and ideas by incorporating them into the lesson that I modeled. The warm learning environment was built from procedures co-constructed by myself and my preservice teachers. In turn, my students reflected the effective CR science teacher characteristics under the themes of "CR learning environment" and "effective pedagogical practices" in their lessons and lesson facilitations.

Limitations

One limitation to this study was the lack of my elementary science methods course connection with their field experience. This made the possibility of direct application of theory to practice solely within or science method course projects. My preservice elementary teachers may have experienced a disconnect between the science methods course and their field experiences. Knowing this limitation, I provided preservice teachers the opportunities to plan and facilitate effective CR science lessons within the methods course instead. But ideally, the science methods course would have been more closely connected with the field experience and both would intentionally include projects and discussions addressing CR teaching in theory and practice.

Future research

My study exemplified the need for further insights into elementary science methods courses, especially when close connections to the field experiences are not included in the initial licensure program's design and the preservice elementary teachers need more support with the science content. Preferably, the field experience would be closely aligned with the science methods course and possibly the science content courses as well. Since this is not always possible, by gaining additional insight into elementary science methods courses without a close field experience connection and limited science content knowledge, other teacher educators in a similar situation would be assisted in the development of the course curriculum and strategies that have demonstrated an impact on CR science teacher development.

Evidenced in my study, science educators need to provide diverse literature which cover all aspects of the six effective CR science teacher characteristics and practices. Specific attention needs to be paid to the area of academics and social inequities. By assuming my preservice elementary teachers' comfort with science content knowledge, the rigor of my-modeled lessons was reduced. My lack to of connecting a social justice issue to the science content also had a negative impact. In contrast, the areas in which I excelled (CR learning environment and effective pedagogical practices) had a positive impact on the preservice elementary teachers. They demonstrated this impact in their lessons, their post-teaching reflections, Milner (2010) reflections and their classroom participation. My study revealed that I needed to intentionally add content and practices under the other themes as well. Knowing this, my future elementary science methods courses will be altered to reflect these findings to increase the impact on preservice elementary teachers' abilities to enact effective CR science lessons in their future classrooms. By eventually increasing the number of CR science lessons in elementary classrooms, teachers will inspire a new, more diverse student population to love science.

Chapter 4

How to Create Culturally Responsive Science Lessons and an Example

Culturally responsive science teaching: lesson creation steps and a 6th grade lesson

The year 2020 in the United States (US) can be summarized through two main current events, the Black Lives Matter movement and the Covid-19 pandemic. As science teachers, we have a duty to our students to engage them in relevant learning which is connected to their lives outside of school and current events. This sentiment is supported by the literature on Culturally Responsive (CR) science teaching. To adequately meet the needs of our diverse students, teachers must develop a critical view of teaching situated within the sociocultural context (Wallace and Brand, 2012). Beyond developing our own view of science withing the context of our students' culture and communities, we must also use class time to acknowledge and address issues of social inequities (Byrd, 2016; Lanier and Glosson, 2014).

These teacher/student racial/ethnic demographics demonstrate a lack of common culture within US public classrooms. To combat the occurrence of cultural clashes, teachers must learn and respond to students' sociocultural realities while also helping students to do the same with their peers (Byrd, 2016). Teachers must also personalize the content by connecting science to relevant or real-world phenomenon students can relate to while including examples from the students' culture (Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012). This article will discuss the necessary steps to develop CR science teaching lessons. Teachers must also implement CR pedagogical practices effective CR science teachers utilize. A comprehensive list of CR pedagogical practices will help in future planning and a K-6 lesson plan which incorporates the Black Lives Matter and the Covid-19 pandemic will exemplify the outcome of this process.

To assist with this process, I developed a step-by-step process for teachers to use while planning and implementing science lessons. This procedure was developed from my experience planning lessons in combination with my reading of the literature on effective CR characteristics and practices, and effective CR teacher development studies. It is also the process I use when developing my own CR science lesson plans for K-12 students and preservice teachers.

Table 1: Steps to Creating a CR Science Lesson

Step	Action
1	Get to know your classroom racial/ethnic backgrounds, their communities and their lives outside of the classroom; Know every student as an individual including the skills they bring to class and their experiences and personal interests.
2	Select Next Generation Science Standard (NGSS) and conduct research on local, community current events and/or social inequities your students may be experiencing outside the classroom.
3	Connect the local, community current events and/or social inequities to specific NGSS content.
4	Identify parent/guardian or other community member as a resource connected to the current event and/or social inequity and invite her or him to the classroom.
5	Using the 5E lesson plan (Bybee, R.W., 2014), develop a student-centered lesson plan which incorporates a variety of pedagogical practices and strategies (see Table 3).
6	Celebrate students' products through physical displays, presentations, etc.

