

Teaching Mathematics and Science Through a Social Justice Lens

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Teaching mathematics and science embedded in social justice is not a familiar concept for many teachers, especially pre-service teachers. This qualitative, descriptive, and interpretative study examines the experiences and reflections of 26 middle grade and secondary pre-service mathematics and science teachers on teaching and learning mathematics and science through the social justice lens as they took a semester-long course concurrently with their student-teaching. The primary research question was, “How may a semester-long course focusing on teaching and learning mathematics and science with social justice awareness provide pre-service teachers with opportunities to reflect on and change their teaching practices?” Data included researchers’ field notes and participating pre-service teachers’ verbal discussions, written reflections, and classroom presentations. The findings suggest that teaching mathematics and science in the context of social justice enhanced the participating pre-services teachers’ awareness of educational opportunity and equity. The findings also indicate teaching mathematics and science from the social justice perspective requires a paradigm shift in teaching and learning. Furthermore, the study exposes the limitations of the current school structure and culture for meaningful learning, the limitations of existing curricula and state-mandated texts, and the lack of adequate resources in teaching mathematics and science in social justice contexts.

KEYWORDS: mathematics and science, social justice, teaching and learning

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As the demographics of the United States become more diverse than ever, concerns remain about the growing number of racially and ethnically diverse populations. With most of the curricula, textbooks, and teaching materials focusing on the values and beliefs of the mainstream culture, the diverse groups receive little attention (Banks, 2013; Nieto, 2000, Sleeter & Grant, 1999). Students from racially and ethnically diverse communities cannot see their lived experiences in the school curricula and establish personal connections with the content being taught. This makes them feel the school does not belong to them, and they seem to always ask, “Why do I need to learn this?”

Historically, mathematics and science curricula have been presented from an ethnocentric perspective in the United States. Students growing up in urban communities with low socioeconomic status, female students, immigrants, and LGBTQI+ students are too often overlooked within the classroom setting. Understanding mathematics and science from a social justice perspective is not the way students across the country experience these subjects. As many scholars argue, teaching a traditional, Western-minded mathematics or science course in a classroom with diverse learners is neither beneficial nor engaging; it not only hinders the utilization of students’ unique characteristics and funds of knowledge (González et al., 2006) but also deprives students of the opportunity to use mathematics to expose and confront obstacles to their success (Gutiérrez, 2002; Gutstein, 2003; Martin, 2003; Tate, 1995). Educating young citizens to become more engaged and critical of the environments they are living in and experiencing is a step toward social justice and equity in education.

According to Garii and Appova, (2013), social justice is grounded in the daily realities of people as they experience and witness inequality and injustice. Students can engage with social justice when the teaching of mathematics and science is done in an integrated way that promotes thinking in terms of relationships, connectedness, and context, which helps students form integrated knowledge and experience meaningful learning relevant to real life (Drake, 2000). According to Larnell et al. (2016), teaching and learning mathematics and science for social justice “represents an ideological commitment to using mathematics as a means of encouraging young students to leverage their own content learning toward redressing sociopolitical injustices in our society” (p. 20). In this sense, preparing pre-service teachers for teaching young citizens from a social justice perspective is a moral obligation of higher education institutions. Based on the argument of Felton-Koestler (2017), pre-service teachers must experience mathematics for social justice as a learner, see examples of what this could look like in practice, and reflect on their own beliefs about mathematics. Literature around teaching mathematics and science for social justice draws attention to the fact that if pre-service teachers do not experience explicit exposure to examples of these lessons and opportunities to plan lessons for themselves, they are unlikely to investigate social justice lessons in their own classrooms (Myers, 2019).

