PRESERVICE TEACHERS' SOCIOPOLITICAL CONSCIOUSNESS IN LIGHT OF THE RACIAL DISPARITIES HIGHLIGHTED BY THE COVID-19 PANDEMIC

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

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presented by R. Tanner Oertli, a candidate for the degree of Doctor of Philosophy of Learning, Teaching, and Curriculum Emphasis in Science Education, and hereby certify that, in their opinion, it is worthy of acceptance.

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Dedication

To Claire, Anderson, and Crew, I know this path was not always easy, thank you for all your support. I would have never been able to finish this without you.

To my Mom and Dad, thank you for always believing in me.

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Thanks to Dr. Laura Zangori for your unending support and picking me up every time I wanted to give up. Had it not been for you, I would have never finished.

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Abstract

Socioscientific issues (SSI) such as COVID-19 and climate change often highlight the inequalities that structural racism creates. If we ever wish to equitably solve these issues, we require a population that has the scientific literacy and the sociopolitical consciousness to do so. Yet, the push for culturally relevant education has had little movement in science education, partially because of the acultural view of science but also from the colorblind ideologies often held by teachers. The purpose of this pre-experimental study was to determine if a pre-service elementary science methods course that applies the SSI Teaching and Learning Framework for Social Justice promoted participant's sociopolitical consciousness, reduced their colorblind ideologies, and increased their socioscientific reasoning (SSR) skills. Linear mixed-effects regression models were run to assess these outcomes. Results indicate that preservice teachers' colorblind ideologies and socioscientific reasoning skills did not change through the semester. However, a statistically significant increase in their sociopolitical consciousness was found and this increase could be predicted by one of the components of SSR, perspective taking. Implications of these findings are discussed.

Chapter One: Introduction

White Americans were half as likely to die from COVID-19 when compared to other Races and Ethnicities at the onset of the pandemic (Garg et al., 2020). Despite this, reports showed that in many areas, White communities had more testing and vaccination sites when they became available (McMinn et al., 2020). Let us take a moment and ask the question; *why*? It is likely that health professionals added testing and vaccination sites in areas where established structures were pre-existing to efficiently test and vaccinate people. Since these structures were never adequately addressed in non-White communities prior to the COVID-19 pandemic and a critical critique of what this might mean for these communities was never made, we are left with perpetuated racism during the pandemic. No ill intent is required to perpetuate racism when the structures and foundations of our society are built on a racist past, only a blind eye is needed.

Racism exists in many sorts and remains one of the more pressing social issues of our time. Of particular concern to this dissertation is structural racism, the intricate tangle of past and present systems within all societal areas that produce, propagate, and sustain inequality along racial lines; predominately impacting Black individuals in the United States (Bailey et al., 2017). Also considered is Environmental racism, an offshoot of structural racism, defined as public policies and industry practices that disproportionately shift the negative impacts of pollution and environmental hazards to communities of color (Bullard, 2018). Throughout this dissertation, I use Kendi's (2019) definition of racism as any policy or idea that supports racial inequities. Notably, this encompasses much more than what many White people might define racism, as an individual act or prejudice and includes the decisions made during the pandemic that caused further inequities.

Socioscientific issues (SSI) such as COVID-19 and climate change often highlight the inequities that structural racism and environmental racism create. The CDC contributes the inequitable results of COVID-19 to residential housing segregation, over-representation in jails and prisons, less access to healthcare, lack of paid sick leave, and over-representation in high infection risk occupations. Environmental racism has been identified as an additional variable increasing the impact of COVID-19, as it is well established that communities of Color are disproportionally exposed to air pollutants (Bell & Ebisu, 2012) which have been shown to increase transmission and death rates of COVID-19 (Ali & Islam, 2020). There are many more examples of inequities, creating an integrated web of complex and often compounding interactions.

If we ever wish to equitably solve these issues, we require a population that has the scientific literacy and the sociopolitical consciousness to do so. As with many problems in our society, teachers are at the forefront of solutions or regrettably, can also act as agents of perpetuation. To combat structural racism and address growing cultural diversity in the U.S. school system, educational reformers have argued for a comprehensive culturally responsive education for all students (Brown, 2017; Gay, 2002; Ladson-Billings, 1995b). Culturally responsive education can increase students' sociopolitical consciousness, which is an individual's ability to identify and critique and the willingness to change the social norms that produce and maintain inequities in our society. However, science education has lagged in these efforts. This is often attributed to a lack of preparation in teacher education science method courses (Ferguson, 2008), the "acultural" view of science held by science teachers (Banks, 2016), and the predominantly White teaching force that generally lacks the sociopolitical consciousness needed to overcome barriers, such as their colorblind ideologies, of implementing culturally responsive practices.

Science education researchers and practitioners often see scientific literacy as the overarching goal of science education (Roberts, 2007). Scientific literacy is the ability to understand and apply science concepts and practices in contexts beyond the classroom. By overlapping the tenets of sociopolitical consciousness with scientific literacy goals, and asking future teachers to acknowledge their colorblind ideologies, science teacher educators can assist future teachers in developing an understanding and implementation of comprehensive culturally responsive education. An effective path for this to occur is through Socio-Scientific Issues-based teaching.

Scientific Literacy and Socio-Scientific Issues (SSI)

Scientific literacy is generally broken down into two distinct, yet interrelated goals known as vision I and vision II (Roberts, 2007). Vision I scientific literacy includes established science; knowledge of concepts and the practices associated with doing science. Vision I is well represented in the three-dimensional (disciplinary content knowledge, science and engineering practices, and crosscutting concepts) learning of the Next Generation Science Standards (National Research Council, 2012; NGSS Lead States, 2013). Vision II scientific literacy is the ability to use the knowledge and skills established in vision I to solve real-world problems while considering other components beyond science (e.g., social, economic, political; Sadler & Zeidler, 2009).

Researchers have shown that teaching science through SSI's promotes vision I and II scientific literacy. SSIs are complex, often controversial, social issues that are conceptually, procedurally, and/or technologically connected with science (Sadler & Zeidler, 2005). Examples of SSIs include global warming, the antivaccination movement, antibiotic-resistant bacteria, and mining practices (e.g., fracking). Science skills and knowledge are needed to solve SSIs. However, because they are open-ended problems with multiple solutions and perspectives their resolution also requires social, political, moral, and/or economic considerations (Sadler, 2004a; Zeidler, 2003). When students engage with SSIs, they are more likely to understand the relevance of science to their lives (Stuckey et al., 2013) and can promote responsible citizenship (Evagorou & Dillon, 2020). For example, SSI instruction has shown to increase student understanding of science ideas (Dawson & Venville, 2010; Herman et al., 2019; Klosterman et al., 2012; Peel et al., 2019; Sadler, Romine, et al., 2016; Shoulders & Myers, 2013) and improve students' science practices (Kolstø et al., 2006; Peel et al., 2019; Venville & Dawson, 2010; Zangori et al., 2017). SSI instruction also improves students' ability to reason with SSIs (Justi & Mendonça, 2016; Sadler et al., 2007; Topçu et al., 2011; Wu & Tsai, 2007), critical thinking and decision-making skills (Dolan et al., 2009; Evagorou et al., 2012), and helps improve moral, ethical, and character development (Fowler et al., 2009; Lee et al., 2006, 2013; Zeidler & Keefer, 2003). Additionally, some researchers found that SSI instruction has the potential to increase students' willingness to act on these issues (Herman, 2018; Zafrani & Yarden, 2017).

When students are engaging with an SSI, they are using socioscientific reasoning (SSR). SSR are the skills and knowledge required to navigate SSI's successfully. As described by Sadler et al. (2007), Sadler, Foulk, and Friedrichsen (2016), and Kinslow (2018), SSR is comprised of five interconnected competencies which are: (1) Recognizing and understanding the inherent *complexity* of the SSI; (2) Examining the issue through *multiple perspectives; (3)* Identifying aspects of the issue that require further *inquiry: (4)* Using *skepticism* when analyzing potentially biased information; and (5) Exploring the *affordances and limitations of science* regarding the issue. Not only are these competencies interconnected they have been found to be hierarchical with an understanding that SSIs are complex as the easiest competency which leads to the realization that SSI are difficult to resolve because choosing a resolution is impacted by the many different ideologies and motives of people involved.

Sociopolitical Consciousness and Colorblind Ideologies

Beyond the primary utility notion of vision II science literacy, sociopolitical consciousness represents an individual's knowledge of and *willingness* to act in response to social considerations influencing society (Watts & Flanagan, 2007). Ladson-

Billings (1995b) explains sociopolitical consciousness as a means to challenge the cultural norms, values, and institutions that create and maintain social inequities. Considering the components of SSR, SSR has many attributes in common with how we might promote sociopolitical consciousness using SSIs that highlight structural and/or environmental racism. This can occur through SSI by Introducing data that shows disparate outcomes along racial lines, investigating the perspectives of different racial groups, providing opportunities for individuals to consider their own privilege with regards to the SSI, and develop resolutions that challenge the societal norms and structures that created the racial inequity in the first place. While science literacy and SSR enables students to be active participants in democracy, sociopolitical consciousness positions students as “justice oriented citizen” (Westheimer & Kahne, 2004). Once students have obtained a sociopolitical consciousness and a vision II scientific understanding of a socioscientific issue, they can critically examine the issue in an equitable manner.

Colorblind ideologies are in direct contrast to sociopolitical consciousness and create a barrier to culturally responsive teaching. Colorblind ideologies attempt to make nonracial explanations for racial inequalities (Bonilla-Silva, 2014). As such, an individual holding a colorblind ideology will be less likely to critically examine racism because they see the world as being post-racist and view racism as occurring infrequently and concretely, such as blatant racist attacks, and not as a larger system creating and maintaining inequalities between racial groups. In doing so, colorblind ideologies perpetuate racist outcomes without sounding racist because they do not critically examine and challenge the underlying causes of these racial inequalities like an individual exhibiting sociopolitical consciousness might.

When considering SSIs, individuals with colorblind ideologies would look for alternative explanations other than race to explain inequalities. For example, an individual might use socioeconomic status to explain why Black and White communities experience different outcomes due to COVID-19 without considering the complex historical and current structures in place that created, maintain, and exacerbate socioeconomic differences between Black and White communities.

Problem Statement

Socioscientific issues represent some of the most pressing yet difficult problems to solve in our society and they often impact People of Color disproportionately. If students are expected to gain a sociopolitical consciousness of how to resolve SSIs in a socially equitable way, preservice teachers need also hold these skills and knowledge. Additionally, if future educators are to teach science through SSI in a manner that challenges status quo inequalities, they will need to teach in culturally responsive ways. Two of the primary barriers to teaching in culturally responsive ways is teachers' colorblind ideologies and a lack of sociopolitical consciousness.

Purpose of Study

The purpose of this study is to determine if a pre-service elementary teacher science methods course that frames teaching science through the SSI of COVID-19 promotes preservice elementary teachers' sociopolitical consciousness, challenges their colorblind ideologies, and increases their socioscientific consciousness.

Positioning Myself

Given the focus of this project, I believe it is important to position myself. I am a White, middle class, cisgender, straight, and enabled bodied male. In sum - the epitome of what traditional education is geared towards. With this, I recognize the privilege that has helped me through my primary education, bachelor's degree in biology from the University of Montana (a state not known for its diversity), and my seven years as a high school science teacher. I also recognize the privilege that I continue to receive as a graduate student at the University of Missouri where I teach a section of the elementary science methods course. I am not new to the field of science education, but I am new to the field of culturally responsive education. However, I wish to start using my privilege to promote change toward a more equitable society.

I should also place my writing of this paper in context; when I was not writing, I was reading the news articles about the murder of George Floyd and the subsequent protests. As I read these articles and thought about similar acts of racism and the larger more complex structural racism in our society, I constantly struggled with my conceptualization of the following framework: "Is it enough? Is it right? Who am I to speak about racism as a White male? Am I inappropriately positioning people of Color as 'in need of saving'?". As a preservice science methods instructor holding these questions in mind, I envisioned this project to promote a much-needed sociopolitical consciousness in individuals like myself; White, middle class, teachers. My goal is to that elevating sociopolitical consciousness within preservice teachers will better position them to use culturally responsive education.

Research Questions

This project implemented a unit that guided preservice elementary teachers in the production of their own SSI based unit that focused on the coronavirus pandemic and the associated social inequalities highlighted by the pandemic and caused by current structures of racism in our country. I believe that in highlighting and reflecting on the impacts of structural racism, preservice elementary teachers will become more sociopolitical consciousness and it may challenge their colorblind ideologies as well as increase their socioscientific reasoning skills. I also acknowledge that decreasing preservice teachers' colorblind ideologies and increasing their socioscientific reasoning skills in such a short amount of time is not likely to change according to prior research. However, the novelty of this study in which PSTs were asked to reflect on their colorblind ideologies and sociopolitical consciousness of the COVID-19 pandemic while also experiencing the COVID-19 pandemic, requires a critical look at the ideas they hold and if the daily experiences of the pandemic impacted changes to their ideas. The following research questions guided the project:

1. Do elementary preservice teachers' colorblind ideologies change while using an SSI unit across a semester?

2. Do elementary preservice teachers' socioscientific reasoning skills change while using an SSI unit across a semester?
3. Do elementary preservice teachers develop sociopolitical consciousness through an SSI unit across a semester? Can a change in sociopolitical consciousness be predicted by preservice teachers' colorblind ideologies and socioscientific reasoning skills?

Chapter Two: Literature Review

Introduction

This study is situated within and attempts to combine two strands of literature: teaching science with socioscientific issues and culturally responsive education. These combined strands focused on challenging preservice teachers' colorblind ideologies and promoting their sociopolitical consciousness through engaging with socioscientific issues that highlight structural and/or environmental racism. The importance of this work is twofold; making education impactful beyond the walls of the classroom by employing issues based teaching practices and bringing science education further into the fight against structural and environmental racism.

Teaching with Socioscientific Issues

Science education reform efforts have long sought to make science education relevant to students' everyday lives (Kuhn, 1993) and prepare students for responsible citizenship (Ramsey, 1993). One way science educators have achieved this is by teaching through socioscientific issues (SSI; Sadler & Zeidler, 2005). However, teacher beliefs are often the determining factor for the uptake of reform-based practices like SSI based instruction (Fletcher & Luft, 2011).

SSI based instruction is rarely found in curriculum materials or standards such as the Next Generation Science Standards (NGSS). Considering this, it is up to teachers to determine if/when/how SSI based instruction takes place. Cohen, Zafrani, and Yarden (2020) explained how teachers rely on standards to determine their instruction unless they feel passionate enough to teach SSIs on their own accord. These findings are supported by others who determined that when teachers used SSI based instruction, they did so because of their passions, values, and ideals that aligned with the approach (Hancock et al., 2019; Lee & Witz, 2009; Zangori et al., 2018).

However, even if teachers have these attributes to utilize SSI in their teaching, there are additional barriers to SSI implementation. For example, SSI lessons are typically longer than other lesson types (such as content only) as SSI lessons require ample student discussion about how the science content connects to sociopolitical elements. Therefore, teaching SSI does not fit within typical classroom time constraints, so SSI units are rarely completed. Also, since SSI lessons are typically developed by researchers and introduced through teacher professional development, there is a lack of widely available support materials (Pitpiorntapin & Topcu, 2016; Sadler et al., 2006) Some teachers shy away from SSI based instruction due to their controversial nature because they are uncomfortable holding what they consider as "non-science" discussions within their classrooms (Duschl et al., 2002). In addition, teachers hold a low self-efficacy for SSI based pedagogy as they do not think they have the knowledge to implement sociopolitical connections (Lee et al., 2006).

Teachers that do end up teaching SSIs do so in diverse ways depending on how they perceive the SSI and their teaching role. Reflecting on the traditional compartmentalization of school subjects, especially at the high school level, Tidemand and Nielsen (2017) found that secondary science teachers tend not to focus on the societal aspects of SSIs and merely view SSIs as a means to teach science content. This could be because SSI require skills and knowledge often not utilized by science teachers (Simonneaux & Simonneaux, 2009). Alternatively, elementary teachers who are generalists and teach all subject areas, tend to perceive SSI as a method to foster responsible citizenship in their students (Friedrichsen et al., 2020) and as cross-curricular means to make science relevant to students' everyday lives (Zangori et al., 2018). Many researchers have identified elementary teachers' potential for SSI instruction as they are more comfortable implementing cross-curricular content which reflects the multidisciplinary nature of SSIs (e.g., Friedrichsen et al., 2020; Zeidler & Nichols, 2009).

Challenges of Preparing Teachers to Enact SSI Based Science Instruction

There are many challenges in preparing teachers to enact SSI based science instruction. Leung, Wong, and Chan (2020) outline these challenges as including limited knowledge about SSIs, how to lead a discussion about controversial issues, and transferring from a focus on content knowledge that often has definite answers to SSIs that are complex, open-ended, and require value judgements. Additionally, Foulk (2019) identifies a lack of support materials which leaves teachers on their own to develop SSI curriculum or lack of specific pedagogical content knowledge that is required to successfully identify and utilize SSI.

Researchers have identified that overcoming barriers to implementing SSI units in classrooms can take teachers many years before they feel successful (Cohen et al., 2020; Friedrichsen et al., 2020; Furman et al., 2020; Tidemand & Nielsen, 2017). These barriers take so long to overcome for many reasons; for example, teachers require teaching experience before they are able to tackle SSIs on their own. However, if SSIs are introduced earlier within teacher education practice, then preservice and beginning teachers are provided support and time with a knowledgeable other to develop knowledge and skills to prepare them to include SSIs within their own classroom. Therefore, for teachers to uptake SSI's, teacher SSI development should begin in teacher education programs. Also supporting this claim; preservice and new teachers are more likely to change their beliefs (Crawford, 2007; Fletcher & Luft, 2011) and take up teaching SSIs over their veteran peers.