Step 1 Get to Know Your Students

Since the lesson included in this article addresses a larger audience than a local community, this research includes all US public schools. For lessons in specific classrooms, research should be conducted at the local level with specific students in mind. As of 2017, a disparity between teacher and student racial/ethic backgrounds was present in US public schools (NCES, 2020). As the Figures 1 and 2 below depict, the majority (79%) of public school teachers for the 2017-2018 school year identified as White (NCES, 2020). In contrast, a little more than half of students enrolled in public schools as of the fall of 2017 identified as

Hispanic (27%), Black (15%), Asian (5%) or two or more races (1%) (NCES, 2020). Students identified as White made up 48% of the population (NCES, 2020).

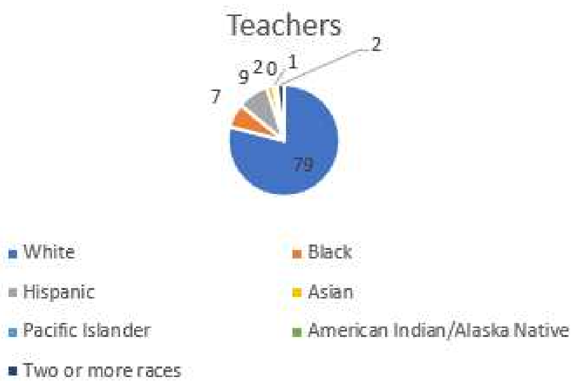

Figure 1: Percentage Distribution of Teachers in Public Elementary and Secondary Schools by Race/Ethnicity for the 2017-18 School Year

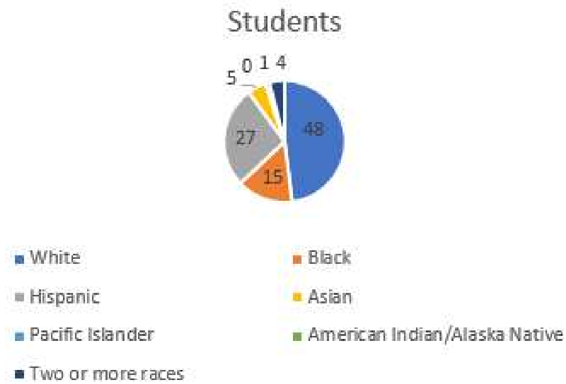

Figure 2: Percentage Distribution of Students Enrolled in Public Elementary and Secondary Schools by Race/Ethnicity for the Fall of 2017

Step 2 Select Standard and Conduct Research

Again, this section should be as specific as possible by connecting to students in specific classrooms. For this article, the focus is the entire US. According to Hooper et al. (2020), Covid-19 disproportionately impacts African Americans and Latinos due to "racism and discrimination, economic and educational disadvantages, health care access and quality, individual behavior, and biology". Environmental injustice such as air pollution, which impacts low income communities more than high income communities, also contribute to deaths from Covid-19 (Turrentine, 2020). Talk to your students about their experience with Covid-19 and learn about the potential health hazards your students may face within their community.

Step 3 Make Explicit Connections to the Science Content

The Next Generation Science Standards (NGSS) were published in 2013. Since then, twenty states adopted NGSS while twenty-four developed their own state standards based on NGSS guidelines making NGSS the most prevalent list of science standards in the US (National Science Teaching Association NSTA, 2014). With a "focus on issues of student diversity and equity in relation to the NGSS specifically as the NGSS present both learning opportunities and challenges to all students, particularly non-dominant student groups" NGSS strive to reach all students, regardless of race/ethnicity (NGSS, 2013, Appendix p. 26). Since NGSS is present in some form or another in the majority of US states and seek to teach science to a diverse population of students, Table 2 lists the K-6 NGSS stands which connect to the CR science lesson plan incorporating Covid-19.

Table 2: NGSS K-6 Connections

Standard	
6-LS1-2	Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.
6-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Step 4 Invite Community Members into Your Classroom

Within a local community, reach out to nurses, doctors and other healthcare employees to speak to your class. Since the focus here is nationwide, several YouTube videos for a classroom with a less-localized focus are on Table 3 below.