Learning mathematics and science through a social justice lens provides students opportunities to analyze their world critically and ultimately promote a democratic society in which everyone can get an opportunity to participate fully (Frankenstein, 1995; Skovsmose, 1994). Mathematics and science can be used as meaningful tools to teach and learn about issues of social injustice and to support arguments and actions aimed at promoting equitable change (Bartell, 2013). The first step to remedy the archaic form of instruction is to understand students and the different sociocultural backgrounds they come from. Teaching mathematics and science embedded in social justice contexts provides an alternative pedagogy to present content related to students' backgrounds (Bartell, 2013; Wager & Stinson, 2012). However, many teachers, rather than educating students in sociocultural and sociopolitical contexts, often teach mathematics and science in the way they were taught, such as covering the required curriculum handed to them by their school district, administering an exam, and promptly continuing to the next unit of study. Although this approach is considered to be effective for state testing purposes, it lacks a serious reflection of whether instructors are teaching for testing or teaching for learning. The key to solving this issue is through introducing activities related to students' lives that are meaningful and can provide students with a sense of purpose. Therefore, teaching mathematics and science in a social justice context must engage learners in critical thinking, multiple representations, argumentations, discussions, and debates. This is an act of love for teaching and learning within a caring and belonging learning community.

It is further important to note that the experiences and practices of middle grade and secondary mathematics and science teachers cannot be understood in isolation. These experiences and practices must be studied within the sociocultural contexts the instructors live in and interact with (Frankenstein, 2012, 2013; Gutierrez, 2013, Gutstein & Peterson, 2013; Tate, 2013). To this end, this study explored 26 middle grade and secondary pre-service mathematics and science teachers' engagement in a semester-long course through their participation in classroom discussions, critical reflections, and presentations. The research question was, "How may a semester-long course focusing on teaching and learning mathematics and science with social justice awareness provide pre-service teachers with opportunities to reflect on and change their teaching practices?"

Review of Literature

Just as Apple (1995) designated social justice as "sliding signifiers," there exist multiple interpretations or definitions of teaching through the perspective of social justice. According to Apple (1995), "what social justice teaching actually means is struggled over, in the same way that concepts such as democracy are subject to different senses by different groups with sometimes radically different ideological and educational agendas" (p. 335). Freire (1968/1970) termed the *pedagogy of the oppressed* as a pedagogy which "must be forged with, not for, the oppressed (whether

individuals or peoples) in the incessant struggle to regain their humanity” (p. 30). Our conception of teaching through a social justice lens in the current study is mainly guided by Freirian epistemology (Freire, 1968/1970), which refers to such pedagogy that aims to establish a society where people actively engage in the transformation of it to achieve a better one. As Bartell (2013) stated, “the purpose of education is not to integrate those who are marginalized into the existing society but rather to change society so that all are included” (p. 131).

The shift to social justice may be part of an evolving and perhaps more recent sociopolitical shift in the area (Gutierrez, 2013; Stinson & Bullock, 2012). There has been a large amount of research addressing teachers learning to teach from a social justice perspective in teacher preparation programs and disciplines other than mathematics and science (see, for example, Adams et al., 1997; Ayers et al., 1998; Barton, 2003; Cochran-Smith, 1999, 2000; Darling-Hammond et al., 2002). de Freitas (2008), however, argued that “addressing social justice issues should be a primary goal of all education, including mathematics [and science] education” (p. 43). With social justice receiving more and more attention in mathematics and science education, and with many of the perspectives having been adopted in mainstream mathematics education discourse, Martin (2003) noted that the formulation of these projects is narrowly based on “modifying curricula, classroom environments, and school cultures absent any consideration of the social and structural realities faced by marginalized students outside of school and the ways that mathematical opportunities are situated in those larger realities” (p. 7). Although extant research documenting teaching mathematics and science in a social justice context is sparse, an increasing number of scholars believe that this pedagogy can provide support for the ongoing struggle for equity in mathematics and science education (e.g., Frankenstein, 1995; Gutstein, 2003; Skovsmose & Valero, 2002; Tate, 1995).