Socioscientific Issues and Preservice Teacher Education

SSI studies focused on elementary and secondary pre-service teachers (PST) vary across implementation (auxiliary and full-scale), supports (strategies and teaching frameworks), and outcomes (SSI knowledge/reasoning and teacher implementation). When SSI is included as an auxiliary component of the course, SSI instruction is merely added to existing courses (Borgerding & Dagistan, 2018; Forbes & Davis, 2008; Özden, 2015). Full-scale SSI implementation changes to course are extensive, resulting in a full-scale remodeling of a course to infuse SSI instruction throughout (e.g., Evagorou & Puig Mauriz, 2017; Foulk, 2019; Yerdelen et al., 2018). In either auxiliary or full-scale studies, support provided to PSTs range from simple strategies where teacher educators guide PSTs in their pedagogical skills and conceptions of SSI based science teaching. This is often done by modeling SSI based science instruction (e.g., Garrido Espeja & Couso, 2020) or using teaching frameworks. Frameworks are more involved and provide scaffolds that assist teachers in the development and implementation of SSI based instructional units/lessons such as the Socioscientific Teaching and Learning Framework (Foulk, 2019).

Most intervention studies focused on assessing PST on their understanding and reasoning of SSI as students rather than future teachers. Much fewer research studies provide interventions that support PSTs in their current/future teaching using SSI practices, thereby focusing on how PSTs integrate SSIs into their teaching practice. In sum, investigated outcomes fall into two categories; PSTs as students receiving SSI based science instruction and PSTs as teachers implementing SSI based science instruction. The following sections are used to review the relevant literature regarding SSI studies within teacher education programs with the above distinctions in mind.

Teaching Frameworks

General teaching and learning frameworks are typically taught in preservice teacher methods courses as they provide a scaffold for teachers to use in the development of curricular lessons/units within any content area. Teaching frameworks such as Bybee’s (1997) 5E model (Engage, Explore, Explain, Extend, and Evaluate) is often used in science teacher education courses. The 5E model is a flexible, general science education teaching framework that guides teachers in the creation of lessons/units. It is important to have a flexible and generalizable framework, such as the

5E, because introducing PSTs to teaching science through an SSI approach is a difficult task. The generalizable framework provides the necessary flexibility with which to embed more specific frameworks for SSI teaching and learning.

Each “E” defines for preservice teachers what to do with their students (Bybee et al., 2006). Engage has the teacher introduce the topic to the students and gain an understanding of their prior knowledge and misconceptions. During the Explore phase teachers create opportunities for students to experience the phenomenon for themselves, gathering evidence to be used in the next stage. The Explain phase is broken into two steps: first, students use the evidence they gathered from the Explore phase to develop their own explanations of the phenomenon. Second, once the students’ explanations are close enough to the scientifically excepted explanation, the teacher provides the explanation to their students. During the Extend phase, students apply what they learned to something new. Finally, the Evaluate phase consists of a summative assessment but also considers how teachers will perform formative evaluations throughout the lesson. Since SSI is a teaching strategy that specifically introduces real-world problems to the science classroom, it can easily be situated in a 5E teaching framework.

SSI instruction is often not the only new aspect of reformed based practices teacher educators are introduced during an intervention (Nielsen et al., 2020). The generalized framework supports PSTs in figuring out how to plan and teach a lesson that they can apply across content. In addition, The SSI community has produced specialized teaching frameworks that are specific for SSI based science instruction that can be fit within the generalized framework. Particularly, the SSI Teaching and Learning (SSI-TL) framework integrates NGSS alignment into SSI lessons. The framework was developed by Sadler and colleagues and is further explained in the Theoretical Framing for this dissertation titled *Socioscientific Issues Teaching and Learning for Social Justice Framework: Promoting Sociopolitical Consciousness and Challenging Colorblind Ideologies* section.

There is little research on using this framework within pre-service teacher education. Since The SSI-TL framework integrates the NGSS, embedding this framework within the generalized 5E requires that teachers hold some competence with the NGSS. In addition to the supportive frameworks, ample scaffolds, and appropriate strategies enacted by teacher educators are also needed for PSTs to successfully implement SSI.

Strategies

Strategies involve study interventions and teacher educator practices that are used to foster PST development of SSI based science instruction, most often in a science methods course. These strategies fall within four stages: experience, design, enactment, and reflection. Teacher educator implementation of these stages ranges from utilizing only one to all four and is not necessarily sequential.

Experience of SSI based learning. Nearly all studies examined in this literature review that widely implemented SSI based instruction held the notion that PSTs need to experience SSI instruction as students before attempting to developing/utilizing them as teachers. As they have likely have not experienced an SSI in the classroom before, they need to understand the complexity, open-endedness, and learn how to construct arguments with evidence on their own before they can be expected to foster these aspects of SSI in their future students (Garrido Espeja & Couso, 2020).

It is also important to model SSI based instruction for PSTs. However, only a handful of studies have done this. One example comes from Foulk (2019), where she used the SSI-TL framework to guide her secondary PSTs through an SSI lesson focused on the issue of nutrition and “fat taxes” (Sadler, Foulk, et al., 2016). Gul and Akcay (2019) combined the 5E and SSI-TL frameworks around the issue of climate change and the guiding question of “Can you decrease the effects [of] climate change by not making barbecue?” (p. 149).

There are also studies in which teacher educators modeled SSI based instruction without using a framework. For example, Evagorou, Guven, and Mugaloglu (2014) introduced the nature of SSI to their elementary PSTs through a lesson on global warming. Borgerding and Dagistan (2018) modeled SSI instruction by guiding secondary PSTs in argumentation practices involving the examination of multiple lines of evidence, anticipating opposing positions, and delivering counterarguments. Finally, Yerdelen et al. (2018) used class discussions about what SSIs are followed by role-playing as different stakeholders of an SSI to give PSTs experiences and an understanding of all that SSIs entail. One study asked PSTs investigate SSIs on their own. Karışan, Yılmaz Tüzün, and Zeidler (2017) had PSTs prepare a presentation for the class on a given SSI.

Presentations were made to emphasize essential concepts, address multiple perspectives, construct moral positions and arguments, and increase content understandings. The importance of these presentations was to allow students to take part in argumentation around an SSI. Two studies had PSTs perform primary and/or secondary research on SSIs to give them more ownership of their findings (Bencze & Sperling, 2012; Özden, 2015).

(Re)Design of SSI based lessons. Preservice teachers (PST) that have more opportunities to create/modify lesson plans are more confident and successful (Darling-Hammond et al., 2005). PST design of SSI based science lessons/units ranges from simple critique and modification of existing curriculum to the complete design of SSI infused units from scratch. Forbes and Davis (2008) investigated how elementary PSTs critiqued and changed existing SSI materials. They recommend this strategy rather than asking elementary PST to develop original curriculum because elementary PSTs have more barriers compared to their secondary PST peers, such as limited content knowledge. Borgerding and Dagistan (2018) had pairs of secondary PSTs design SSI microteaching presentations focusing on discussion strategies and found that PSTs eagerly adopted these strategies to teach about issues but were not able to distinguish the difference between SSIs and scientific topics that were controversial (e.g., evolution). Evagorou and colleagues (2014) required their elementary PSTs to design a lesson plan centered around an SSI with specific emphasis on how they would assess students on SSI attributes throughout the lesson. SSI assessment discussions focused on issues of what knowledge, understandings, and skills the SSI lesson is trying to develop. This strategy aligns with Nielsen (2020), who highlights the importance of providing scaffolds to PSTs to operationalize science learning goals within an SSI lesson. Evagorou and Puig Mauriz (2017) required their elementary PSTs to design a lesson plan around an SSI of their choice for their final project.

Few studies explicitly stated the types of scaffolds they provided PSTs for SSI curriculum design. Garrido Espeja and Couso (2020) gave their elementary PSTs a design guide for an SSI lesson they were to create. Following their first design of the SSI lesson, PSTs were given "constant researcher guidance" while they improved their designs. Secondary PSTs in Amos, Knippels, and Levinson's (2020) study co-designed SSI lessons using a framework similar to the SSI-TL framework with support from experienced teacher mentors. Foulk (2019) asked her secondary PSTs to design an entire unit with multiple lesson plans around an SSI of their choosing. Foulk provided many resources to PSTs during their SSI unit design (e.g., SSI unit template) as well as opportunities for peer collaboration and frequent feedback by the author.

PSTs have many challenges in the (re)design of SSI based curriculum that require teacher educators to provide scaffolds to support them in this endeavor (Amos et al., 2020; Garrido Espeja & Couso, 2020; Leung et al., 2020). However, few studies detail any of the scaffolds used to support PSTs in SSI curriculum development. The SSI-TL framework could serve as a potentially useful scaffold as it defines what to include and how to approach SSI teaching, as I describe later in this chapter.

Enactment of SSI based teaching. Providing opportunities for PSTs to enact their designs is critical to their development as teachers (Hammerness et al., 2005). However, few studies followed through with such strategies (Amos et al., 2020; Borgerding & Dagistan, 2018; Garrido Espeja & Couso, 2020). These studies range from teaching mini-SSI lessons to their peers to enacting full SSI lessons for students in the classroom. There are many barriers to enacting SSI based teaching in science methods courses, such as time constraints for PSTs to develop and teach their lessons and access to grade-level students in order to teach their SSI-lessons. These constraints make providing these opportunities challenging within science methods coursework.

Reflection. Reflection most often occurs after PSTs experience or enact an SSI based science lesson. PST reflection of their own learning experiences helps them identify their assumptions about teaching and learning which is important for the critical analysis needed to disrupt misconceptions about teaching and learning (Bransford et al., 2005).

Evagorou and colleagues (2014) employed discursive activities to encourage secondary PSTs to reflect on teaching strategies for SSI following their experiences with SSI based science learning. Reflections focused on three aspects of SSI: understanding SSI, beliefs about teaching SSI, and ideas about SSI assessment. Reflections about PST understanding included the nature of SSI and discussions about identifying the controversy within the issue. PSTs reflected about their beliefs in teaching SSI as they identified if and why they found teaching SSI important and what they viewed as challenges for learners.

Reflections regarding assessment of SSI teaching involved identifying challenges to assessment and what they believe should be assessed. PSTs also considered how they might assess their future SSI teaching and how this might benefit them. Evagorou and Puig Mauriz (2017) used similar reflections following elementary PST experience of an SSI lesson. However, their reflections went beyond SSI specifically and included reflections on how PSTs defined science and how science should be taught.

During Foulk's (2019) dissertation study, secondary PSTs completed writing prompts and in-class discussions to reflect on their perceptions of SSI and its utility for teaching science. While reflecting on their experience with SSI as students, they were asked to consider the perspective of teachers to help prepare them in designing an SSI unit using the SSI-TL framework. Specific reflection about the cost and benefits of the SSI-TL framework was also done in both phases (experiences and design).

Garrido Espeja and Couso (2020) provided opportunities for reflection following elementary PST experiences with SSI as students and again after enacting designed lesson. The PSTs reflected both individually and in a group with the assistance of video clips taken while teaching their SSI focused-lesson. This final reflection aimed to identify the challenges and benefits of SSI based science instruction.

Another SSI reflection focused study also used group discussions and written reflections after PSTs designed and enacted their SSI lesson using a framework like the

SSI-TL (Amos et al., 2020). In this case, PSTs used self-evaluations and evaluations from their co-planner to reflect. In another study, PSTs watched the video of their microteaching activity and reflected on how they maintained a constructive learning environment, encouraged active learning, used scientific practices, engaged students in evidence-based argumentation, and ideas for how they could improve their teaching in the future (Borgerding & Dagistan, 2018).

The themes that are apparent in the research regarding reflection, focuses on experiences and enactments of SSI lessons; understanding SSI, identifying the importance of teaching SSI, identifying strategies in teaching SSI, and identifying challenges of SSI based instruction. As PSTs are likely new to teaching and learning with SSI, they must have the opportunity to reflect on their understanding of the nature of SSIs so they can better understand how they might design and enact an SSI lesson.

Reflection is particularly important because, as indicated by Zangori and colleagues (2018), teachers' beliefs mediate their decisions on enactment of SSI based science instruction. It is through reflection, that teachers have opportunities to uncover and explore their beliefs. Additionally, specifically within the elementary classroom, elementary teachers see SSI as a way to promote students becoming responsible citizens (Friedrichsen et al., 2020). As such, identifying the importance of teaching SSI during elementary teacher education has the potential for fostering the long-term commitment needed for teachers to become successful at implementing SSI based science instruction. Finally, reflection on enactment of teaching SSI lesson is required because SSI based science instruction is a complex and difficult task that requires a critical analysis for improvement.

Preservice Teacher Outcomes

Across the studies cited above that focus on SSI implementation in preservice teacher education, the research falls into two categories: PST as students experiencing SSI lessons and PST as teachers enacting SSI lessons. Outcomes involving PST as students focus on how well participants understand SSI, engage with socioscientific reasoning and/or argumentation skills, and other related attributes. Whereas outcomes highlighting PST as teachers focuses on belief alignment and/or change, challenges (perceived and observed), and the ability to design SSI based lessons.

Pre-service teachers as students. Many studies position PSTs as students receiving SSI based science instruction. These studies have investigated things such as argumentation and reasoning of PSTs (Karışan et al., 2017; Ozturk & Yilmaz-Tuzun, 2017; Pezaro et al., 2014; Topçu et al., 2011), how PSTs discuss SSIs in class (Kim et al., 2014), critical thinking skills (Gul & Akcay, 2019), and understanding the cultural aspects of science and SSI (Evagorou & Puig Mauriz, 2017; Özden, 2015). It is important that PSTs first experience SSIs as students so that they better understand SSIs as gain some of the skills that they will attempt to teacher their students when they plan and implement SSIs based lessons.

Pre-service teachers as teachers. Studies that focus on attributes associated with the implementation of SSI based science instruction range widely in their attempts of preparing PSTs to implement SSI based science instruction. Some studies provide little to no guidance in teaching science through SSIs and others offer highly embedded SSI practices throughout a science methods course. Of the studies that promote SSI instruction, few use SSI teaching frameworks. Regardless of method, outcomes of these studies are presented below.

Preservice teachers' beliefs about teaching and learning through a socioscientific issue. Within the research regarding PSTs' beliefs about SSI teaching and learning there two main categories: beliefs related to PST commitments to teaching science through SSIs and beliefs about the utility/importance of SSI.

Beliefs related to commitment. While many PSTs throughout the studies discussed below show a general commitment to teaching science through SSI, much of the focus of these studies were on the beliefs that caused PSTs not to be committed to teaching SSI based science. Foulk (2019) found that beliefs about teaching SSI are mediated by PSTs' beliefs about science education in general. For example, one PST in her study understood science as a collection of facts and that science teachers are responsible for imparting these facts on to their students. This PST saw the SSI-TL framework as distracting from science. This finding is also apparent in Genel and Topçu's study (2016), who found that some PSTs did not believe SSI to be a central theme for science teaching. Barrett and Nieswandt (2010) and Leung and colleagues (2020) found that the interdisciplinary nature of SSI causes some secondary PSTs to believe it would be more appropriate to teach in other subjects. These findings support the view that elementary teachers may be particularly suited to using SSI as they are generalists and can use SSI to interconnect the subjects they teach.

However, other PSTs in Foulk's study viewed science as much more complex, including aspects like scientific knowledge and practices, decision-making, and communication. These PSTs saw the SSI-TL framework as truly encompassing what science is and they were committed to its use. Bencze and Sperling (2012) also saw commitments to use SSI in future classroom instruction. Similarly, Yerdelen et al. (2018) found that after an entire course focused on teaching science through SSI increased PSTs' interest and beliefs of the usefulness of SSI based science instruction.

Beliefs about the utility of SSI based science instruction. There are three main beliefs about the utility of SSI based instruction: those that believe it is not useful, those that believe it is useful but only as an instrument to teach science, and those that believe understanding and navigating SSI is an important goal of science education. Foulk's study showed that PSTs with goals for k-12 science education that aligned with only vision I scientific literacy (science knowledge and skills that are often limited to the science classroom) did not see the utility of the SSI-TL framework. Many other PSTs see SSI as merely an instructional tool to help students obtain content knowledge and not something more (Sadler, 2006).

However, others have shown that it is possible to help PSTs shift from an instrumental view about SSI to a belief in using SSIs as a way to create deep connections between the classroom and the real world and possibly even prepare students to be more critical about and involved in such issues (Leung et al., 2020). They stress the importance of addressing the interrelationship among SSI, content knowledge, and nature of science so that PSTs are less likely to see SSI as a mere instrument. Similarly, Foulk identified that PSTs with more comprehensive goals for science education that aligned with vision I and II saw the SSI-TL framework promoting responsible citizens through science education.

Supporting Foulk's realizations, Evagorou and Puig Mauriz (2017) explained that PSTs beliefs about teaching science through SSIs are mediated by their beliefs about science; PSTs that view science as having social aspects, promote social aspects in their science instruction. Similarly, if PSTs saw science as value-free they were less likely to teach ethics using SSIs (Barrett & Nieswandt, 2010).

Preservice teacher enactment. Not surprisingly, PSTs without guidance as to how to teach science through SSIs, struggled to do so (Genel & Topçu, 2016). Guidance has been shown to increase self-efficacy for teaching SSIs to moderate levels (Kara, 2012; Pitiporntapin et al., 2016), PSTs still struggle to fully implement SSI based science instruction, as highlighted in the following findings. When it comes to designing SSI lessons, PSTs have difficulties making connections between SSIs and curricular content (Garrido Espeja & Couso, 2020; Pitiporntapin et al., 2016). Pitiporntapin et al. (2016) found that PSTs had difficulty properly threading SSI throughout a unit to tie it all together.