Table 3: Video Titles, Weblinks and CR Pedagogical Practice

Video Title	Weblink	CR Pedagogical Practice
Flu Attack! How A Virus Invades Your Body	https://www.youtube.com/watch?v=Rpj0emEGShQ	Connecting students' cold infections to cells and viruses
The Coronavirus Explained and What You Should Do	https://www.youtube.com/watch?v=BtN-goy9VOY	Bridging experiences outside the classroom with science content
How COVID-19 is highlighting racial disparities in Americans' health	https://www.youtube.com/watch?v=LIIEx_SvTj0	Linking the science content to social injustice

Step 5 Use the 5E Lesson Model for Planning

The pedagogical strategies exemplified on Table 4 were compiled during a meta-analysis of the current CR science teacher studies (Pinneo, 2020). They offer a variety of practical strategies which elementary science teachers can select from and/or adapt to fit their classroom.

Table 4: Pedagogical Strategies of Effective CR Science Teachers

Pedagogical strategies (Author, date)
Offer multiple standpoints on the same science concept (Xu et al., 2012)
Make direct connections between students' life outside of the classroom, personal interests and the science content while planning and facilitating (Byrd, 2016; Lanier and Glosson, 2014)
Incorporate peer discussions, inquiry-based, exploration activities, hands-on experiments, making authentic connections, providing new exposures, song, technology, physical/virtual field trips, science content readings, group projects, referencing previous experiences, evidence-gathering activities, story-telling, comics, trial-and-error opportunities, drawings, writings, and whole-class discussions (Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012)
Personalize the content by connecting science to relevant or real-world phenomenon students can relate to and include examples from the students' culture (Lanier and Glosson, 2014; Wallace and Brand, 2012; Xu et al., 2012)
Develop reciprocal learning experiences through inquiry activities and by giving up some authority (Lanier and Glasson, 2014; Xu et al., 2012)
Incorporate the "funds of knowledge" from the community and students into instruction while harnessing a constructivist view of by building from what students already know (Byrd, 2016; Lanier and Glosson, 2014)
Utilize a variety of authentic assessment opportunities and tools; provide specific feedback and positive reinforcement (Lanier and Glosson, 2014; Wallace and Brand, 2012)
Science learning should be fun and incorporate laughter (Lanier and Glosson, 2014)
Encourage students to make sense of the science content by making their own connections from prior experiences (Lanier and Glosson, 2014)
Incorporate opportunities for students to be involved in decision making, specifically in science content, forms of expression and grouping (Byrd, 2012; Lanier and Glosson, 2014; Xu et al., 2012)
Include opportunities to teach about different cultures regardless of the demographic makeup of the classroom (Byrd, 2012)
Inviting community members/parents/guardians into the classroom and encourage students to share science content with their families (Lanier and Glosson, 2014; Xu et al., 2012)
Address students' science misconceptions by redirecting rather than correcting (Lanier and Glosson, 2014)
Exhibit and possess personal interest in science (Xu et al., 2012)
Encourage students to make sense of science ideas/ vocabulary with their own words and use student-friendly wording when introducing science vocabular (Lanier and Glosson, 2014; Xu et al., 2012)
Encourage students to share what they learn with their families (Lanier and Glosson, 2014; Xu et al., 2012)

For the lesson plan in this article, strategies exemplified by Byrd (2016), Lanier and Glosson (2014), Wallace and Brand (2012) and Xu et al. (2012) were incorporated. The lesson will require fifty minutes of instruction for four to five consecutive days. Students will begin the lesson with a Know, Wonder, Learn (KWL) chart that is to be displayed throughout the entire process. Students will be encouraged to modify the KWL chart as they progress. In pairs, students will first hang a notecard that has been covered with Vaseline. They will observe the card at the beginning of each of the fifty minutes, recording all observations. They will watch a series of brief videos, read an article and participate in class discussions. By the third day, students will begin conducting research in their groups for their class presentations, presented on the final day.