Sociocultural and sociopolitical contexts embody pedagogical and organizational forms and methods that inform mathematicians and scientists how concepts and ideas were conceived and evolved from distant antecedents (Gutierrez, 2013; Kokka, 2019; Swetz, 1995). The evolution of mathematics and science pedagogy and practices cannot be attributed to a single group; they are primarily of Babylonian and Chinese descent and have influenced modern education (Kelly & Lesh, 2012). Culturally relevant teaching supports academic success, cultural competence, and the development of critical consciousness; it also facilitates reflection, participatory engagement, and transformative knowledge, beliefs, and attitudes (McDonald 2005, 2008; Nolan, 2009). Further, its practice can offer opportunities to learn “in ways that are deeply meaningful and influential to the development of a positive mathematics [and science] identity” (Leonard et al., 2010, p. 261). Developing a strong mathematics and science identity through culturally responsive teaching and social justice pedagogy is critical for students’ academic success and understanding of their world (Bartell, 2013; Gay, 2010; Ladson-Billings, 2014; Leonard et al., 2010; Tate, 2013).

There are multiple contemporary empirical studies that provide examples of this work in different contexts. Brown et al.'s (2019) study reported on teachers' understandings of cultural relevance and practices learned in professional development, moving culturally responsive teaching and cognitive apprenticeship from theory to application. The findings of this study indicated that, ideologically, teachers were well aware of culturally responsive teaching as an educational construct but struggled to explain how it existed pedagogically and in translation from theory to practice (Brown et al., 2019). Teachers need to connect theory and practice with the principles of culturally responsive teaching—providing support in the form of collaboration to promote success in planning, creating opportunities to adopt languages that elicit the role of educators to engage students in knowledge, as well as finding personal relevance and developing critical awareness to deepen students' understanding (Gay, 2010; Ladson-Billings, 2014; Mensah, 2011; Tate, 2013).

Combining culturally relevant instruction and teaching mathematics for social justice, Leonard et al. (2010) conceptualized ways to offer opportunities for marginalized students to learn mathematics and develop a positive mathematics identity. To determine the nuances and complexity of coupling teaching mathematics for social justice and culturally relevant pedagogy, these researchers investigated four case studies across racial dynamics, grade levels, class backgrounds, and school contexts. They concluded that when teacher educators model teaching mathematics for social justice and culturally relevant pedagogy in their methods courses and professional development sessions, mathematics teachers can envision how to implement this pedagogy in their daily classroom instruction.

In contrast, Upadhyay (2010) conducted a study documenting the perceptions articulated by two middle school science teachers on social justice and how they implemented it in their instruction. Schools are built on mainstream structures and values, and that complies with the cultural norms and expectations of the majority population in society. Consequently, those students “from low-income and ethnic minority communities who do not fit these norms are either excluded or marginalized in science classes” (Upadhyay, 2010, p. 67). This makes it difficult to teach science for social justice in urban schools that consist of mostly poor, immigrant, and minority students. Upadhyay determined that the concepts of social justice frameworks were enacted in three forms—attending to individual students' needs, valuing and recognizing individuals' experiences, and working against institutional oppression and inequities. The study concluded that teachers must understand the greater social structures of inequality that impact students' lives in order to teach mathematics and science for social justice (see also Gutstein & Peterson, 2013; Kokka, 2019).

A similar study was conducted by Gonzalez (2009), who explored the developing identities of seven New York City public high school teachers as both teachers of mathematics and agents of change. The researcher met with the teachers weekly for 10 weeks and prepared them to act as agents of change through their practice of

teaching mathematics for social justice. They developed a unit of study connecting high school mathematics standards to a range of social justice issues that affected the lives of urban students. Gonzalez (2009) found that the teachers' awareness of the importance of infusing social justice into their teaching increased as the study continued, and the data analysis indicated that the teachers became keenly aware of the injustices their students face, the living conditions of students' family, inadequate academic preparation, and lack of opportunities for students and their families. Gonzalez (2009) recommended future research on the development of teachers' understandings of teaching mathematics in social justice contexts and the ways to provide support for teachers to move from simply understanding teaching mathematics for social justice to implementing it in their classrooms.