Even when PSTs are given a teaching framework, they struggle to implement all aspects of the approach (Amos et al., 2020). Additionally, Evagorou and Puig Mauriz (2017) found it challenging for PSTs to include social dimensions in their science lesson plans even when they gain an understanding of the social aspects of the SSI. During the implementation of SSI lessons, PSTs have difficulty supporting students with using scientific evidence when defending their opinions and had a hard time facilitating discussions (Garrido Espeja & Couso, 2020). PSTs also have a difficult time evaluating SSI based outcomes (Sadler, 2006).

With all the above difficulties it is apparent that PSTs require many scaffolds when being introduced to teaching science through SSI. For example, Foulk (2019) showed that secondary PSTs successfully used the SSI-TL framework to design an SSI based unit. However, the scaffolds were not the only thing that impacted PSTs' ability to do this, alignment between their beliefs about general science education and teaching with SSIs had an impact as well.

Preservice teachers' challenges/barriers to SSI implementation. Introducing PSTs to teaching science through an SSI approach is a difficult task, as SSI is often not the only new aspect of reformed based practices they are learning (Nielsen et al., 2020). This is evident in the study by Amos and others (2020), which demonstrated that PSTs were not able to implement all aspects of an SSI teaching framework which focused on two reform-based practices: SSI and inquiry-based learning.

While many studies indicate that PSTs generally have a large commitment to the implementation of SSI based teaching strategies (Bencze & Sperling, 2012; Kara, 2012; Pitiporntapin et al., 2016) others show a lack of follow-through in their early years of teaching (Pitiporntapin et al., 2016; Sadler, 2006). This is likely because PSTs perceive barriers, such as lack of time and materials for teaching science with SSI (Kara, 2012) in addition to all the other challenges new teachers face (Adams & Krockover, 1997; Luft & Patterson, 2002). These studies further underline the need for long term support beginning with teacher education programs for teachers to properly implement SSI based science teaching.

Literature Review Conclusion

Authors have assessed many outcomes of SSI based science instruction/preparation for PSTs. Many of these outcomes include varying forms of PSTs' beliefs and focus on PST beliefs regarding SSI overall (whether to implement it in their own practice). However, no studies address how preparing PSTs for SSI based science instruction might be used to promote sociopolitical consciousness for social justice and challenge their colorblind ideologies to better prepare future teachers to teach in a culturally responsive manner. Additionally, despite the obvious need for substantial scaffolds for PSTs when learning to design and implement SSI based science instruction, there are very few known SSI teaching frameworks, and few, if any, utilized SSI teaching frameworks (e.g., SSI-TL) to support elementary PST development. Therefore, it is the aim of this study to investigate the impact of an SSI focused science methods course on elementary PSTs' sociopolitical consciousness and colorblind ideologies. Specifically, this study will utilize the SSI-TL framework emphasizing the structural racism that is highlighted by SSI to enlighten PSTs to the complexities of racism in our country.

Theoretical Framing: Working Towards a Culturally Responsive SSI-TL Framework

The goal of this section is to add teaching for social justice to the SSI-TL framework to make it a framework that critiques, and challenges inequities highlighted by SSIs. I also explain how SSI-based instruction can be leveraged to challenge preservice teachers' colorblind ideologies and promote sociopolitical consciousness.

To do this, I first define sociopolitical consciousness. Next, to introduce science education I present a brief history of science and racism, including how science education is prone to colorblind ideologies. Then a discussion about culturally responsive science education. Finally, Culturally Responsive Education

The term culturally responsive education (CRE; Aronson & Laughter, 2016; Dover, 2013) is used to encompass both Ladson-Billings' (1995a) *culturally relevant pedagogy* and Gay's (2002) *culturally responsive teaching.* These two strands of CRE are often used interchangeably. Ladson-Billings (1995) defines *culturally relevant pedagogy* as a "theoretical model that not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate" (pg. 469). Gay (2002) defines *culturally responsive teaching* as "using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (pg. 106). *Culturally responsive teaching* focuses on instructional practices whereas *culturally relevant pedagogy* focuses more on the attitudes and dispositions of teachers (Aronson & Laughter, 2016). Both, however, have the goal of changing the educational system to better serve all students, not just individuals that are White, male, middle class, cisgender, straight, and enabled body.

Aronson and Laughter (2016) synthesized the CRE framework through four indicators of a culturally relevant teacher:

> 1) Culturally relevant educators use constructivist methods to develop bridges connecting students' cultural references to *academic skills and concepts*. Culturally relevant educators build on the knowledges and cultural assets students bring with them into the classroom; the culturally relevant classroom is inclusive of all students.
> 2) Culturally relevant educators engage students in *critical reflection* about their own lives and societies. In the classroom, culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented.
> 3) Culturally relevant educators facilitate students' *cultural competence*. The culturally relevant classroom is a place where students both learn about their own and others' cultures and also develop pride in their own and others' cultures.
> 4) Culturally relevant educators explicitly unmask and unmake oppressive systems through the *critique of discourses of power*. Culturally relevant educators work not only in the classroom but also in the active pursuit of social justice for all members of society. (p.5)

Many studies have established the positive impacts of CRE on student outcomes. Teaching through CRE has shown to increase academic achievement (Bui & Fagan, 2013; Choi, 2013; Conrad et al., 2003; Duncan-Andrade, 2007; Nykiel-Herbert, 2010; Rodriguez et al., 2004) and engagement (Christianakis, 2011; Feger, 2006; Hefflin, 2002; Martell, 2013; Stanton Wortham & Contreras, 2002; Tate, 1995). It also supports the development of sociopolitical consciousness in students (Epstein et al., 2011; Martell, 2013; Morrell & Duncan-Andrade, 2002; Stovall, 2006) as well as promote positive identity of self and others (Aldana et al., 2012; Brozo et al., 1996; Dessel et al., 2006; Spencer et al., 2008).

Barriers to Enacting Culturally Responsive Education

Preparing culturally responsive teachers has proven an arduous task. To understand these difficulties, a description of the typical elementary preservice and in-service teacher is required. There exists an increasing discrepancy between the demographics of our teachers and their students. According to the most recent data (Hussar et al., 2020), 79% of teachers are White and teaching students that are racially different from themselves; 52% of students are from underrepresented groups (i.e., Hispanic 27%, Black 15%, Asian 5%, Native American 1%, and Pacific Islander 1%). Compounding the problem, these teachers come from the same significantly segregated school system; 79% of White students are enrolled in schools that have a majority White population (even though White students are no longer the majority in our school system). On top of these demographic differences between students and teachers, Castro (2010) and Sleeter (2008) have identified four interrelated barriers to preparing culturally responsive teachers. I discuss each of these in turn:

- Insufficient prior experiences with culturally diverse others
- Insufficient sociopolitical consciousness of structural racism
- Deficit views and lower expectations for students of color
- Colorblind ideology

Insufficient Prior Experiences with Culturally Diverse Others. For numerous reasons, but most noticeably significant school segregation due to redlining and White flight from racially diverse school districts in the 1960s and 1970s, and more recently moving into private and charter schools (Renzulli & Evans, 2005), White preservice teachers lack prior experiences with culturally diverse others. Without a backdrop of experiences with cultural differences, White teachers are not likely to view themselves as cultural entities. This results in their positioning of themselves as the “norm” for which they compare their students to. This reinforces deficit thinking about their students when their students do not meet the metrics assigned by these norms (Sleeter, 2008).

Insufficient Sociopolitical Consciousness of Structural Racism. Additionally, White preservice teachers lack the sociopolitical consciousness needed to comprehend complex systematic racism partially because they lack experiences with racially diverse others, and instead they view racism as individual acts by “bad people” (Castro, 2010).

They often base their understanding of race in individualistic terms, applying their knowledge about their White ethnic past to non-Whites.

Deficit Views and Lower Expectations for Students of Color. Without prior experiences involving culturally diverse others, White PSTs only have their own and similar experiences to construct their understanding of what it takes to succeed. This supports their illusion of meritocracy, that only hard work is required to achieve prosperity and success. Seeing the world through individualism and meritocracy, White preservice teachers are blind to the effects of racism on people of Color. Without seeing the effects of racism, White preservice teachers are only able to make sense of the educational achievement gap by holding deficit views about and lower expectations for students of Color.

Colorblind Ideology*.* Furthermore, preservice teachers tend to adopt a colorblind approach to teaching where they believe they are treating everyone equally by teaching them the same, disregarding cultural differences (DiAngelo, 2018). By treating everyone the same (based on their own perceived norms) and ignoring cultural differences, teachers propagate racism. For teachers to enact CRP they must first critically analyze and appropriately dismantle their own collection of thoughts and ideologies about diversity that are incongruent with CRE (Milner, 2010).

Colorblindness is an ideology that not only is a barrier to teaching in a culturally responsive way, but it is also an ideology that propagates racism as a system (DiAngelo, 2018). Individuals claiming to be colorblind identify that prejudice based on skin color is wrong and that differences are only skin deep. However, by not acknowledging the cultural differences of their students and meeting them on their students' cultural terms, teachers limit the learning opportunities of students of color. Colorblind ideologies create a feedback loop to deficit thinking. This creates and maintains the achievement gap and spreads inequity within our educational system. When there is inequity one group gains advantage in the system (White privilege) and other groups are disadvantaged. White privilege results in White individuals achieving more within the system which reinforces their belief in the superiority of their way of doing things and perceiving the world, in turn reinforcing racist ideologies. In an educational setting, this results in White preservice teachers believing that the way they achieved academic success is the same way that their students should, regardless of their cultural backgrounds.

Promoting Sociopolitical Consciousness and Challenging Colorblind Ideologies in Preservice Teachers

Moving away from the notions of singularity within a colorblind ideology, requires realizing the complexities of cultural diversity including seeing oneself as a cultural being and recognizing White privilege and racism (Bollin & Finkel, 1995; Castro, 2010; S. M. Lawrence & Bunche, 1996; Sleeter, 2008, 2017). White privilege and racism go hand in hand, one community cannot experience inequality without another experiencing privilege (e.g., Black communities cannot have two times higher death rates due to COVID-19 without White communities having half the death rate of Black communities). However, when a White teacher educator, like myself, is preparing primarily White preservice teachers and assisting them to unlearn their colorblind ideology, the focus needs to be on the privilege they have because they are White. Without addressing White privilege first, White preservice teachers are likely to strengthen their stereotypes and generalizations of People of Color (McDiarmid, 1992).

Many scholars and educators have presented practices that White students can utilize to assist them in realizing their privilege, understanding the complexity of structural racism, and how the two are interwoven. Opportunities for self-reflection are important if White students are going to recognize their privilege (Bennett, 2019; Castro, 2014; Diangelo, 2012; Milner, 2003). Identifying the benefit of being White (Heinze, 2008), questioning the origins of stereotypes (Castro, 2010), and self-reflection, can be used by teacher educators to encourage White PSTs to consider the perspectives of their students that are disadvantaged by the same societal structure that creates White privilege (Hurtado et al., 2002; Narvaez & Hill, 2010). However, these attempts have shown to be difficult and are only successful over long periods of time. For example, Goode and colleagues (2020) found that long-term professional development is needed to disrupt colorblind ideologies in teachers. Narvaez and Hill (2010) and Bowman (2010) found that meaningful experiences with diverse others is needed for change.

Science teacher educators can address preservice teachers' colorblindness and promote sociopolitical consciousness through the incorporation of Socioscientific Issues.

In the following section, I introduce the role science and science education has played and continues to play in structural racism and then present a modified teaching framework for challenging colorblindness and promoting sociopolitical consciousness.

Science Education and Social Justice

The following sections give a brief outline of the often-problematic relationship science and science education have had with social justice, as well as work that has and potentially can be used to get science education on a more just trajectory.

Science and Racism. It is important to acknowledge the historic and ongoing scientific racism so that we can appropriately respond to it within science education. Science has long been used to support racism. White people have used science as a tool and/or justification for innumerous atrocities. For example, Linnaeus (the father of biological taxonomy) used his binomial naming system (genera and species) to define and assign what he viewed as a hierarchy of perfection based on physical and intellectual attributes to subgroups of humans with *Homo sapiens europaeus* (White) at the top and *Homo sapiens afer* (Black) at the bottom to justify slavery (Graves, 2003). Medical doctors forcefully developed surgical practices on slaves by holding them down and not giving them pain medicine (Washington, 2006). The United States Government employed eugenics and forced sterilizations on Native Americans as recently as the 1970s (J. Lawrence, 2000). Researchers conducting the Tuskegee syphilis study denied their Black participants the cure to syphilis for 25 years finally ending in 1974 (Brandt, 1978). This history has created a deep mistrust of science and medicine in Black communities (Corbie-Smith, 1999). Additionally, science as an institution has denied access, silenced, and exploited communities and individuals of color.

Science Education and Colorblind Ideology. Despite the long, troubling, and obviously cultural history of science and racism, science education usually regards science as acultural and objective; adopting a colorblind ideology which affectively sustains the status quo. Sheth (2019) explains four colorblind science teaching themes that continue to support racism. 1) Discussing racial differences in a genetics lesson without explicitly *disrupting* the idea that race is biological and not a cultural construct perpetuates racist ideas among students. It also ignores how students' connections to these concepts vary in their cultural meanings and have real consequences, which further others students of color. 2) Tokenizing scientists of color without addressing the structural racism that has limited the participation of People of Color supports ideas of meritocracy. 3) Presenting science as race-neutral wrongfully positions science as equally benefiting or harming all groups, regardless of race. 4) Using objectivity to teach science absent historical, social, and political contexts rather than including questions about ethics, justice, and how various positions and subjectivities inform the answers to these questions.

Culturally Responsive Science Education

Much of the work in culturally responsive science education focuses on bridging the culture of science and the cultures of students. This focus addresses the first two aspects of CRE given by Ladson-Billings (1995); increasing all students' success regardless of cultural differences and support cultural competence. However, fewer studies have addressed Ladson-Billings (1995) third aspect of culturally responsive teaching that helps students “develop a broader sociopolitical consciousness that allows them to critique the cultural norms, values, mores, and institutions that produce and maintain social inequities” (p. 162). Socioscientific issues are perfectly situated to accomplish Ladson-Billings’ third aspect of CRE (Mensah, 2011). Yet, little research about how to incorporate these two frameworks has been done.

Socioscientific Issues and Sociopolitical Consciousness

While science and society are often discussed as separate entities within SSI, it is important to note that this is not a reflection of researchers’ view of science being apart from society. Quite the opposite, because science is a human endeavor, it cannot be separated from society (Sadler, 2004b). Due to the nature of SSIs, they often reveal problems within science and society. For example, global warming has drawn attention to societal dependence on fossil fuels and the inability to place worry over the short-term economic concerns of mitigation attempts over the long-term impacts of global warming. While the wealthy and powerful often decide which solution (if any) to use, it is the poor and disenfranchised that most often suffer from issues such as climate change and environmental pollution because they lack the resources necessary to mitigate impacts. As such, SSIs tend to highlight who our society deems least worthy of, what should be, basic human rights.

For example, as I mentioned in the introduction, early studies show that Black individuals are more likely to be hospitalized and die from COVID-19 than White individuals (Garg et al., 2020). Urban heat islands (areas of higher temperature due to the change from vegetation to asphalt, concrete, and buildings which absorb more of the sun's energy) and lack of proper resources have caused disparities in the effects of global warming for People of Color as they are more likely to live in urban areas and have less wealth due to structural racism (Harlan et al., 2015). Because many SSIs shed light on these issues, science teachers can use SSIs to accomplish Ladson-Billings' third goal of CRE; helping students grow their sociopolitical consciousness that can be used to identify, critique, and change the social norms that produce and maintain inequities in our society. Similarly, the direct evidence of racial inequality that SSI's highlight may assist White preservice teachers in unlearning their colorblind ideologies.

Socioscientific Issues Teaching and Learning for Social Justice Framework: Promoting Sociopolitical Consciousness and Challenging Colorblind Ideologies

Developing a teaching framework that will potentially disrupt preservice teachers' colorblind ideologies and promote their sociopolitical consciousness using socioscientific issues involves taking the existing Socioscientific Issues Teaching and Learning (SSI-TL) framework by Sadler, Foulk, and colleagues (2016) as shown in Figure 1 and emphasizing social justice considerations (i.e., the complexity of racism, White privilege, self-reflection, and perspective-taking). For each element in the SSI-TL framework, I will first give a brief explanation of the original framework produced by

Sadler, Foulk, and colleagues (2016) shown in Figure 1, followed by a section that will explain how I am modifying the framework to promote sociopolitical consciousness in preservice teachers as shown in Figure 2. My modified SSI-TL framework is titled the Socioscientific Issues Teaching and Learning for Social Justice (SSI-SJ) framework shown in Figure 2.

SSI-TL. Sadler, Foulk and colleagues (2016) identify two main components of their SSI-TL framework 1) the sequence of learning experiences and 2) learning outcomes associated with SSI-TL. The first component (seen on the left side of the SSI-TL in Figure 1) is comprised of three main phases in sequence (encounter with the focal issue, engagement with the focal issue, and synthesis of key ideas and practices) followed by two components (opportunities to use information and communication technologies and opportunities for self-reflection) that should be integrated throughout the three main phases. Sadler, Foulk, and colleagues (2016) divide the learning outcomes into two sections 1) alignment with the national science standards, the *Next Generation Science Standards* (NGSS Lead States, 2013) and 2) learning objectives and learning goals associated with Roberts (2007) definition of "Vision II Scientific Literacy".