5E Lesson Plan

Teacher/s Pinneo	
Grade 6th	Title How does the corona virus impact my community and why?
Topic Viruses and Environmental Impacts	
NGSS as Learning Objectives in ABCD* Format: Students will use the science content from class to select a personal topic related to the content, conduct research and then present their findings and possible solutions to their peers.	
CRT Strategies: Connect the current events of Covid-19 and Black Lives Matter movement to the 6th grade science standard;	
Real World Connection/Natural Phenomenon: How viruses spread and cause illnesses; How environmental factors increase the effects of illnesses in humans.	
Materials: Post-it notes, index cards, Vaseline, string, hole puncher, one-to-one technology access and necessary technology to show the referenced YouTube videos to the whole class.	
Safety Concerns (if any): None	
Anticipated Student Misconceptions: There is only one coronavirus. There is not one specific coronavirus linked to Covid-19. Covid-19 is the virus rather than the illness. Race/ethnicity do not impact how people react to a viral infection. There are differences between humans based on race/ethnicity. Environmental conditions are universal and do not impact the local community members.	
1.Engagement The teacher will display a large table with three columns titled “Know”, “Wonder”, “Learned” (KWL) where it is visible to all students. Distribute Post-It note pads around the classroom so every student has access to the as many notes as they would like. Instruct students to respond to your following questions on their post-its: a) What is a virus? b) How does a virus spread?	

c) How do viruses impact humans?
d) What are some names of specific viruses or illnesses caused by viruses?
e) Are all humans impacted the exact same way by specific viruses?

Students will be encouraged to place their post-its within the "Know" column on the table. As the students place the post-its, the teacher should read the student comments aloud without confirming or denying any of the content. Once all student has had the opportunity to place all of their post-its, the teacher will instruct the students to take notes during a brief video *Flu Attack! How A Virus Invades Your Body:* https://www.youtube.com/watch?v=Rpj0emEGShQ Once the video is over, ask the students if they would like to move any of the post-its in the "know" column into the "learned" column? Give them an opportunity to remove any of the post-its from the "know" column as well. Then show the next video *The Coronavirus Explained and What You Should Do*: https://www.youtube.com/watch?v=BtN-goy9VOY Again, at the conclusion of the video permit students to either remove or move the post-its and add any questions they now have in the "wonder" column. The large table containing the student post-its will remain on visible and accessible throughout the duration of the lesson.

1. Exploration

The students will explore their classroom environment by creating "particle catches" from index cards and Vaseline. In pairs, students will punch a hole into the index card, tie a string through the hole, spread both sides of the index card with Vaseline and then place their card in a location within or around the classroom that will not be disturbed. Be sure to instruct the students to label their index cards with their names. Students will keep a daily journal of their observations throughout the week. Simultaneously, students will begin conducting research and create a solution to their local environmental issues.

Teachers will ask students:

a) Why do you think we are placing Vaseline on our notecard?
b) What do you expect to see on your notecard over the next few days?
c) Is there an area that is especially dusty in our classroom?
d) Where do you think this dust comes from?
e) What is in "dust" and does it impact us?

Again, permit students to modify the KWL chart with removal or addition of post-its.

2. Explanation

Daily, the students will record their observations of the Vaseline-covered notecards. After they have made their first observation, read the article: There's No Scientific Basis for Race—It's a Made-Up Label by Elizabeth Kolbert (found here: https://www.nationalgeographic.com/magazine/2018/04/race-genetics-science-africa/). The teacher may choose to read the article aloud while students follow along, permit student volunteers to read sections of the article, assign the article as silent reading or a combination of strategies. Once the article has been read, show the video *How COVID-19 is highlighting racial disparities in Americans' health*: https://www.youtube.com/watch?v=LIIEx_SvTj0

Teacher will ask the students:

a) Are there biological differences between differences between humans based on race/ethnicity?
b) Are different races/ethnicities impacted differently by our environment?
c) How does Covid-19 impact people from different races/ethnicities and why?
d) Do you think our local environment impacts your health?
e) What are some solutions possible solutions to Covid-19 that directly relate to our community?

3. Elaboration
   Students will be given about 50 minutes of class time for 2-3 consecutive days to work in pairs or small groups to conduct research and or collect data on their selected topic (see examples below). Based on the Vaseline observations, the videos, the reading and classroom discussions, have students select an area of interest for research. Possible topics for research and presentations are listed below.
   a) The content of common dust and its impacts on humans
   b) Local air quality using https://www.airnow.gov/ and possible impacts on humans
   c) Air pollution, how humans contribute and are impacted
   d) How a virus spreads and prevention
   e) What is a virus? Is it alive or dead?
   f) What are vaccines?

   Group students based on student interests and their ability to learn together.

4. Evaluation
   Once all students are done with their research and presentations, students will take turns presenting their research to their peers.