Other studies have indicated that such implementation can be a difficult process and often falls short of an instructor's intended goals. For example, Garii and Rule (2009) conducted a content analysis of integrated mathematics and science lessons incorporating social justice to determine the efficacy of such lessons, stressing that social justice pedagogy contextualizes mathematics and science into the lives of students and the communities they live in. Four pedagogical approaches—data analysis, discussion, modeling, and library/internet research—were addressed in this study. Garii and Rule (2009) ultimately found the integration of social justice and academic content was not yet complete in the analyzed lessons, which tended to focus on one or the other. Importantly, the lessons were seriously compromised because the teachers failed to recognize the importance of including social justice education into the curriculum. Recommendations of this study call for practical opportunities for pre-service teachers to understand how social justice can enhance classroom practices.

Science education for social justice is premised on three broad assumptions: "having the opportunity to learn science as content knowledge, discourse, and practice is a civil right, teaching and learning science involve critical activism and citizenship, and the goals of science literacy involve personal, social, and economic empowerment" (Barton & Upadhyay, 2010, p. 5). It provides students with access to traditional knowledge and practices as well as the opportunity to question, challenge, and reconstruct existing theoretical structures. Social justice pedagogy further offers the possibility for transformation, not only in the lives of the learners but in the social, political, and historical contexts in which it takes place as well. It gives the learner a sense of identity and power for changing their living conditions (Barton & Upadhyay, 2010; Frankenstein, 2013; Gutierrez, 2013; Gutstein, 2007; Kokka, 2019; Nolan, 2009). Thus, teaching and learning science for social justice must uphold sociopolitical contexts to contribute to a socially just society at both the individual and community levels. The history of social justice research in fact indicates that we, as a society, have the potential to lay the foundation for equitable mathematics and science education (Barton & Upadhyay, 2010; Kokka, 2019; McDonald, 2005, 2008).

Theoretical Assumption

The theoretical assumption of this study is grounded in sociocultural and sociopolitical perspectives. According to the sociocultural perspective, all learning is related to our social and cultural activities (Gutierrez, 2013; Radford et al., 2018; Rogoff, 1990; Roth & Walshaw, 2015; Rowlands, 2010; Saxe, 1991; Schmittau, 2003; Vygotsky, 1978). There are four main assumptions in sociocultural theory. The first is regarding the active construction of the knowing and understanding of individuals through social interaction with their environments and others. In this sense, learning involves creating a mental representation of the information provided by experiences. The second assumption argues that learning could lead to higher mental development. This is what Vygotsky (1978) called the Zone of Proximal Development (ZPD), which is the distance between individuals' actual knowledge development without assistance and their potential knowledge development with the assistance of their more capable peers or teachers. The concept of ZPD has important implications in teaching because it impacts the way educators plan for activities, assess students' performance with and without assistance, and apply developmentally and culturally appropriate practices. The third assumption states that knowledge development cannot be separated from its social and cultural contexts. For Vygotsky (1978), a child is embedded in their cultural context and society, which has a significant impact on how they think and learn. Therefore, the child's mind is in both their own head and their society. Although people differ from culture to culture, Vygotsky (1978) believed that there is a similar mind structure in all humans. The fourth assumption relates to the importance of language in mental development. Vygotsky (1978) believed language is an essential part of individuals' thinking processes. It allows people to make sense of their world. Language acts as a mediator that allows people to carry their cultural and social experiences for self-regulation and self-actualization. In this regard, social interaction and critical reflection play an important role in knowing and understanding (Radford, 2015; Stemm, 2010).

Consistent with the sociocultural perspective, the sociopolitical perspective focuses on the notions of identity and power. Gutierrez (2013) framed identity as something that a person does rather than something that a person is. She argued that all learning and knowing is inherently situated in social interaction. In this sense, identity is a reflexive relationship between the individual's lived experiences and the sociocultural and sociopolitical milieu the person interacts with. For example, one of the researchers of the current study is male, a political refugee, and a mathematics educator, and he does research relative to transforming mathematics teaching and learning, teachers' critical reflection, and emancipatory action research. It is these actions that define this researcher's identity. Another important idea related to the sociopolitical perspective is the idea of power. Gutierrez (2013) defined power as active participation in and reconstruction of our everyday activities.