Figure 1: Socioscientific Issues Teaching and Learning framework (SSI-TL)

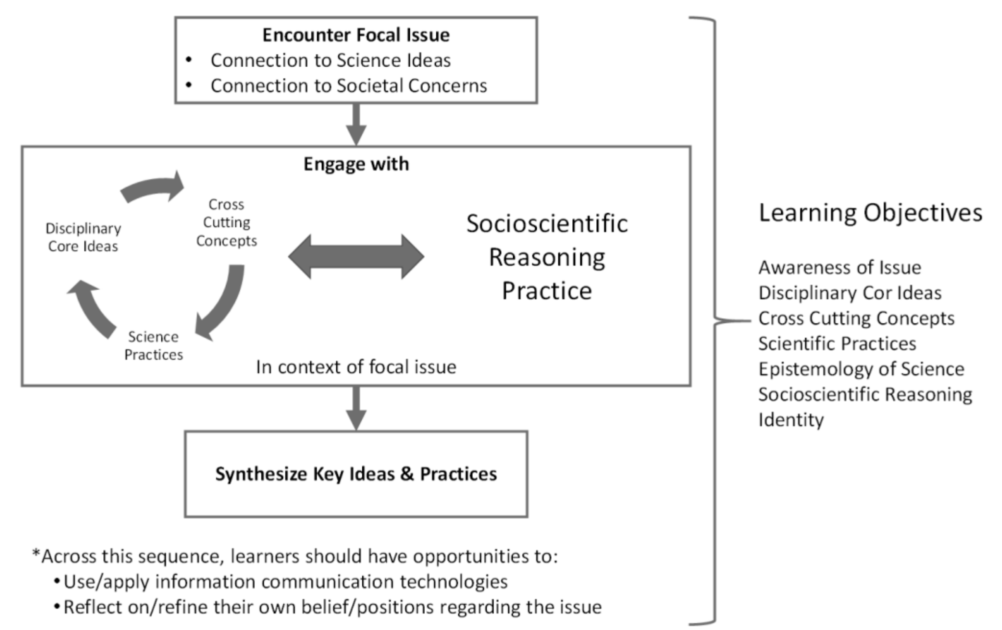
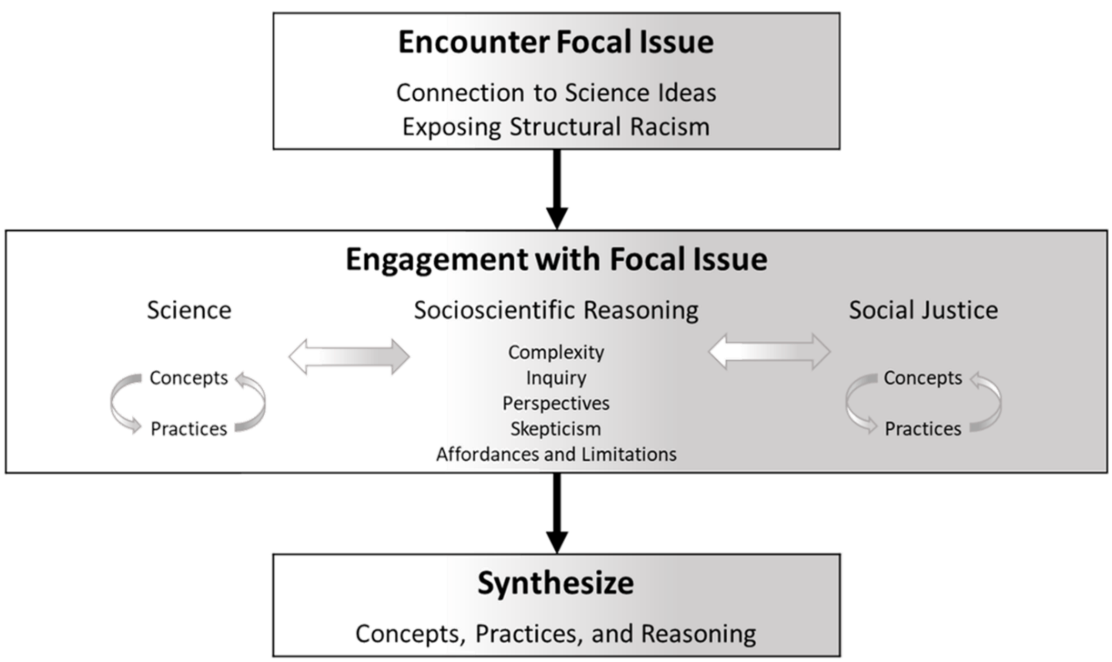


Figure 2: Socioscientific Issues Teaching and Learning for Social Justice framework



Encountering the Focal Issue. During this phase, students are first introduced to the socioscientific issue (e.g., showing a video clip from a contemporary news segment) as would occur within the SSI-TL. Through this introduction, students begin to experience how the issue is connected to science (ideas, principles, and/or practice) and what social considerations are at work within the issue. The SSI-SJ additionally includes sociopolitical consciousness during this phase by emphasizing how the issue disproportionately impacts People of Color and how White people, in turn, have gained advantages (i.e., COVID-19 transmission, hospitalizations, and deaths by race and/or initial testing site locations compared to neighborhood demographics). However, considering this is potentially the first experience in which students critically examine an SSI with an emphasis on social justice, placing Whiteness at the center of the issue might support White students in identifying their privilege. If a particular marginalized group was placed in the center, this could indicate they need saving, which could potentially promote deficit views of the group. For example, an individual could reframe their examination of the causes of structural racism with an examination of the causes of White Privilege. For example, changing the guiding question of "why are Black people are 4 times more likely than White people to die from COVID-19?" to "why are White people are 4 times less likely to die from COVID-19?". Followed by an opportunity for self-reflection and perspective taking.

Engagement with Focal Issues. The general goal of this phase does not change in the SSI-SJ, but the focus is directed at issues of social justice and inequality. Students spend the most time in the *engagement with the focal issue* phase. During this time, students engage with the three dimensions of the NGSS (i.e., disciplinary core ideas, science practices, and cross-cutting concepts) as they gain an understanding of the underlying science practices and concepts associated with the issue through science learning activities. Within the SSI-TL, students are guided to consider aspects of socioscientific reasoning (SSR), where they begin to make connections to the science and social considerations of the issue. I build on the SSI-TL to also make the aspects of Socioscientific reasoning (SSR) explicit with respect to social justice. In the following sections, I provide concise explanation of each SSR competency and how they are utilized within the SSI-SJ to promote sociopolitical consciousness.

Complexity. SSIs are inherently complex because they require understanding the issue through not just a scientific lens but social, cultural, political, economic, and/or historical (to name a few) and the interactions between these fields as well. Therefore, students engaging with SSI's should show an ability to understand and communicate these complexities as opposed to reducing them to simple cause and effect explanations. To promote sociopolitical consciousness in the SSI-SJ framework the complex nature of how structural racism compounds the impacts of the SSI on People of Color should be examined and, especially for White students, how the same structures create White privilege.

Multiple Perspectives. Another aspect that makes SSI's so complex are the many diverse positions one can have on the issue. Each perspective can be well-reasoned and well-meaning yet produce vastly different solutions to the SSI, reflecting the individual's priorities, values, and biases (Sadler et al., 2007). Students working within an SSI unit are encouraged to consider perspectives other than their own. However, when Sadler et al. considered biases, it was evident that his team was speaking primarily of biases as related to such things that are economic or political (e.g., oil companies economic biases when it comes to global warming) and not racial biases. Within the SSI-SJ framework, race-based perspectives would be highlighted as well and in conjunction with other types of perspectives. Teachers should give voice to and encourage students to consider the perspectives of racial group(s) that experience structural racism through the effects of the SSI. Additionally, students should consider and reflect on how race and racial biases may impact other types of perspectives around the issue, including their own.

Inquiry. Stakeholders involved with an SSI never have all the information required to make a fully informed decision because of the complex, ill-structured, and the ongoing investigative nature of SSI's (Barab et al., 2007). Not only is the science within SSI's often at the forefront of science and thus tentative, but the social, cultural, and economic impacts of a particular solution are regularly unknown and in need of further inquiry. Within the SSI-SJ, to promote sociopolitical consciousness, students should take part in inquiries into how specific groups of people are impacted (positively and negatively) by a solution.

Skepticism. A fair degree of skepticism is important when navigating information regarding SSIs, because there are many perspectives with differing solutions and their own biases. Information regarding SSIs that come from these different perspectives are bound to reflect their biases. Students need to be skeptical of the information they are viewing. Especially, in today's world of smartphones, Facebook, Twitter, and Google, information regardless of its validity is easily disseminated worldwide. Yet, when considering SSI's, it is imperative that students still consider other perspectives and review information from the internet/other media sources. This is precisely why a Sadler and others (2016) created a resource for supporting critical analysis of media. However, skepticism can be a dangerous deflection of individuals that deny the existence of White privilege. Most White people in the United States are skeptical that structural racism is a reality for Black people (Horowitz et al., 2019). Therefore, within the SSI-SJ, skepticism includes a direct discussion and considerations of the extent skepticism should be used in varying situations.

Affordances and Limitations of Science. SSIs are explicitly connected to social *and* scientific ways of knowing. As such, students need to consider and utilize other epistemologies beyond science when considering resolutions to these issues. They also need to understand what science can and cannot (or likely cannot) do. For example, some believe that science/engineering will invent a way to "fix" the climate and use this as a reason for inaction now. A major limitation of science in terms of social justice is its inability to inform moral judgements regarding an SSI, social considerations are often tapped for deciding what is right and wrong with respect to possible solutions. The SSI-SJ framework focuses on social justice by emphasizing the ability for science to uncover/highlight racial inequities, but sciences' inability to pass moral judgments, and sciences' often complicit history with racism.

Synthesis of Ideas and Practices. The final phase in the SSI-TL framework involves students integrating ideas and practices they have encountered and engaged with throughout the SSI unit into a culminating project (Sadler, Foulk, et al., 2016). Oftentimes this involves using science and socioscientific reasoning concepts and practices to generate or argue a solution to the issue while reflecting on their perspectives on the issue and how those perspectives might relate to their solution. Within the SSI-SJ, promoting sociopolitical consciousness involves emphasizing social justice-oriented solutions. Including reflections of how proposed solutions might impact individuals of varying racial perspectives especially those that are disproportionately impacted by the issue.

Additional Elements. There are two additional elements that Sadler, Foulk, and colleagues (2016) recommend utilizing throughout the SSI-TL framework; providing opportunities for students to gather information from contemporaneous media sources (e.g., news outlets, blogs/vlogs, and scientific literature) and opportunities for self-reflection of their beliefs and perspectives surrounding the issue. The SSI-SJ framework promotes sociopolitical consciousness by selecting media that present racial perspectives and using prompts that facilitate race reflection (Milner, 2003).

Learning Objectives. Sadler and colleagues present two types of learning goals; mainstream NGSS learning objectives (vision I) and learning objectives associated with vision II scientific literacy (Robert, 2007). While a focus on social justice would have strong connections with the latter which includes awareness of the issue, epistemology of science, SSR, and identity development, it is important to distinguish sociopolitical consciousness regarding racial equity as a standalone learning objective in the SSI-SJ. Such a learning objective reflects Ladson-Billings' (1995b) definition of sociopolitical consciousness to challenge the cultural norms, values, and institutions that create and maintain social inequities.

Summary

The Socioscientific Issues Teaching and Learning (SSI-TL) framework was modified and renamed the Socioscientific Issues Teaching and Learning for Social Justice (SSI-SJ) framework to take a deliberate step for science education to engage in culturally responsive education more fully. However, it is well documented that PSTs have barriers to teaching in culturally responsive ways; barriers such as colorblind ideologies and a lack of sociopolitical consciousness. The SSI-SJ was used in this study in attempt to breakdown these barriers that preservice elementary teachers have.

Chapter Three: Methods

Introduction

The purpose of this quantitative study is to determine if a pre-service elementary teacher science methods course that frames teaching science through the SSI of COVID-19 promotes preservice elementary teachers' sociopolitical consciousness, challenges their colorblind ideologies, and increases their socioscientific consciousness.

Due to limited resources, availability of participants, and the novel focus of this study it was appropriate to conduct a pre-experimental design. A pre-experimental design is a research method used to test if an intervention has the potential to cause a change in a limited study (e.g., small sample size), indicating whether the line of research is worth pursuing at a larger scale (Frey, 2018). Convenience sampling was used to select two groups of participants for this study. Participants first completed pre-test measures, then experienced an intervention (Table 1), and finally post-test measures. The following sections cover research context, participants, intervention design, data collection, and data analysis methods. An outline of the research questions and their associated data sources and analysis is in Table 2.

Research Context and Participants

The project took place in an elementary science methods course at a large Mid-western R1 university. This course was a one-semester course situated within a four-year undergraduate program for elementary teaching. Preservice teachers (PST) generally take this course during their junior year, and it is one of several methods courses they take (e.g., math, English language arts, art, social studies, and music). Importantly, I was the instructor of record and I have taught the elementary science methods course from fall 2018 to the time of the study, spring 2021. While teaching this course I often used the SSI-TL framework as a tool for course design. The SSI-TL framework supported my incorporation of socioscientific issues-based science instruction. It also provided the preservice teachers in my class a scaffold for science lesson development. However, this study was the first time I built onto this framework to add the Social Justice components for teaching science. For this study, I taught two sections of the elementary science methods course during the same semester. I taught the courses as identically as the different groups of students allowed. In each section, I included a nine-week unit (Table 1) where PSTs collaborated in small groups of 4-5 students to learn about the SSI-SJ framework and produce their own SSI based lessons during a science methods course for elementary preservice teachers. This was the only science method course the PSTs received during their undergraduate elementary education program. Due to the COVID-19 pandemic and the lack of a widely available vaccine at the point of implementation, teaching and learning took place entirely online. Each section met via an online video platform once a week for 1.5 hours (section 1 – Monday and section 2 – Fridays). Beyond our synchronous online class meeting, PSTs were expected to work on asynchronous aspects of the online course (e.g., readings, videos, assignments, group work etc.).

Enrollment in sections one and two of the elementary science methods courses was 24 and 27, respectively. Of these 51 students, all were working toward a Bachelor of Science in elementary education, 37 were juniors and 14 were seniors at the time of the study. Like previous semesters in the course, 92% (47) individuals were female and 8% (4) were male; 80% (41) were White, 8% (4) were Black, and 6% (3) were Hispanic. This majority White teacher education classroom is typical of elementary educations majors. The students enrolled in the course described where they lived prior to college as suburban (73%), rural (18%), and urban (10%).

Intervention Design

Table 1Table 1 contains an outline of the intervention unit and what the PSTs did during each phase of the unit. Each new subject (row) began with a discussion and example of the topic, The intervention unit had two levels of focus: PSTs as teachers and PSTs as students.

PSTs as teachers focus. The goal of the unit was to guide PSTs in their own creation of a lesson that utilized specific issues within the SSI of COVID-19 (i.e., masking and social distancing) to teach science. This was done by modeling for the PSTs an elementary SSI lesson that focused on the issue of the decline of the monarch butterfly. Teacher decisions with regards to the planning of the lesson were made visible to the PST and supporting videos of student learning within the unit were used to mimic real world classroom experiences.

To create their own units, small groups of PSTs (4-5 individuals) first used the SSI-TL framework to create a unit focused on COVID-19. Due to time and course structure constraints, I provided the SSI-SJ framework as an option (but not a requirement) for use while creating their COVID-19 lessons. PSTs used backward design to create their units, starting with creating a driving question (e.g., should masks be required in our classroom?) and a corresponding culminating activity (e.g., creating an info graphic in support of/opposition to a particular solution) regarding the issue, then determining the science explanations students would need to complete the culminating activity (e.g., NGSS DCI PS1.A: Structure and Properties of Matter), then decided on the experiences/evidence/data/information their elementary students would need to create explanations. Finally, PSTs developed how they would initially present the issue/driving question to their students.

PSTs as students focus. When teaching the SSI to students, I used the SSI-SJ frameworks so that PSTs could consider (as learners) the broader social justice issues regarding the COVID-19 pandemic. During the PSTs as students focus of the intervention, the class reviewed the evidence of inequity highlighted by the COVID-19 pandemic, considered the root causes of these inequities, and considered others' perspectives of the issue. PSTs were also given a chance to reflect on their own perspective and how it may differ from others.

Data Collection Timeline

Data collection occurred in two phases, pre- and post-intervention. Before the intervention demographic data was collected. I administered two different instruments (CoBRAS-SSI and QuASSR-SJ both described below) prior to and following the intervention using online Qualtrics survey software. Causal maps were also assigned pre- and post-intervention and collected through Canvas. A detailed data collection intervention timeline is in Table 1.