Assessment of Student Learning:

5-6 points	3-4 points	1-2 points
All group members contributed equally and participated equally.	All group members contributed and participated.	Only 1 student contributes and participates
All group members speak clearly and are easy to understand.	Only 1 student speaks clearly and are easy to understand.	Neither student speaks clearly making understanding difficult.
The presentation covers the entire research question with accurate and updated information.	The presentation covers most of the research question with accurate and updated information.	The presentation does not answer the entire question and/or does not contain accurate and updated information.
Presentation is visually organized and complete.	Presentation is complete.	Presentation is disorganized or incomplete.
A minimum of 3 quality resources are included.	Only 2 quality resources are included.	Less than 2 or poor-quality resources are included.

Resources:
https://www.youtube.com/watch?v=Rpj0emEGShQ
https://www.youtube.com/watch?v=BtN-goy9VOY
https://www.nationalgeographic.com/magazine/2018/04/race-genetics-science-africa/
https://www.youtube.com/watch?v=LIIEx_SvTj0
https://www.airnow.gov/

*ABCD Format: Performance expectation includes the audience (the student), the behavior (what the student is doing), the condition (how they will perform to the task) and to what degree (fully, 4/5, etc.).

Step 6 Celebrate Students' Products

If students create a visual aide that can be displayed in the classroom, do so. For electronic presentations, grant access to the students' parents/guardians so they can view the students work. Ideally, invite community members to sit in on the day of presentations, giving your elementary students an authentic audience. Student work should be used to celebrate the achievements and contributions of the elementary students. By valuing their work, the students will learn to value it as well.

As science teachers, we have a duty to appeal to all our elementary students, with their ethnic/racial backgrounds in mind. By acknowledging differences, valuing students' perspectives and connecting these to the content, science becomes personal and more exciting for the students. Following the steps for CR science lesson planning is one practical application for all elementary teachers. I challenge you to take this step, enhancing your current science lessons with CR science characteristics and practices, to see for yourself the impact it will have on your elementary students.

Chapter 5

Conclusion

This dissertation is the exploration of effective CR science teaching characteristics and pedagogical practices, specifically in a preservice elementary science course. The meta-analysis revealed a gap in the literature and lack of cohesion regarding the language of CR theory. This study sought to address the lack of cohesion and offer one possible lens for future research. Six themes which encompass the characteristics and pedagogical practices of effective CR science teachers emerged, academics, cultural competency, social inequities, CR learning environment, rejection of the deficit lens and pedagogical strategies.

These six themes were used to conceptualize an elementary science methods course and then investigated how preservice teachers exhibited those themes in the course products. The greatest impact on the preservice science teachers' lessons and reflections were in those modeled by the instructor in addition to the classroom discussions. The preservice elementary teachers' lack of comfort with the science content was also demonstrated. Time to address the science content subtracted from the time spent on CR science lessons and pedagogical practices. It may also be important to have the methods course explicitly connected to the field experience.

Both studies contributed to the third article (chapter 4). The practitioner piece, while not providing traditional findings as the two qualitative studies, provides a practical tool for in-service teachers. Using it, current elementary science teachers can create and implement their own CR science lessons.

Implications for Practice

Elementary students need to develop the skills of using science to address local issues. For example, the Covid-19 pandemic and systemic racism in the US both have clear connections to science content. According to Hooper et al. (2020), Covid-19 disproportionately impacts

African Americans and Latinos due to “racism and discrimination, economic and educational disadvantages, health care access and quality, individual behavior, and biology”. This is due to, in part, environmental injustice such as air pollution, which impacts low income communities at higher rates, also contribute to deaths from Covid-19 (Turrentine, 2020). Science teachers need to know how to connect their science content to current events and others that are important to their students. This research adds to the literature on how to implement CR science lessons in classrooms.

At the post-secondary level, science educators need guidance selecting pedagogical strategies for the development of effective CR science teachers, especially at the elementary level since elementary teachers in order to reach young students. The findings in the meta-analysis provide an organized table with six themes and direct examples. These themes are supported by the current literature and provide a snapshot of effective CR teacher characteristics and pedagogical practices, ready to be applied to any science methods course for preservice teachers.

The application of those themes to a preservice science elementary methods course for the third study reveals the impact that application has on preservice teachers. The structure of the science methods course, limited by its lack of connection with the field experience, demonstrated the need for explicit modeling of each theme by the course instructor. Areas in which the course instructor successfully modeled emerged in the preservice elementary teachers’ science lessons and post-teaching reflections. This study adds to the literature of the development of effective CR science teachers, providing insight to science teacher educators.

Limitations of the Study

The qualitative study on the impacts of the application of effective CR science teacher themes is limited in that it only reports the findings revealed from twelve participant preservice teachers. The participants, all in a traditional undergraduate program, live and complete their field experiences in an urban setting in the southern US. Theses preservice teachers do not reflect the experiences or perspectives of all preservice elementary teachers. Instead, they offer insight into their personal impact.