Table 1: Intervention Outline

Week number(s) and Topic	**Description** ○ PSTs as Teachers ▪ PSTs as Students ✓ Data items *New aspects of methods course curriculum implemented during the semester of this study are noted in italics*
Weeks 1-4: Normal beginning of semester (introduction to teaching science and the NGSS)	✓ Demographics ✓ Pre-tests implemented prior to intervention: QuASSR-SJ and CoBRAS-SSI
Week 5: Introduction to SSIs	○ Discussion about the definition and examples of socioscientific issues ○ Small groups considered what the potential benefits of teaching science through a socioscientific issue might be ▪ Considering the complexity of SSIs: Causal map introduction ✓ Assignment: COVID-19 causal map

Week number(s) and Topic	**Description** ○ PSTs as Teachers ▪ PSTs as Students ✓ Data items *New aspects of methods course curriculum implemented during the semester of this study are noted in italics*
Week 6: Introduction to SSI-TL framework	○ PSTs were introduced to the SSI-TL framework ○ Small groups used their causal map assignment to make connections between COVID-19 and Next Generation Science Standard's Disciplinary Core Ideas

Week 7: Selecting DCI(s) and Driving Questions	○ *Small groups considered how you can take the larger issue of COVID-19 and create an issue, question, or problem statement that could drive a science unit that focuses on COVID-19 and the impacts at the local, neighborhood, small community, school, and/or classroom level*
	▪ *PSTs were introduced to the SSI-SJ framework*
	▪ *PSTs introduced to social justice issues highlighted by COVID-19*
	    ▪ *Risk for COVID-19 Infection, Hospitalization, and Death by Race/Ethnicity* (CDC, 2021a)
	    ▪ *Health Equity Considerations and Racial and Ethnic Minority Groups* (CDC, 2021b)
	○ Small groups created a list of possible culminating activities; given science ideas, social considerations, and their driving question
	✓ Assignment: COVID-19 causal map update and reflection on perspectives

Week number(s) and Topic	**Description** ○ PSTs as Teachers ▪ PSTs as Students ✓ Data items *New aspects of methods course curriculum implemented during the semester of this study are noted in italics*

Week 8: Creating a Culminating Activity	○ PSTs created a driving question for their unit that students will respond to in the culminating activity along with potential perspectives regarding the question
	○ PSTs developed a prompt for their culminating activity
	▪ *PSTs further investigated social justice issues highlighted by COVID-19*
	  ▪ *How Herd Immunity Works — And What Stands in Its Way* (Thomas Wildburn & Richard Harris, 2021)
	  ▪ *Consider This from NPR: Who's Getting Vaccinated and Who Isn't: NPR Analysis Finds Stark Racial Divide* (Ashley Lopez et al., 2021)

Weeks 9-11: Engagement with the focal issue (Science)	○ Small groups considered what students need to know (DCI) and be able to do (practice) to complete their culminating activity ○ Small groups decided how students would explain what they know ○ Small groups developed experiences for students to collect data/information so they can construct explanations and be given the opportunity to do the practices

Week number(s) and Topic	Description ○ PSTs as Teachers ▪ PSTs as Students ✓ Data items *New aspects of methods course curriculum implemented during the semester of this study are noted in italics*

Weeks 12-13: Engagement with the focal issue (Social)	○ Small groups brainstormed social aspects of their driving question and possible experiences to give students that would have them consider these social aspects
	▪ *Overview of science/science education and racism*
	▪ *Discussion of COVID-19 inequalities as presented in the following media:*
	  ▪ *The Atlantic: The Coronavirus Pandemic Will Cleave America in Two* (Joe Pinsker, 2020)
	  ▪ *Community Pulse from KOPN: Racial Disparities Highlighted by Coronavirus* (Elizabeth Allemann & Traci Wilson-Kleekamp, 2020)
	  ▪ *Consider This from NPR: Masks Are Even More Important Than We Thought* (Kelly Mcevers, 2020)
	  ▪ *Code Switch from NPR: A Shot in The Dark* (Gene Demby, 2021)
	  ▪ *The Daily from The New York Times: The Pandemic Economy in 7 Numbers* (Michael Barbaro, 2020)

Week number(s) and Topic	**Description** ○ PSTs as Teachers ▪ PSTs as Students ✓ Data items *New aspects of methods course curriculum implemented during the semester of this study are noted in italics*
Week 14: Encountering the Focal Issue	○ Small groups determined how they would present the driving question and get students' initial responses, identify students' prior knowledge and misconceptions, and get students interested ✓ Assignment: Final COVID-19 causal map ✓ Post-tests implemented after intervention: QuASSR-SJ and CoBRAS-SSI

Data Collection

Each of the three main constructs of interest in this study (colorblind ideology, socioscientific reasoning, and sociopolitical consciousness) align with one of the three research questions:

Research Question 1: Do elementary preservice teachers' colorblind ideologies change while using an SSI unit across a semester?

Research Question 2: Do elementary preservice teachers' socioscientific reasoning skills change while using an SSI unit across a semester?

Research Question 3: Do elementary preservice teachers develop sociopolitical consciousness through an SSI unit across a semester? Can a change in sociopolitical consciousness be predicted by preservice teachers' colorblind ideologies and socioscientific reasoning skills?

Data was collected to assess PSTs in each of these three constructs. A version of the instrument, the Color-Blind Racial Attitudes Scale ([CoBRAS] Neville, Lilly, Duran, Lee, & Browne, 2000; Appendix A) was modified to include environmental racism and used to measure participants' colorblind ideologies. The second instrument, a version of the Quantitative Assessment of Socio-Scientific Reasoning – open-ended ([QuASSR-oe2];Romine, Sadler, & Kinslow, 2017; Appendix B) was modified to include a racial consideration and used to assess participants' SSR skills. Finally, to assess one aspect of sociopolitical consciousness, an individual's knowledge of social considerations influencing the society, participants created causal maps (Appendix C). While the other aspect of sociopolitical consciousness (i.e., willingness to act in response to this knowledge) would have been of interest, this study was limited in its ability to assess such a construct in any meaningful manner as we only met online, and the study took place over a short period during the COVID-19 pandemic. The following is a description of each data collection tool and how the data collection tools were developed and/or modified.

Color-Blind Racial Attitudes Scale. The components within CoBRAS, as noted by Neville et al. (2000), include racial privilege, institutional discrimination, and blatant racial discrimination. Each component is assessed using 6-7 items where participants respond to a statement using a 6-point Likert scale (1 = strongly agree; 6 = strongly disagree). Nearly a third of the items are reverse coded to determine if participants are satisficing. This instrument does not include contexts associated with environmental racism, a specific type of structural racism that is often highlighted by SSIs, which was of interest here. I use the definition of Environmental racism, by Bullard (2018) as public policies and industry practices that disproportionately shift the negative impacts of pollution and environmental hazards to communities of Color. To address environmental racism, I added six questions to the original CoBRAS (see Appendix A). The format and tone of these questions were written to match the original questions and the content was determined through a review of relevant literature about the causes and outcomes of environmental racism (Bell & Ebisu, 2012; Bryant & Mohai, 2019; Tobin, 2015). These questions constitute a fourth factor that I call Unawareness of Environmental Racism. I have named this modified CoBRAS the Color-Blind Racial Attitudes Scale – Socioscientific Issues (CoBRAS – SSI).

Quantitative Assessment of Socio-Scientific Reasoning. The QuASSR-oe2 assesses the components of SSR: complexity, perspectives, inquiry, skepticism, and affordances and limitations of science. There are multiple published QuASSR instruments (Kinslow, 2018; Kinslow et al., 2019; Romine et al., 2017). Each version is modified for a specific SSI (e.g., debate over the release of genetically modified mosquitoes, who should pay to clean water due to agricultural practices, and the debate over fracking) and type of questions – open ended or Likert. Each QuASSR begins with text that explains the science behind the issue and at least two conflicting perspectives followed by prompts to assess each of the SSR components. The open-ended aspect of the QuASSR-oe2 was of particular use here, as it has the potential of measuring another variable not originally designed for the QuASSR-oe2 - how racial considerations are used throughout students' socioscientific reasoning.

However, none of the current versions of the QuASSR depicted an SSI that could be viewed through a racial social justice lens. As such, I have modified the Pavilion Wyoming Fracking QuASSR (Romine et al., 2017) to include a racial social justice perspective. I made minor changes to this QuASSR to highlight social justice considerations by changing the location to a similar real-world SSI in Arlington Texas. The original Wyoming Fracking QuASSR opened with the following:

> *Pavilion is a town in Wyoming located in the west central part of the state. Pavilion has a population of 240 people and is situated near a site where hydraulic fracturing (or "fracking") of natural gas takes place.*

Which I modified to:

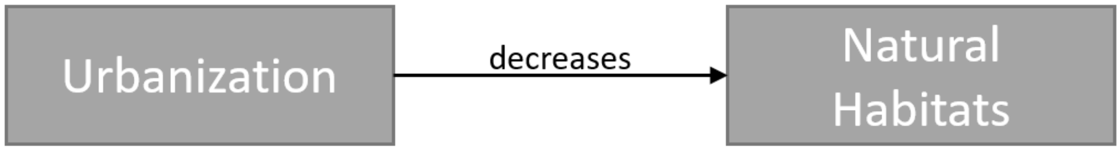
> *Arlington is a city in Texas west of Dallas. A neighborhood of predominantly Black and Hispanic working-class families in East Arlington is situated near a site where hydraulic fracturing (or "fracking") of natural gas takes place.*

Additionally, the original Pavilion Wyoming Fracking QuASSR used Likert responses for each prompt. I changed the prompts to match the QuASSR-oe2 to gleam a deeper understanding about student's SSR regarding environmental justice. I call this modified instrument the QuASSR - social justice (QuASSR-SJ). It is found in Appendix B.

Causal Map. PSTs created causal maps before and after the intervention to demonstrate their sociopolitical consciousness regarding what they knew about the COVID-19 pandemic. The prompt for the causal map (appendix C) was created using Jonassen and Strobel's (2006) explanation of how to coach students in the construction of causal maps. PSTs were first shown an example of a causal map (Figure 9) for the SSI of urbanization and monarch butterfly decline. During this example, PSTs were shown how to produce a causal map, the structure of maps (nodes and links), and they were given a list of possible linking words.

The prompt scaffolded PSTs through the planning and creation of their causal maps. First, they were to establish their perspective in creating their map (i.e., someone trying to reduce the spread of COVID-19) and determine what major aspects they were to consider (i.e., science and social considerations). Next, they identified the social and scientific concepts they believed to be pertinent (i.e., vaccines, masking, specific impacts on the economy and education, etc.) and made nodes (shapes containing a description of the concepts). Lastly, they connected their concept nodes with causal links, arrows with descriptive word(s) that explained the causal relationship between the two concept nodes. An example given to PSTs is in Figure 3 which explains that urbanization (node) causes a decrease (causal link between the nodes) in natural habitats (node). The complete causal map for Figure 3 is found in Figure 9 of Appendix C.

Figure 3: Example Concept Nodes Connected by a Causal Link



Data Analysis

My dual identities as the instructor of the course and a researcher required me to take a precaution to partition the research and instruction of the course; no data was viewed nor used as analysis towards research until after final grades were submitted for the course. At this time, RStudio (R Core Team, 2020) was used to determine the validity of all data analysis tools above, item response theory for Likert items and Kohen's Cappa for open ended items that were scored. RStudio (R Core Team, 2020) was also used to run linear mixed effects models to assess the three research questions.

Color-Blind Racial Attitudes Scale – Socioscientific Issues. Item response theory (IRT) was used to score student responses to the CoBRAS-SSI. IRT was chosen over classical test theory because the latter does not handle variation in item difficulty as scores are generally the sum of the correct response. The primary advantages of IRT scaled scores over classical test theory is that items are weighted based on their discriminating powers, they have more accurate standard errors, scores are on the same scale as item difficulties, and scores can be compared even when the number of items differ (R. J. de Ayala, 2013).

IRT models place each test item on a difficulty scale, which is equivalent to the person trait scale, a continuum of the level of the latent variable being measured (e.g., proficiency or level). Theta represents an individual's location on the continuum and delta represents a single item's location on the continuum. An individual's theta can be predicted by how they respond to various items with different delta values along the spectrum. Theta is generally shown as a standardized z-score where a theta of zero is the mean of the latent trait and a theta of 0.85 is nearly 1 standard deviation above the mean. For a dichotomous item, if a person's theta equals the item's difficulty, then there are equal odds of either response. Each item also has a value that identifies how well it can discriminate between individuals with different *thetas*. For Likert type data, the IRT model follows a similar structure with the separation between each response choice having its own values like those of dichotomous items (difficulty and discrimination).

CoBRAS-SSI scaled scores were calculated using the mirt package (Chalmers, 2012). The mirt package was chosen because it provides the statistical equations used to create IRT scores utilizing the Bayes estimation scaled scores method (Embretson & Reise, 2013).

Quantitative Assessment of Socio-Scientific Reasoning. The QuASSR-SJ is an open response measure, so student responses were scored using the QuASSR-oe2 scoring rubric (Appendix B, Womack, 2019). I was the co-scorer for the validation of this rubric during Womack's (2019) dissertation. We established a Cohen's Kapa of 0.88, indicating near perfect agreement. Considering my prior established inter-rater reliability using this rubric, it was not necessary for the current study to reestablish this measure with another researcher.

Casual Map. The rubric for scoring causal maps was developed in collaboration with Dr. Laura Zangori and can be found in Appendix C. The rubric considers four aspects: type of racism included (if any), science explanation, complexity of social consideration by type (e.g., education, political, racial, etc.), causal reasoning, and systems reasonings. The type of racism item was coded as nominal data and included: racial privilege, institutional discrimination, blatant racism, environmental racism, vague, and none. All other items were scored on an ordinal four-point scale.

Inter-rater reliability (IRR) was established through co-coding with S. Otto, a fellow graduate student. From our co-coding, I calculated the consistency of the rubric. We performed multiple iterations of blind scoring of a random subset of causal maps. After each round, IRR was calculated, discrepancies were flagged, and raters discussed these discrepancies with the purpose of altering the rubric for better validity. Once an IRR of 0.875 was reached, indicating almost perfect agreement (Landis & Koch, 1977), I scored the remaining causal maps.

Linear Mixed-Effects Regression Modeling

Table 2 is an outline of data sources and data analysis methods for each research question. As an exploratory design, power analysis was not performed, as the study attempted to assess the possibility of a causal relationship between the outcomes and the intervention, and I was willing to make a type II error in my attempt at this – accepting the null hypothesis when it should be rejected.

Table 2: Data Information

Research Question	**Data Source(s)**	**Analysis Strategy**
RQ1	Pre-CoBRAS-SSI Post-CoBRAS-SSI	• Linear Mixed Effects Model
RQ2	Pre-QuASSR-SJ Post-QuASSR-SJ	• Linear Mixed Effects Model
RQ3	Pre-Causal Map Post-Causal Map Pre-CoBRAS-SSI Pre-QuASSR-SJ	• Linear Mixed Effects Model • Summary Statistics • Exemplars

The primary statistical analysis method chosen for all three research questions is Linear Mixed-Effects Regression Models (LMER; Bates et al., 2015). LMER is an extension of linear regression that allows random effects in addition to the normal fixed effects of linear regression. Random effects are introduced in the model when values within a grouping variable (PSTs in this case) are allowed to vary with regards to their intercept (PSTs' start position), slope (PSTs' growth), or both intercept and slope. LMER is especially useful when data violate the assumption of independence for linear regression models, for example, in longitudinal studies an individual's scores are not independent from one another because the scores represent the same individual. Allowing individuals to vary with regards to their intercept and/or slope (random effects) solves the violation of independence by inserting individual models within the regression model that accounts for all individuals, fixed effects.

For each research question, time (level one) was nested within individuals (level two). The lmerTest package (Kuznetsova et al., 2017) with the lmer() function was used to create the models within R (R Core Team, 2020) for all analyses. Each model implemented a single random effect, the intercept, while keeping slopes fixed. Slopes were not added as a random effect (not allowed to vary by individual) because LMER models require more values within level one (time points in this case) than the number of random effects. This created a linear regression for each PST where they were allowed to have different intercepts, or starting positions, but were required to have the same slopes, or growth over time. Equation 1 shows an intercept LMER model where the β coefficients are the fixed effects, the b coefficient is the random effect, ϵ is the error term, the i subscripts index the level two variable (individual), and the j subscripts index the level one variable (time).

Equation 1: Generic Random Intercept LMER Model

$$Y_{ij} = \beta_0 + \beta_1(X_{ij}) + b_{0i} + \epsilon_{ij}$$

The following overviews each research question with its corresponding LMER model equation. Beyond what is shown in the following equations, demographic data (gender, race/ethnicity, and location where PST grew up) was also included as a predictor in each equation to control for potential group differences. All variables of interest, except time, were standardized to account for differences in scales, making the output easier to interpret. The standardization of the scores to z-scores results in a mean of zero and a standard deviation of one.

Research Question 1: Equation 2 was created to assess how preservice teachers' colorblind ideologies (CB) changed while using an SSI unit across a semester (TIME). The hypothesis for research question one was that there was a statistically significant (p<0.05) decrease in preservice teachers' colorblind ideologies while using an SSI unit across the semester.

Equation 2: Colorblind Ideology LMER Model

$$CB_{ij} = \beta_0 + \beta_1(TIME_{ij}) + \beta_{0i} + \epsilon_{ij}$$

Research Question 2: Equation 3 was created to assess how preservice teachers' socioscientific reasoning skills (SSR) change while using an SSI unit across a semester (TIME). The hypothesis for research question two was that there was a statistically significant (p<0.05) increase in preservice teachers' socioscientific reasoning while using an SSI unit across the semester.

Equation 3: Socioscientific Reasoning LMER Model

$$SSR_{ij} = \beta_0 + \beta_1(TIME_{ij}) + b_{0i} + \epsilon_{ij}$$

Research Question 3: This research question was evaluated through two different equations. Equation 4 was created to assess how preservice teachers' sociopolitical consciousness (SPC) with regards to the COVID-19 pandemic change while using an SSI unit across a semester (TIME). The hypothesis for this aspect of research question three was that there was a statistically significant (p<0.05) increase in preservice teachers' sociopolitical consciousness while using an SSI unit across the semester.

Equation 4: Sociopolitical Consciousness LMER Model

$$SPC_{ij} = \beta_0 + \beta_1(TIME_{ij}) + b_{0i} + \epsilon_{ij}$$

Equation 5 was created to further assess how preservice teachers' initial socioscientific reasoning components, initial colorblind ideologies factor scores, and time predict sociopolitical consciousness across the semester (TIME). SSR components include complexity (comp), perspectives taking (pers), inquiry (inq), skepticism or the nature of science ($skep_{nos}$), skepticism of media ($skep_{media}$), and affordances (aff) and limitations (lim) of science. The colorblind factors include unawareness of racial privilege (priv), unawareness of institutional discrimination (inst), unawareness to blatant racial issues (blat), unawareness of environmental racism (envi). The hypothesis for this aspect of research question three was that some of the components of SSR and/or the colorblind ideology factor scores statistically significantly predicted (p<0.05) preservice teachers' sociopolitical consciousness scores, with a negative relationship between colorblind ideologies and sociopolitical consciousness and a positive relationship between SSR and sociopolitical consciousness.

Equation 5: Sociopolitical Consciousness LMER Model

$$
\begin{aligned}
SPC_{ij} = \quad & \beta_0 + \beta_1(TIME_{ij}) \\
& + \beta_2(lim_{ij}) + \beta_3(aff_{ij}) + \beta_4\left(skep_{nos_{ij}}\right) + \beta_5\left(skep_{media_{ij}}\right) \\
& + \beta_6(inq_{ij}) + \beta_7(comp_{ij}) + \beta_8(pers_{ij}) + \beta_9(priv_{ij}) + \beta_{10}(inst_{ij}) \\
& + \beta_{11}(blat_{ij}) + \beta_{12}(envi_{ij}) + b_{0i} + \epsilon_{ij}
\end{aligned}
$$

Once the models were created and outputs completed, diagnostics were done on all analysis. Residuals were used to check linearity, examined for outliers, assessed normality, examined influential observations, and checked the assumption of homogeneity. Additionally, multicollinearity was assessed. No violations of the assumptions for LMER were found for any of the models.

Chapter Four: Results

The analysis reveals the extent to which the hypotheses for each research question was supported or not supported. Showing how preservice teachers grew or did not grow through the semester with respects to their colorblind ideologies, socioscientific reasoning, and sociopolitical consciousness. The analysis also attempts to look at how preservice teachers' colorblind ideologies and socioscientific reasoning predicts an individual's sociopolitical consciousness.

Did Preservice Teachers' Colorblind Ideologies Change?

The results of LMER models predictions on how preservice colorblind ideologies changed over the semester are in Table 3 through Table 7. Table 3 predicts preservice teacher's total colorblind ideology scores. This model indicates that there was no statistically significant difference of preservice teacher's total colorblind ideologies scores over time ($p>0.05$). This finding does not support the hypothesis that colorblind ideologies would decrease from pre- to post-intervention.

Table 3: LMER Results for Change in Total Colorblind Ideology Scores Across the Semester

Total Colorblind Ideology Score			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.05	-0.43 – 0.52	0.85
Time	0.00	-0.23 – 0.23	0.99
Random Effects			
σ^2	0.32		
τ_{00}	0.73 $_{id}$		
ICC	0.69		
N	51 $_{id}$		
Observations	100		
Conditional R^2	0.72		

While the results for the total colorblind ideology scores over time are not surprising, further LMER models were run to show that this lack of change over time in the total score was not due to offsetting increases and decreases in the individual component scores within the CoBRAS (for example if PSTs decreased in their unawareness of structural racism and increased in their unawareness of racial privilege creating a net zero change). A model was run to test if each of the four components of the CoBRAS (unawareness of racial privilege, institutional discrimination, blatant racial discrimination, and environmental racism) changed over the semester. The estimate for the model predicting change in unawareness of racial privilege (Table 4) was nearly zero (-0.01 standard deviation) and not statistically significant ($p>0.05$) indicating that the PSTs did not change in their unawareness of racial privilege. The estimates for the models predicting change in unawareness of institutional discrimination (Table 5) and blatant racism (Table 6) were positive (0.08 and 0.09 standard deviations respectively) indicating that PSTs actually increased in their colorblind ideologies with respect to these factors. However, these increases were not statistically significant (p>0.05), meaning they were likely due to chance. The estimate for the model predicting change in unawareness of environmental racism (Table 7) shows a reduction (-0.13 standard deviation) in the colorblindness of this component for preservice teachers over time; however, this was also not statistically significant (p>0.05).

Table 4: LMER Results for Change in Unawareness of Racial Privilege Scores Across the Semester

Unawareness of Racial Privilege			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.11	-0.34 – 0.55	0.63
Time	-0.01	-0.21 – 0.18	0.88
Random Effects			
σ^2	0.24		
τ_{00}	0.80 $_{id}$		
ICC	0.77		
N	51 $_{id}$		
Observations	100		
Conditional R^2	0.79		

Table 5: LMER Results for Change in Unawareness of Institutional Discrimination Scores Across the Semester

Unawareness of Institutional Discrimination			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.01	-0.48 – 0.46	0.96
Time	0.08	-0.15 – 0.31	0.48
Random Effects			
σ^2	0.32		
τ_{00}	0.68 $_{id}$		
ICC	0.68		
N	51 $_{id}$		
Observations	100		
Conditional R^2	0.71		

Table 6: LMER Results for Change in Unawareness of Blatant Racial Issues Scores Across the Semester

Unawareness of Blatant Racial Issues			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.12	-0.66 – 0.42	0.66
Time	0.09	-0.20 – 0.39	0.55
Random Effects			
σ^2	0.55		
τ_{00}	0.53 $_{id}$		
ICC	0.49		
N	51 $_{id}$		
Observations	100		
Conditional R^2	0.51		

Table 7: LMER Results for Change in Unawareness of Environmental Racism Scores Across the Semester

Unawareness of Environmental Racism			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.16	-0.35 – 0.67	0.54
Time	-0.13	-0.41 – 0.14	0.34
Random Effects			
σ^2	0.48		
τ_{00}	0.50 $_{id}$		
ICC	0.51		
N	51 $_{id}$		
Observations	100		
Conditional R^2	0.57		

Did Preservice Teachers' Socioscientific Reasoning Change?

The results of LMER models predicting how preservice socioscientific reasoning (SSR) changed over the semester are presented in Table 8-Table 15. Predictions on how preservice teacher's total SSR change over the semester can be seen in Table 8. The estimate for time in this model indicates a 0.14 standard deviation increase; indicating that PSTs' socioscientific reasoning skills increased over the semester, but this estimate is not statistically significant ($p>0.05$). This finding does not support the hypothesis that SSR increased from pre- to post-intervention.

Table 8: LMER Results for Change in Total Socioscientific Reasoning Scores Across the Semester

Total Socioscientific Reasoning Score			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.08	-0.63 – 0.48	0.78
Time	0.14	-0.18 – 0.46	0.38
Random Effects			
σ^2	0.6		
τ_{00}	0.36 $_{id}$		
ICC	0.38		
N	51 $_{id}$		
Observations	96		
Conditional R^2	0.45		

Six additional models were run to predict each of the SSR component scores over time (Table 9-Table 15). However, two of these models, complexity (Table 9) and limitations of science (Table 15), were not able to fit the random effects portion of the LMER model due to nominal variation in the small number of participants. Instead, a one tailed paired t-test was used to see if scores at the end of the course were larger than scores at the beginning. Results for complexity, inquiry, perspective taking, skepticism in science, skepticism in media, and affordances of science indicate that there was no change over time for these SSR components ($p>0.05$). The only SSR component that showed growth from pre to post were preservice teachers' limitations of science scores. The one tailed paired t-test results (Table 15) indicate that the increase of 0.55 points from pre to post for limitation of science scores was statistically significant ($p<0.05$).

Table 9: One Tailed Paired T-Test Results for Change in Complexity Scores Across the Semester

Complexity		
Mean Difference	*95% Confidence Interval*	*p*
0.13	> -0.36	0.33

Table 10: LMER Results for Change in Inquiry Scores Across the Semester

Inquiry			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.01	-0.53 – 0.55	0.98
Time	0.17	-0.14 – 0.48	0.28
Random Effects			
σ^2	0.57		
τ_{00}	0.34 id		
ICC	0.37		
N	51 id		
Observations	96		
Conditional R^2	0.48		

Table 11: LMER Results for Change in Perspective Taking Scores Across the Semester

Perspective Taking			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.34	-0.25 – 0.92	0.26
Time	-0.13	-0.48 – 0.23	0.48
Random Effects			
σ^2	0.75		
τ_{00}	0.18 id		
ICC	0.19		
N	51 id		
Observations	96		
Conditional R^2	0.31		

Table 12: LMER Results for Change in Skepticism of Media Scores Across the Semester

Skepticism of Media			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.08	-0.48 – 0.64	0.78
Time	-0.02	-0.35 – 0.31	0.91
Random Effects			
σ^2	0.63		
τ_{00}	0.34 $_{id}$		
ICC	0.35		
N	51 $_{id}$		
Observations	96		
Conditional R^2	0.42		

Table 13: LMER Results for Change in Skepticism of Science Scores Across the Semester

Skepticism of Science			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.04	-0.64 – 0.56	0.90
Time	-0.01	-0.37 – 0.34	0.94
Random Effects			
σ^2	0.74		
τ_{00}	0.32 $_{id}$		
ICC	0.30		
N	51 $_{id}$		
Observations	96		
Conditional R^2	0.33		

Table 14: LMER Results for Change in Affordances of Science Scores Across the Semester

Affordances of Science			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	0.26	-0.34 – 0.86	0.39
Time	-0.22	-0.58 – 0.14	0.22
Random Effects			
σ^2	0.78		
τ_{00}	0.17 $_{id}$		
ICC	0.18		
N	51 $_{id}$		
Observations	96		
Conditional R^2	0.29		

Table 15: One Tailed Paired T-Test Results for Change in Limitations of Science Scores Across the Semester

Limitations of Science		
Mean Difference	*95% Confidence Interval*	*p*
0.56	> 0.24	0.002

Did Preservice Teachers' Sociopolitical Consciousness Change?

The results of the LMER model used to predict preservice teachers' sociopolitical consciousness scores as measured by their causal maps is presented in Table 16. The results show a statistically significant (p<0.05) increase of 0.30 standard deviations over the course. While these findings support the hypothesis that preservice teachers' sociopolitical consciousness scores would increase from pre- to post-intervention, there are some important caveats that come with this finding.

Table 16: LMER Results for Change in Sociopolitical Consciousness Causal Map Scores Across the Semester

Sociopolitical Consciousness Causal Map Score			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.28	-0.80 – 0.24	0.29
Time	0.30	0.02 – 0.59	**0.04**
Random Effects			
σ^2	0.52		
τ_{00}	0.45		
ICC	0.47		
N	50		
Observations	100		
Conditional R^2	0.54		

While this change is statistically significant, it is minimal. Of the 50 students that completed pre- and post-causal maps, only 14 (28%) included racial justice considerations. Figure 4 shows how these 14 PSTs changed through the course of the semester. The highest score these 14 PSTs received was a 2 on the 3-point scoring rubric This suggests that they never considered how to mitigate these issues as this was required to score a 3; however, they did identify them in vague ways. As seen in Table 17, PSTs were vague in their inclusion of racial justice considerations such as merely mentioning the Black Lives Matter movement without context as seen in Figure 5 or only considered blatant racism such as, physical violence on Asian Americans as seen in Figure 6. The few PSTs that did include considerations of institutional discrimination, environmental racism, or structural racism, did so without considering how changes might be made to reduce such racism. For example, in Figure 7, one PST identified how "minorities" received less health care treatment and suffered from higher transmission rates and deaths due to COVID-19, but never considered how to lower transmission rates or increase health care treatment to these groups.

Of the 14 PSTs that included race, 5 maintained the same sociopolitical score from pre to post, 7 increased from pre to post, and 2 lowered their score by removing their racial considerations from pre to post. For example, PST 14 stated that there is "Different Impacts on racial groups" due to COVID-19 on their pre-causal map, and on the post-causal map, they replaced this statement with "Impacts all people" (Figure 8), a common retort to the Black Lives Matter movement.

Figure 4: Change in Individual Preservice Teacher's Sociopolitical Consciousness Scores

Table 17: Summary of Types of Racial Justice Issues Included in PSTs' Causal Maps

Racial Justice Issue	Pre-Causal Map	Post-Causal Map
None	43	38
Vague	5	5
Blatant Racism	2	4
Institutional Discrimination	0	3

Figure 5: PST 6's Post-Causal Map

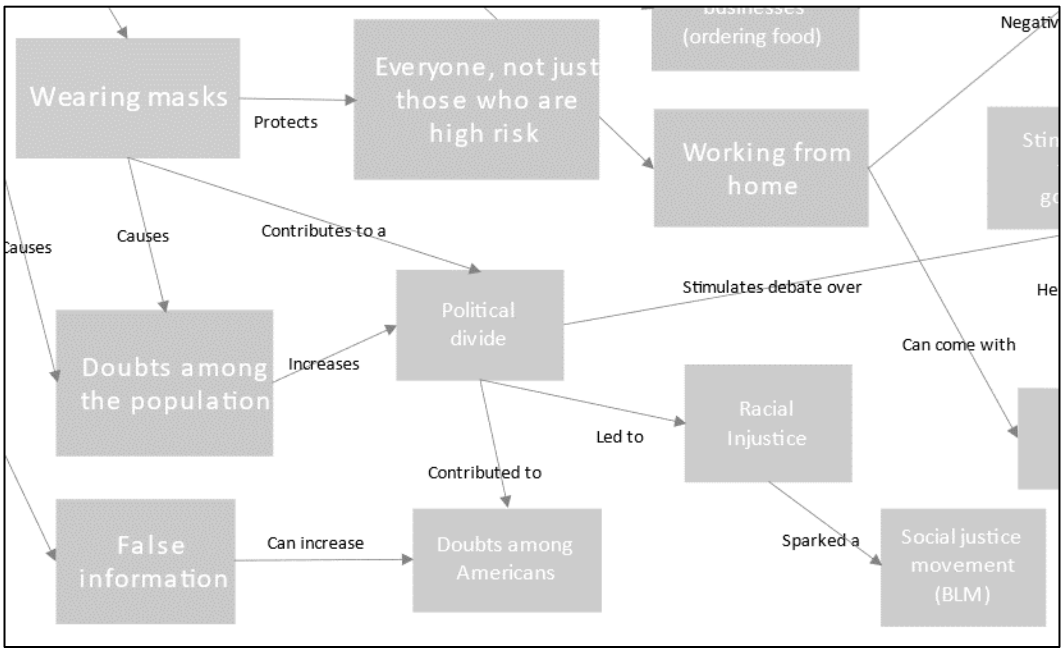


Figure 6: PST 41's Post-Causal Map

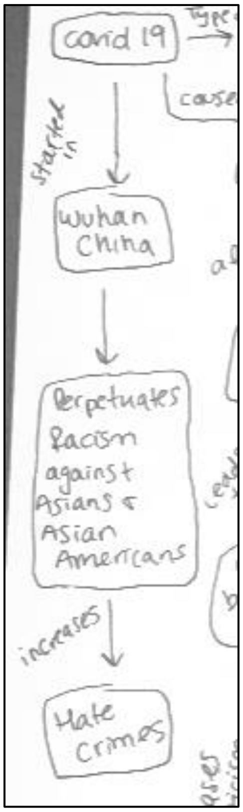


Figure 7: PST 30's Post-Causal Map

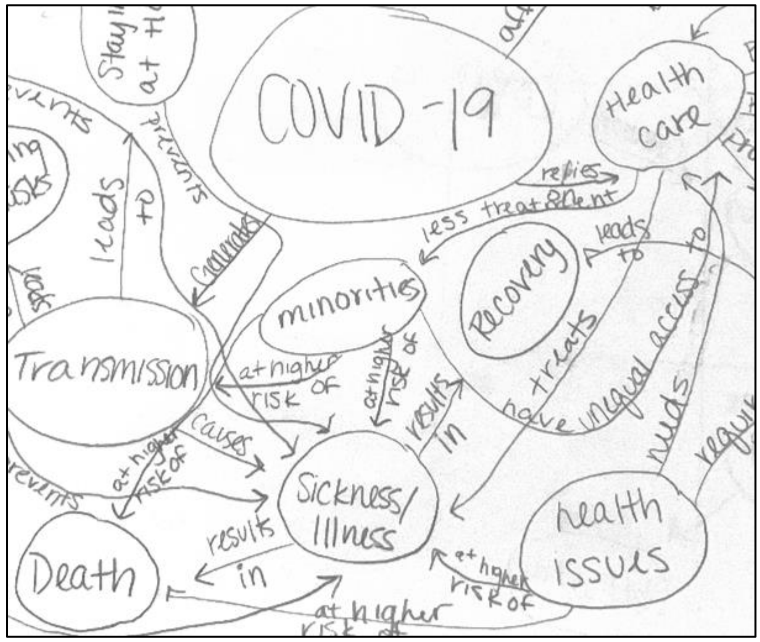
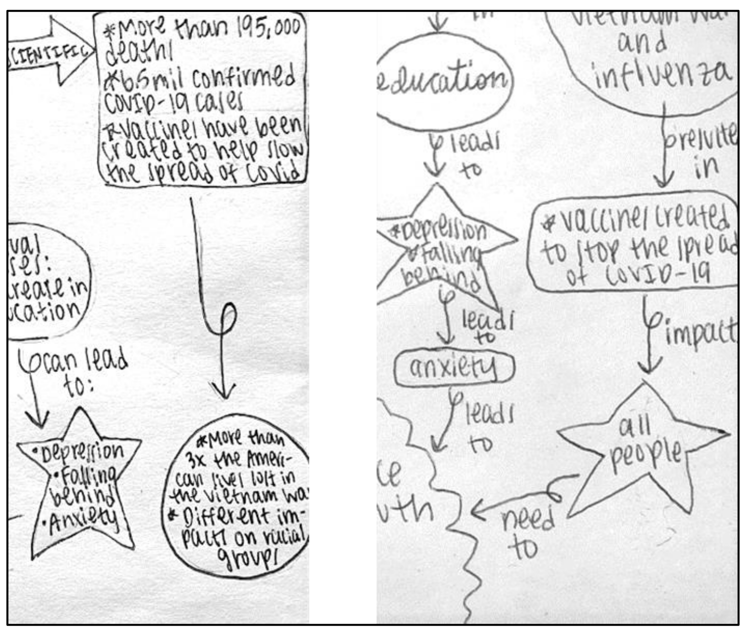


Figure 8: PST 14's Pre and Post Causal Map Comparison



Can Preservice Teachers' Change in Sociopolitical Consciousness be Predicted?