The elementary science methods course is also disconnected from the preservice teachers' field experiences. All four of the preservice teacher studies, Burgess et al. (2018), Brown and Crippen (2016a), Hernandez et al. (2013) and Mensah, F.M. (2011) designed their studies around intentional field experiences. The information about their intended curriculum as revealed through lesson planning and not any information about the enacted curriculum. Another limitation is that the students' understandings were revealed only through lesson plans and reflections. It is unlikely that a complete picture of their thoughts regarding these themes was captured. As stated by Remillard, J.T. (2005), "the teacher-curriculum relationship is intertwined with other teaching practices, is dependent on the particular teacher and curriculum, and is situated in a specific context" (p 212).

Recommendations for Future Research

For future research, science teacher educators need to continue to study effective CR elementary science teachers in their classrooms to build on what is known about their characteristics and pedagogical practices. Elementary teachers especially need to be an area of focus since limited studies are within lower grades. Elementary science teacher educators should assess their impact on the development of effective CR teachers. One possible method would be the application of the six themes. But science educators need to explicitly address each of the six themes. Assessment of the preservice teachers' science content needs to be conducted and, if necessary, addressed as well. Ideally, a path for CR science teacher development will be more clearly defined regardless of the field experience.

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Appendices

Appendix A

5E Lesson Plan Template

Teacher/s

Grade | Title

Topic

Standards (from AR State) and Learning Objectives in ABCD* Format:

CRT Strategies:

Real World Connection/Natural Phenomenon:

Materials:

Safety Concerns (if any):

Anticipated Student Misconceptions:

Student Performance: Step-by-step

Include all guiding questions.

1. Engagement (How will you "hook" the students?)
2. Exploration (What will the students be doing?)
3. Explanation (List the questions the teacher will ask the students to encourage student explanations).
4. Elaboration (How will the students apply this concept to everyday lives?)
5. Evaluation (How will the students demonstrate the learning objective?)

Assessment of Student Learning:

Short description of the evidence the teacher is willing to accept that a student is proficient with the performance expectations. This may be a rubric, narrative, or other set of descriptors that are useful for distinguishing proficient from non proficient performers.

Sources:

Appendix B

Culturally Responsive Teaching in Science Consent Form

Introduction You are invited to participate in a research project to study. In this research study, we are investigating pre-service elementary teacher's Culturally Responsive Teaching (CRT) in science.

Description Participation is completely voluntary. The participants are not being asked to do anything outside of their normal classwork; you are only being asked to consent for class submissions and results to be used in the research.

Risks There are no anticipated risks.

Benefits There are no anticipated benefits.

Confidentiality or Anonymity and Data Security I will make every effort to keep information about you anonymous. The data collected will be kept confidential to the extent allowed by law and University policy.

Compensation Compensation will not be given for participation.

Your rights as a participant Please take whatever time you need to ask the researcher questions about the study. Choosing or refusing to allow your classwork to be used in the research will have no effect on your relationship with the University, your teacher, or your grades in the course. If you choose to not participate, your information will not be included in the study

Contacts for questions or problems Email Lundon Pinneo at lapinneo@ualr.edu or Dr. Stephen Burgin (Faculty Supervisor) at srburgin@uark.edu if you have any questions about the study, or if you think that something unusual or unexpected is happening.

If you have questions or concerns about your rights as a research participant, please contact Ro Windwalker, the University's IRB Compliance Coordinator, at 479-575-2208 or irb@uark.edu.

Consent of participant (or legally authorized representative) I affirm that I am 18 years old or older. I have read, understood and agree to participate.

Name (First and Last): Click or tap here to enter text. Date: Click or tap here to enter text.

Signature of participant or representative

Upon signing, the participant, or the legally authorized representative, may receive a copy of this form or must have access to it. If signed, the original will be held by the PI. Signed forms must be kept for three years past the life in the study.

Appendix C

IRB Approval Memo

UNIVERSITY OF ARKANSAS

To:	Lundon Ann Pinneo
From:	Douglas James Adams, Chair IRB Committee
Date:	01/27/2020
Action:	**Exemption Granted**
Action Date:	01/27/2020
Protocol #:	1910223356
Study Title:	Culturally Responsive Teaching in an Integrated Science, Pre-service Elementary Course

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Stephen R Burgin, Investigator

Image 1