The statistical output of the LMER model (Equation 5) that was created to assess if the components of the QuASSR-SJ and the CoBRAS-SSI predicted PSTs' sociopolitical consciousness scores are presented in Table 18. The results indicate that only one item across both instruments significantly predicted the PSTs sociopolitical consciousness. There is a statistically significant ($p<0.05$) relationship between the PSTs' SSR *taking perspectives* scores and PSTs' sociopolitical consciousness scores. As the perspective score increased by 1 standard deviation, sociopolitical consciousness increased by 0.44 standard deviations. This indicates that students that are better at considering others' perspectives also have greater sociopolitical consciousness. The estimate for time shows an increase of 0.25 standard deviations across the semester. However, adding the each of the individual components from QuASSR-SJ and CoBRAS-SSI as predictive variables caused time to lose its statistical significance ($p>0.05$). It is possible that the loss of statistical significance in change over time is due to the small sample size of the study. These finding partially support the hypothesis that sociopolitical consciousness can be predicted from SRR component scores and/or colorblind ideology factor scores.

Table 18: LMER Results for Change in Sociopolitical Consciousness Causal Map Scores Across the Semester; Predicted by Pre-SSR Component Scores and Pre-Colorblind Ideology Component Scores

Sociopolitical Consciousness Causal Map Score			
Predictors	*Estimates*	*95% Confidence Interval*	*p*
Intercept	-0.05	-1.08 – 0.99	0.93
Time	0.25	-0.02 – 0.52	0.07
Limitations of Science	-0.06	-0.34 – 0.21	0.66
Affordances of Science	0.22	-0.08 – 0.52	0.14
Skepticism in Science	-0.18	-0.46 – 0.09	0.19
Skepticism in Media	-0.13	-0.46 – 0.20	0.42
Inquiry	-0.06	-0.38 – 0.25	0.69
Perspectives	0.47	0.18 – 0.77	**0.00**
Privilege	0.44	-0.12 – 1.00	0.12
Institutional	-0.11	-0.54 – 0.32	0.61
Blatant	-0.16	-0.57 – 0.25	0.44
Environmental	-0.24	-0.76 – 0.28	0.36
Random Effects			
σ^2	0.45		
τ_{00}	0.39 $_{id}$		
ICC	0.46		
N	49 $_{id}$		
Observations	98		
Conditional R^2	0.62		

Does Change in Sociopolitical Consciousness Transfer to Another Socioscientific Issue?

Similar to the models predicting PSTs' complexity (Table 9) and limitations of science (Table 15), a LMER model for change in the inclusion of race as a consideration in PSTs' responses to the QuASSR-SJ was not able to fit the random effects portion of the model. This was due to nominal variation in the small number of participants. Instead, a one tailed paired t-test was used to see if scores at the end of the course were larger than scores at the beginning. The results of this test (Table 19) show that scores did not change from pre to post, indicating that the minimal increase in sociopolitical consciousness was limited to the SSI of COVID-19 and did not transfer to the novel question regarding West Arlington Fracking SSI.

Table 19: One Tailed Paired T-Test Results for Change in PSTs' Inclusion of Race as a Considerations in QuASSR-SJ

Inclusion of Race as a Considerations in QuASSR-SJ Responses		
Mean Difference	*95% Confidence Interval*	*p*
0.022	> -0.04	0.28

Summary

This analysis indicated that little to no change occurred in PSTs' colorblind ideology scores nor socioscientific reasoning scores. However, some increases in sociopolitical consciousness scores with respect to the COVID-19 pandemic were apparent. These changes only occurred in a small portion of the PST's studied and were largely superficial as they mostly identified blatant (e.g., violence against Asian Americans) or vague racial issues (e.g., adding Black Live Matter into their causal map with no meaningful connections) and rarely considered more complex concepts like structural racism. Additionally, none of the PSTs considered ways to mediate or resolve racial justice issues despite the causal map prompt asking PSTs to consider how to resolve/mediate the SSI.

Chapter Five: Discussion

Summary of Findings

This study shows that elementary preservice teachers did not change their colorblind ideologies through a semester long science methods course that focused on teaching science through socioscientific issues that highlight the inequities that structural racism creates. The PSTs' combined colorblind ideology scores did not change from pre to post measures nor did their pre to post scores of specific components within the CoBRAS-SSI (privilege, institutional, blatant, & environmental). In addition, their combined socioscientific reasoning (SSR) scores did not change which also indicates that their reasoning about these issues did not grow in complexity. The only SSR component that showed growth was PSTs understandings of the limitations of science, which indicate that PSTs changed in the way they think about how science is limited in resolving global issues, such as COVID-19.

Of the three main constructs of interests in this study (colorblind ideology, socioscientific reasoning, and sociopolitical consciousness), only PSTs' sociopolitical consciousness increased throughout the semester. However, the increases only occurred in a small number of PSTs and were mostly vague and simple, such as listing Black Lives Matter as a social consideration without explication or explanation with how it fits in with the larger issue. Most notably, no PST in this study included mediation factors for racial justice issues, despite the specific prompt within the causal map assignment asking them to approach the causal map as someone trying to resolve the issue for all individuals.

To further understand the change in PSTs sociopolitical consciousness with regards to the COVID-19 pandemic, I ran a statistical model that predicted sociopolitical consciousness scores using individual components of the CoBRAS-SSJ and the QuASSR as predictors. This model found that PSTs' perspectives scores from the QuASSR was the only item with a statistically significant prediction of PSTs' sociopolitical consciousness. Finally, the minimal increase in sociopolitical consciousness scores was only associated with COVID-19 causal maps and was not found in the QuASSR-SJ, indicating that increases in sociopolitical consciousness were not transferable to other issues within this study.

A Lack of Change in Preservice Teacher's Colorblind Ideologies

Reducing colorblind ideologies is an important step in preparing preservice teachers to teach in culturally responsive ways, as colorblind ideologies are one of the primary barriers to this type of teaching (Castro, 2010; Sleeter, 2008). However, doing so has proved a difficult undertaking. Some studies have found statistically significant change in individuals' colorblind ideologies through interventions ranging from less than a week to one school year using the CoBRAS tool (Bañales et al., 2021; Coivin-Burque et al., 2007; Neville et al., 2014; Robey & Dickter, 2022; Spanierman et al., 2008). However, the effect sizes of these studies were low as they used large samples and only saw small changes in CoBRAS scores. Long-lasting and meaningful change, such as seen within a large effect size likely only occurs after long term multiprong approaches, if at all (e.g., experiences with diverse others, multi-course interventions, and personal reflection - all of which is heavily mediated by participants' past experiences; Castro, 2010).

Of the factors within the CoBRAS-SSI, unawareness of environmental racism was of most interest in this study and it did show the greatest decrease, although not statistically significant. Overall, the current study failed to find a statistically significant change in PST's colorblind ideologies as measured by the CoBRAS instrument. This is not consistent with other pre-post studies using the CoBRAS; however, it is consistent with how difficult and long it takes to change teachers' beliefs (Bryan, 2012; Castro, 2010). In addition, prior work that used the CoBRAS had larger sample sizes allowing them to find smaller changes in colorblind ideologies as statistically significant. These small changes were generally measured directly following an intervention, making it impossible to know if these changes are long term and meaningful (i.e., resulting in actual changes to the systems and structures producing inequities). Given these findings, it is likely that with a larger sample size the decrease in unawareness of environmental racism seen in this study of -0.13 standard deviations would be statistically significant. However, to determine if these changes were long term and meaningful, the PSTs should be retested at different time points after their science methods course was over (such as during student teaching and again during their first teaching years).

Therefore, recommendation for future work include larger samples sizes and focus on the impacts of the interventions in the long term and what is needed to sustain these decreases in individuals' colorblind ideologies. For example, even though one PSTs spoke with me about her annoyance of having to learn about racism in so many of her classes, it might be possible that many interventions coordinated across multiple methods courses throughout the teacher education program can "chip away" at individual's colorblindness.

A Lack of Change in Preservice Teacher's Socioscientific Reasoning Skills

A teacher's own ability to reason through socioscientific issues is necessary if they are going to teach these skills to their students. However, as seen in this study and others, increasing preservice teacher's socioscientific reasoning skills is not a simple task that can be completed in a short period of time. Not seeing a change in SSR over a relatively short intervention (9 weeks) aligns with past research. Romine and colleagues (2017) found no significant change in SSR after a short intervention of one week. Sadler and Klosterman (2011) found that students' understandings of content improved but not SSR during a three-week intervention. Only after a longer twelve-week intervention with a primary focus of increasing students SSR did Cansiz (2014) find significant change in preservice teacher's SSR skills. These results are not surprising because much like the issues that SSR is used to resolve, SSR is a complex construct. It has roots in an individuals' moral, ethical, and political ideologies (Romine et al., 2017).

While the overall SSR scores of the PSTs in this study did not show a statistically significant change, their understanding of the limitations of science did. This measure increased 0.56 points on a 5-point scale. The change is interesting, as the course did not focus on this specifically and, unfortunately, data was not collected that could illuminate the reasons for the change in PST's understanding of the limitations of science. Only conjectures can be made.

A possible driving factor for this change was the PSTs own experience with and reflections of their experiences with the COVID-19 pandemic. Throughout the semester they would have seen little day-to-day change within their personal burdens due to the COVID-19 pandemic. Until the vaccine became available in February 2021, they only saw science as the culprit of the disruptions to their personal lives (e.g., not being able to socialize during their time at college; attending classes online). Additionally, the apparent increased understanding of the limitations of science might be an increased mistrust of science which was proliferated on social media and some news outlets (e.g., Fox News). Finally, and most regrettably, students may have experienced early on that science could not or did not save the life of a loved one due to COVID-19.

An Increase in Preservice Teacher's Sociopolitical Consciousness

Another barrier for teachers to enact culturally relevant teaching is a lack of sociopolitical consciousness. There is scant research that looks at the development of preservice teachers' sociopolitical consciousness, as sociopolitical consciousness overall is understudied (Jones & Taylor, 2022). Literature searches did not reveal research that focused on sociopolitical consciousness with regards to SSIs and social justice. Most research in this area focused on empowering students and current teachers of color (Jackson & Knight-Manuel, 2019; Ngo et al., 2017; Watts & Hipolito-Delgado, 2015). One study that focused on new White teachers found that the teachers were able to develop a deeper understanding of structural racism and showed ability and willingness to be agents of change (Zion et al., 2015). While the specifics of how this was done are not straightforward, there are some tangible differences between the current study and the study by Zion and colleagues (2015). Most notably, the authors studied participants that were actively teaching in an urban middle school and who chose to participate in a yearlong course on how to support their own students' sociopolitical consciousness. Additionally, this study took place over a period that was twice as long as the current study, further underscoring how long it takes to make any changes to constructs that are so deeply held as sociopolitical consciousness.

Reviewing PSTs' sociopolitical consciousness scores revealed a clear limitation in their thinking about social justice. While their average score saw a statistically significant increase from an average of 0.20 to 0.40 on a 4-point scale, this increase still places PSTs average scores on the very low end of the scale and includes no PSTs scoring a 4. PSTs in this study failed to reach a level of sociopolitical consciousness that showed a complex understanding of the issue and any attempt to consider how to mitigate the issue. The levels of sociopolitical consciousness in this study align with Watts and colleges (1999) stages of sociopolitical development. These stages of sociopolitical development include 1) an unawareness, unwillingness, or justification of social inequalities, 2) awareness of social inequalities with the believe the system cannot be changed, 3) awareness of social inequalities and questioning the structural causes, 4) a desire to learn more and a conclusion that the social inequalities are unjust and change is required, 5) the individual acts on their beliefs to bring the required changes to fruition.

While the current study found statistically significant change in PST's sociopolitical consciousness of COVID-19, none of the students reached Watts' highest level. Most PSTs in this study showed signs of egocentrism in their causal maps, only considering social aspects that were impacting them (e.g., education and their social life), despite being asked in the causal map prompt to consider other's perspectives and the courses focus on the racism highlighted by COVID-19. Moving past one's own egocentrism is something that Watts does not highlight within his own levels and appears to be another important step in the progress toward the development of an individual's sociopolitical consciousness. Beyond their egocentrism, these PSTs largely come from rural and likely conservative backgrounds where there has been a noticeable "anti-wokeism" movement (Woke being the colloquial term for sociopolitical consciousness) ranging from social media posts to state laws like "Stop WOKE" act in Florida (Greg Allen, 2022; Pete Schroeder, 2022)

PSTs beginning to understand structural racism is a step in the right direction, but it is only the start of a long journey toward becoming agents of change. Without a higher level of sociopolitical consciousness exhibited by these PSTs, once they become teachers, they are unlikely to enact culturally relevant teaching within their practice. This will continue the slow progress within science education of the culturally relevant education movement. Unfortunately, this is not likely remedied by altering a single science methods course in a teacher education program. The lack of statistically significant improvement seen in this study suggests that an interwoven multicourse and multiyear approach may be necessary to increase PSTs' sociopolitical consciousness and the likelihood they take up culturally responsive educational practices.

Predicting Preservice Teachers' Sociopolitical Consciousness

Many PSTs scored high on the CoBRAS; however, it is evident that these high scores did not equate to or predict higher sociopolitical consciousness scores. This is likely an indication that PSTs were responding to the CoBRAS in socially desirable ways - what they interpreted that I, as their instructor, wanted to hear and/or how they interpret society expects them to respond. Self-reported surveys like the CoBRAS have known issues when dealing with behaviors or thoughts that are not socially desirable. Survey takers do not want to report what they think can be interpreted as a negative image of themselves (Gnambs & Kaspar, 2015).

CoBRAS might not be the best tool to understand an individual's colorblind ideology as is because it is self-reported and this study failed to use a social desirability indicator to adjust for this (a limitation of the study). Future research using the CoBRAS should implement strategies to address social desirability bias through direct reduction of bias (e.g., anonymous responses, statements in the introduction, etc.), indirect reduction (e.g., modifying questions to make the answers to seem more neutral, using card-sorting, etc.), and ways to measure and control for bias through statistical approaches (Larson, 2019). Beyond mere self-reported data, additional data should also be collected. One such data collection method could include something like the Equity Quantified in Participation (EQUIP) observation tool (Reinholz & Shah, 2018) that collects data on how often teachers call on students of different demographics to look for disparities in the teacher's actions. Another useful data collection method would include interviews to gain a deeper understanding of preservice teachers' colorblind ideologies.

Summary

While results of this study are discouraging regarding PSTs colorblind ideologies and sociopolitical consciousness, the finding connecting socioscientific reasoning and sociopolitical consciousness was encouraging. Prior research has not defined if and how SSR and SPC are linked. While this study found a small connection between the two constructs, there are promising possibilities for future research in this vein. This work also shows the promise of using SSR and SPC to support one another within the SSI-SJ. Embedding this within methods coursework in cross curricular fashion such as between science and social studies classes provides enhanced opportunities for PSTs to investigate contentious issues, gaining an understanding of the science and social considerations at play.

In addition, the connection between SSR and SPC provides evidence that SSI instruction can be a useful tool to challenge individuals' understandings and potentially their willingness to act on social justice issues. The constructs leverage each other as they both pull from similar political, moral, and ethical ideologies. However, as the roots of these constructs imply and as others have reported within SSI and social justice research, promoting the skills and ideologies needed to make a meaningful difference in the world is a challenging and a long-term process, one that cannot be done with a single unit that covers only one sliver of one dimension of social justice.

Limitations

Firstly, the small sample size (*n* = 51) limited the ability of statistical models to find statistical significance. A lack of statistical significance does not necessarily mean there was no change from pre to post. PSTs changes within measured variable may have occurred; however, the small sample size created conditions in which the change was undetected as more than just by chance alone (Waigandt & Wang, 2010). Second, the intervention and data collection were completed online in the Fall of 2020 during the COVID-19 pandemic. The nature of pandemic (shutdowns, limited access to friends and family) limited any potential impacts of the intervention and likely caused issues with assessing the PSTs due to their own personal constraints due to the pandemic.

These limitations included the online environment which created difficulties for both me and the PSTs to develop a classroom community that we experience in a face-to-face classroom. Without this community, it was difficult to create an environment in which we could engage in critical discussions about race and inequities and respond thoughtfully and truthfully. Conducting an online intervention in these circumstances may have allowed participants to more easily disconnect and recede from discussions that were likely uncomfortable for them. Conducting this intervention now, after the pandemic, in an in-person format, may provide opportunities to create a space that would provide for more meaningful and open discussions.

Third, there were my own limitations as an instructor. This was my first attempt at teaching elementary science methods online and teaching about racial justice. I often felt unsure and lacked confidence, especially teaching students online that I had never met in person.

Conclusion

The elementary environment is one that promotes integration, as elementary teachers are generalists prepared to teach all content areas. Yet, within elementary teacher preparation, content areas are not integrated, thus making it difficult for elementary teachers to see how the content areas are connected. As shown within this study implications for elementary teacher education include breaking down the partitions between curricular subjects and treating education as a wholistic endeavor, one that more closely mirrors the real world, the SSI-SJ, and the elementary classroom. More specifically, science teacher educators should challenge themselves and include social justice considerations in their teaching, especially when teaching through SSI as many, if not most, highlight the racial disparities created by structural racism.

Given the findings of this study, future research should further investigate the connection between SSR and sociopolitical consciousness. This could be accomplished through implementing a combined science and social studies methods course that utilizes the SSI-SJ framework. Data collection should build on the self-reported surveys used here and include a social desirability scale to adjust for response bias as well as qualitative data analysis such as interviews and classroom discussions. Additionally, adding qualitative data would also support further enhancement of the the SSI-SJ framework to create a better balance between social studies and science.

In conclusion, this pre-experimental design study highlights the promise of the Socioscientific Issues Teaching and Learning for Social Justice (SSI-SJ) framework. The SSI-SJ framework is the first teaching framework to connect teaching science through socioscientific issues and social justice. While the current study found increases in PSTs understanding of the racism that is highlighted by the COVID-19 pandemic, it seemingly did not impact their understanding of how to act. However, as we know with myriad other studies, such increases require long term multifaceted approaches. The SSI-SJ provides one facet for science education to use in the endeavor to build scientific literacy for social justice.

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Appendix A

Color-Blind Racial Attitudes Scale Scoring Information

Adapted from (Neville et al., 2000). Modifications to the CoBRAS are in italics.

Directions: Below is a set of questions that deal with social issues in the United States (U.S.). Using the 6-point scale, please give your honest rating about the degree to which you personally agree or disagree with each statement. Please be as open and honest as you can; there are no right or wrong answers. Record your response to the left of each item.

1	2	3	4	5	6
Strongly Disagree					Strongly Agree

1. ***Race plays a critical role in understanding who is impacted the most by natural disasters.***
2. It is important that people begin to think of themselves as American and not African American, Mexican American or Italian American.
3. **Due to racial discrimination, programs such as affirmative action are necessary to help create equality.**
4. **Racism is a major problem in the U.S.**
5. *Racial and ethnic minorities are impacted more by socioscientific issues such as climate change, COVID-19, and industrial waste/pollution.*
6. **Race is very important in determining who is successful and who is not.**
7. ***Racial inequities should be considered when resolving socioscientific issues.***

8. Racism may have been a problem in the past, but it is not an important problem today.
9. **Racial and ethnic minorities do not have the same opportunities as White people in the U.S.**
10. White people in the U.S. are discriminated against because of the color their skin.
11. Talking about racial issues causes unnecessary tension.
12. **It is important for political leaders to talk about racism to help work through or solve society's problems.**
13. **White people in the U.S. have certain advantages because of the color of their skin.**
14. *Resources to help mitigate or resolve socioscientific issues should be equally distributed regardless of race.*
15. Immigrants should try to fit into the culture and adopt the values of the U.S.
16. English should be the only official language in the U.S.
17. ***Racial minorities are more likely to be negatively impacted (e.g., economically, reduced health, death) due to environmental causes than White people as a result of past and current racism in the U.S.***
18. **White people are more to blame for racial discrimination in the U.S. than racial and ethnic minorities.**
19. Social policies, such as affirmative action, discriminate unfairly against White people.
20. **It is important for public schools to teach about the history and contributions of racial and ethnic minorities.**

21. Racial and ethnic minorities in the U.S. have certain advantages because of the color of their skin.

22. *People who are negatively impacted by socioscientific issues, no matter what race they are, should move or change their lifestyles to reduce their susceptibility.*

23. Racial problems in the U.S. are rare, isolated situations.

24. **Race plays an important role in who gets sent to prison.**

25. Everyone who works hard, no matter what race they are, has an equal chance to become rich.

26. **Race plays a major role in the type of social services (such as type of health care or day care) that people receive in the U.S.**

The following items (which are bolded above) are reversed score (such that 6 = 1, 5 = 2, 4 = 3, 3 = 4, 2 = 5, 1 = 6): item #1, 3, 4, 6, 7, 9, 12, 13, 17, 18, 20, 24, 26. Higher scores show greater levels of "blindness", denial, or unawareness.

Factor 1: Unawareness of Racial Privilege consists of the following 7 items: 6, 9, 13, 18, 24, 25, 26,

Factor 2: Unawareness of Institutional Discrimination consists of the following 7 items: 2, 3, 10, 15, 16, 19, 21

Factor 3: Unawareness of Blatant Racial Issues consists of the following 6 items: 4, 8, 11, 12, 20, 23

Factor 4: Unawareness of Environmental Racism consists of the following 6 items: 1, 5, 7, 14, 17, 22

Appendix B

Quantitate Assessment of Socio-Scientific Reasoning – Social Justice (QuASSR-SJ): Fracking in Arlington, Texas

Adapted from Romine et al. (2017).

Arlington is a city in Texas west of Dallas. A neighborhood of predominantly Black and Hispanic working-class families in East Arlington is situated near a site where hydraulic fracturing (or "fracking") of natural gas takes place. In fracking, pressurized water mixed with chemicals and particles like sand are forced into layers of shale (a rock composed of sheets of hard mud which lay on top of each other like the pages in a book), opening fractures which allow large amounts of natural gas to be extracted. After cracking the rocks, the liquid then returns to the surface where it is stored in a sealed container or pond, and the sand remains in the cracks to keep them open. Proponents of fracking consider it a breakthrough in the energy industry. Fracking allows extraction of much larger quantities of natural gas than traditional natural gas extraction methods and allows us to tap into reserves that were previously impossible to reach. The oil and gas industry is an important part of Texas' economy, bringing billions of dollars into the state. Total, a French oil and gas company now plans to expand its fracking operation in East Arlington to include three more wells. However, residents of the area, as well as scientists from the Environmental Protection Agency (EPA) and the United States Geology Survey (USGS) who collected the data, point out that fracking in the area is possibly to blame for negative health effects that birth defects and different types of cancer caused by groundwater pollution. The data from these tests go against claims by the drilling industry, which reports that injecting water, sand, and chemicals underground has never led to groundwater contamination. The company denies that the pollution is related to its operations. They cite a similar incident that took place in the Marcellus Shale region of Pennsylvania; similar pollution there was found to be a result of a gas reserve near the resident's water well, and not due to nearby fracking activities. The company also cites the important economic factor of the jobs it provides to the residents of East Arlington. A Concerned Citizens Group are pressuring the city council to not only deny the expansion request but to require Total to scale down the fracking they are currently doing in the area. What should be done about this situation?

1. Imagine that you are in charge of resolving this issue. Would this be a difficult issue to resolve?

A) YES

B) NO

If YES, then: What aspects of this issue make it difficult to resolve? *(Please be as detailed as possible)*

If NO, then: Why do you think this issue is easily resolved? *(Please be as detailed as possible)*

2. If you were responsible for deciding how to resolve the fracking issue in Arlington, would you need additional information regarding the situation before making your decision?

A) Yes, I would need to have additional information to make a decision.

B) No, I have sufficient information to make a decision.

If YES, then: What kinds of additional information would be necessary for you to make a decision regarding the fracking issue in Arlington? *(Please be as detailed as possible)*

If NO, then: What information would be most important for your decision-making? *(Please be as detailed as possible)*

3. Local leaders met to discuss a solution for the fracking issue in Arlington. The group suggested that Total resumes current operations in the area while additional tests are made to determine the safety of fracking in the area.

3a. How do you think Total would respond to this suggestion? *(Please support your response with details and/or examples)*

3b. How do you think Concerned Citizens Group would respond to this suggestion? *(Please support your response with details and/or examples)*

4. The local leaders working on this issue ask you to write a report that predicts the most likely outcomes that will result from each potential solution (stopping all fracking in the area, continuing current fracking, or expanding current fracking). The following sources of information are available to you:

Interviews with Total officials & residents of the East Arlington

Social Media, Blog, and Wikipedia posts about the issue

Research studies published in reputable science journals

Are these equally good sources of information for the preparation of your report?

A) YES

B) NO

If YES, then: Explain why you think these sources are equally good. Be as specific as possible. *(Please support your response with details and/or examples)*

If NO, then: Explain why you think there are differences in the quality of these three sources of information. Be as specific as possible. *(Please support your response with details and/or examples)*

5. A town hall meeting is organized to discuss the fracking in Arlington. The following presentations are given:

A report from scientists hired by the Total Corporation

A report from scientists hired by the Concerned Citizens Group

Would you expect these reports to be similar or different?

If SIMILAR, then: Why would the reports be similar? *(Please support your response with details and/or examples)*

If DIFFERENT, then: Why would the reports be different? *(Please support your response with details and/or examples)*

6. Do you think that scientists can help to resolve the fracking issue?

IF Yes, What could scientists do to help resolve the issue? *(Please support your response with details and/or examples)*

IF NO, Why would scientists NOT be helpful for resolving this issue? *(Please support your response with details and/or examples)*

7. Some people think that a full understanding of the science related to the fracking issue will provide the best solution. Others suggest that a solution should be informed by the science as well as other, non-science considerations. What do you think?

A. The solution to the fracking issue in Arlington should be determined by the science.
B. The solution to the fracking issue in Arlington should be determined by the science AND other, non-science considerations.

If A, Why should the solution to the fracking issue in Arlington be determined by scientific information? *(Please support your response with details and/or examples)*

If B, What non-science information should be considered in order to determine a good solution for the fracking issue in Arlington? *(Please support your response with details and/or examples)*

Rubric

The following rubric is taken from Womack (2019):

SSR Component	**Level**				
	0	1	2	3	4
Q1 Complexity	Suggests that the issue is not complex or provides an illogical response.	Identifies at least one source of complexity.	Identifies at least one source of complexity and provides a contextual explanation or justification of a source	Identifies at least two sources of complexity and provides a contextual explanation or justification for one of those sources	Identifies two or more sources of complexity and provides contextual explanations or justifications for at least two of those sources.
Q2 Inquiry	Suggests that no further inquiry is required or provides an illogical response.	Identifies an area of further inquiry.	Identifies at least one area of further inquiry and provides a contextual explanation, justification, or description of an area of inquiry	Identifies at least two areas of further inquiry and provides contextual explanation, justification, or description for one of those areas	Identifies Two or more areas of inquiry and provides contextual explanation/justification/description for at least two.

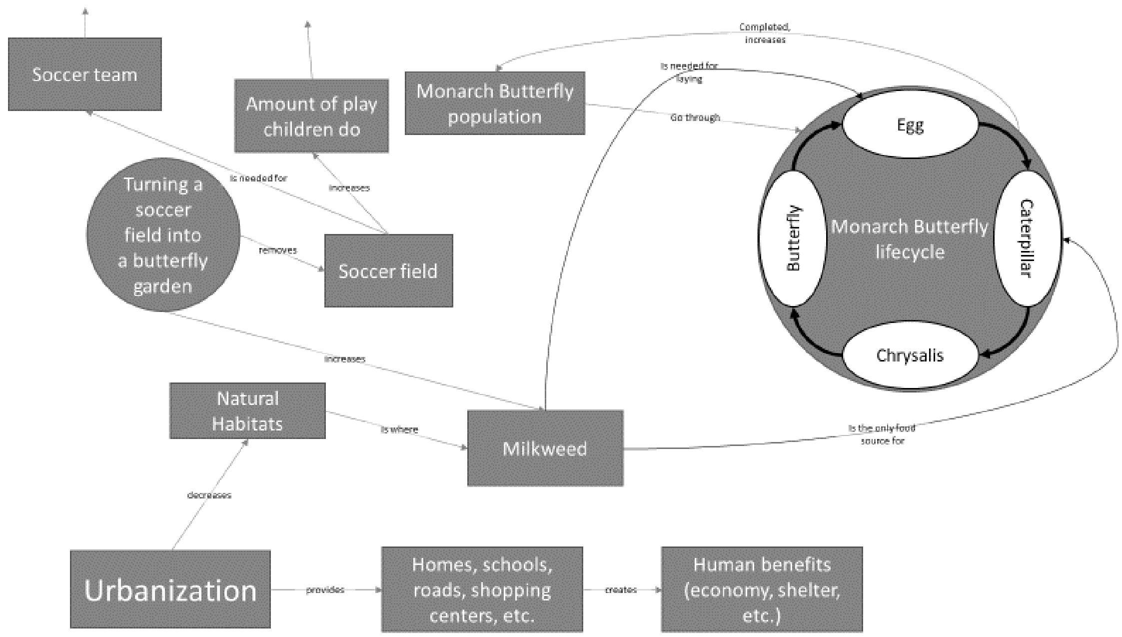
Q3 Perspective Taking	Presents perspectives that are NOT consistent with stakeholder views Judgment answer with no detail (i.e., "they would not like it")	Presents a perspective consistent with a stakeholder view.	Presents a perspective consistent with a stakeholder view and provides a contextual explanation, justification, or elaboration of the perspective.	Presents perspectives consistent with both stakeholder views and provides a contextual explanation, justification, or elaboration of one of those perspectives.	Presents perspectives consistent with both stakeholder views and provides a contextual explanation, justification, or elaboration of both perspectives.
Q4 Media Skepticism	Suggests that the sources are equally good.	Identifies one reason for differences in source quality.	Identifies one reason for differences in source quality and provides an explanation or justification for the difference.	Identifies two reasons for differences in source quality and provides an explanation or justification for one difference.	Identifies two reasons for differences in source quality and provides an explanation or justification for both differences.
Q5 NOS Skepticism	Suggests that the reports would be similar or provides an illogical response.	Identifies one way in which the reports would be different.	Identifies one way in which the reports would be different and provides an explanation or justification for the difference.	Identifies two ways in which the reports would be different and provides an explanation or justification for one difference.	Identifies two ways in which the reports would be different and provides an explanation or justification for both differences.

Q6 Affordance of Science	Suggests that science would not be helpful or provides an illogical response.	Identifies one way in which science would be helpful for issue resolution.	Identifies one way in which science would be helpful and provides an explanation or justification.	Identifies two ways in which science would be helpful and provides an explanation or justification for one.	Identifies two ways in which science would be helpful and provides an explanation or justification for both.
Q7 Limitations of Science	Suggests that science alone can solve the issue or provides an illogical response.	Identifies one non-science consideration.	Identifies one non-science consideration and provides an explanation or description.	Identifies at least two non-science considerations and provides an explanation or description for one consideration.	Identifies at least two non-science considerations and provides an explanation or description for two considerations.

Appendix C

Causal Map Example Given in Class

Figure 9: Monarch Butterfly SSI Causal Map



SSI Causal Map Assessment

The following prompt was giving to students following a detailed explanation of how to create a causal map.

Over the next half of the course, we will be creating a teaching unit in which we utilize the COVID-19 pandemic as a socioscientific issue (SSI) to teach science practices, concepts, and ideas. Teaching with SSIs also gives us the opportunity to teach other subjects as well. This is important for many reasons (i.e., subjects in "real life" are not compartmentalized like they are in school, it's engaging for students, it develops critical thinking skills, it helps with the issue of not having enough time to teach all the subjects, etc.) However, before we can develop this unit, we need to make sure we understand the complexity of the COVID-19 pandemic. To help you with this, you will create a model that helps explain this complexity. We often call these models, causal maps or concept maps. Before you begin, please review the PowerPoint from class and if you were not able to attend our Zoom call, watch the recorded meeting.

Steps to make your causal map:

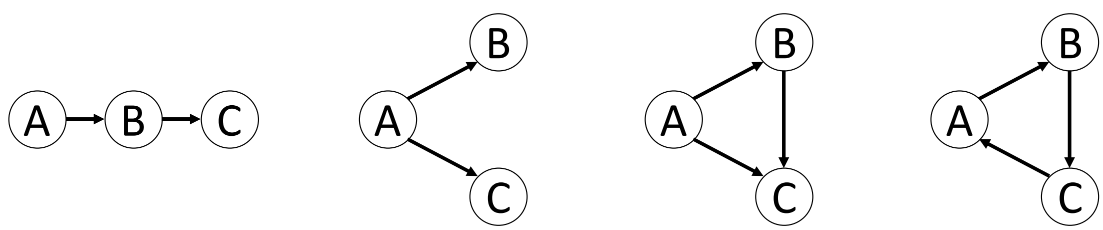
1. Plan and set perspective
   - Perspective: Someone trying to help reduce the spread of COVID-19
   - What are they interested in representing? Both Science AND Social considerations of the impacts of COVID-19
2. Identify Concepts:
   - Science: Transmission and what steps we take to reduce transmission
   - Social: Generally, this will be impacts from the steps we have taken to reduce the transmission as well as impacts of the disease itself. Plus, anything else you think is pertinent.
3. Create the nodes with your concepts inside of them. If needed, add descriptions and/or images to help explain the concept (for example, the butterfly life cycle node in my example)
4. Construct links and link concepts (arrows that connect nodes). Recall that these should read like this from node 1 -> node 2; "node 1 is connected/related to node two". Connection will vary. There is a list of common connections on the PowerPoint from class, but you are welcome to use more.

You may use whichever medium you would like to create your causal map (e.g., pencil and paper, PowerPoint, online concept mapping tool).

Rubric

Racial Issue Included (nominal)	
5	Vague
4	Racial Privilege
3	Institutional Discrimination
2	Blatant Racial Issues
1	Environmental Racism
0	None

Sociopolitical Consciousness	
4	Consideration consists of multiple nodes that include mitigation(s) and connections between nodes are complex (closed branching or causal loop).
3	Consideration consists of multiple nodes that include mitigation(s) or connections between nodes are complex (closed branching or causal loop) but only include impacts.
2	Consideration consists of multiple nodes that are connected linearly or scattered across map.
1	Consideration consists of single node
0	Consideration is missing



Linear   Simple Branching   Closed Branching   Causal Loop

Vita

R. Tanner Oertli was born September 10, 1985 to Gerald L. Oertli and Patricia Tully Oertli in Billings, MT. Growing up with his two older sisters, Wendy and Christine; they often spent their weekends on the Tully ranch just outside Roundup, MT. He attended Washington Elementary School, Lewis and Clark Junior High School, and Senior High School. However, it was not until he attended the University of Montana that he discovered his love for science. He earned a bachelor's degree in biology and immediately started teaching at Sentinel High School in Missoula, MT. He ended up teaching Science and Engineering for seven years as well as coaching pole vault for the track team. During this time, he met his wife, Claire. They were married June of 2016. A year later they moved to Columbia, MO to be close to family. Once in Columbia, Tanner began his master's degree in science education at the University of Missouri. During this time, Tanner and Claire were blessed with their first son, Anderson on June 25, 2019. After completing his master's, Tanner immediately began his PhD in science education. During this time, Tanner and Claire were blessed again, with their second son, Crew on January 3, 2022. Throughout his graduate studies, Tanner taught the Elementary Science Methods course at the University of Missouri, worked on research projects, and stayed home with the kids (sometimes even having to teach with a baby wrapped to his chest). Before completing his PhD, Tanner took a job with Columbia Public Schools as a Programmer and Analyst.