The sociopolitical turn signals the shift in theoretical perspectives that see knowledge, power, and identity as interwoven and arising from (and constituted within) social discourses. Adopting such a stance means uncovering the taken-for-granted rules and ways of operating that privilege some individuals and exclude others. Those who have taken the sociopolitical turn seek not just to better understand mathematics education in all of its social forms but to transform mathematics education in ways that privilege more socially just practices. (Gutierrez, 2013, p. 4)

The sociocultural and sociopolitical perspectives provide a basis for understanding, describing, and interpreting pre-service teachers' experiences, discussions, and reflections on the teaching of middle grade and secondary mathematics and science through a social justice lens in urban settings.

Context of the Study

This study was conducted in a state-supported urban university in the Midwestern United States. The course titled Perspectives in Mathematics and Science was developed for middle and secondary school pre-service mathematics and science teachers to take concurrently with their student teaching requirements during the spring semester each year. The three-credit-hour course took place once a week for three hours. There were 26 pre-service teachers in the class during the spring semester of 2020 (13 with mathematics backgrounds, nine with science backgrounds, and four with middle school mathematics and science specialization backgrounds). Nineteen of the pre-service teachers were female and seven were male. Participants self-identified with the following ethnic backgrounds: African American (3), Latinx (4), Asian (1), Middle Eastern (1), Native American (2), Eastern European (4), and Western European (11). Eighteen participants were undergraduates and eight were post-baccalaureates. Their age varied from 22 years to 39 years. All the pre-service teachers were placed in urban middle and secondary school settings for their student-teaching practice.

The Perspectives in Mathematics and Science course has four broad, interlocking goals: 1) provide an overview of the history of mathematics and science, 2) enable future teachers to enact these historical perspectives and contexts throughout their pedagogy, 3) promote intellectual curiosity and sharpen critical thinking skills, and 4) improve verbal and written communication. Throughout the semester, the pre-service teachers completed the following required assignments and activities: A) reading, reflecting, and discussing issues regarding their reading assignments from two required textbooks; B) participating in and contributing to the classroom activities; C) choosing, preparing, writing, and presenting a project that contains two interconnected pieces—historical development of a mathematics or science topic and a lesson plan and presentation connecting Part 1 to Part 2; D) selecting and communicating with another pair from the classroom and providing critiques of their peers' lesson

plans; and E) writing a final reflective paper related to their experiences throughout the semester. The critiques of their peers' lesson plans were more constructive and suggestive than evaluative, and this portion of the course activity intended to promote a caring learning community in which risk-taking, trust and belonging, common interests, and meaning-making were encouraged and celebrated.

The first required textbook was *Rethinking Mathematics: Teaching Social Justice by the Numbers* by Gutstein and Peterson (2013), which proposes an alternative perspective from which mathematics is taught in a way that helps students understand concepts in connection with their own life and as an approach to solving social injustices. The book also shows the importance of equity in mathematics teaching, emphasizes the significance of teacher-student relationships, and tries to enable teaching and learning to be contextualized around students' lived experiences in their communities. Furthermore, this book illustrates the viability of critical thinking, allowing students to recognize mathematical power as an analytical tool that connects their cultural and community histories and equips them for playing a more active role in society.

The second required textbook was *The Story of Science* by Hakim (2007), which explains the evolution of science beginning in the 1500s through the present. One underlying theme of this book is that progress in one area of science directly or indirectly leads to progress or discovery in another, and they are interrelated. The book celebrates the contributions of many scientists around the world, arguing that the evolution of science cannot be attributed to a single person or group. It also emphasizes the relationship between the history of science and the evolution of science, which has been vastly shaped and influenced by the sociocultural activities of people around the world. The book goes beyond providing a basic understanding of the content; it explains science as a study of patterns and relationships.

Methodology

This qualitative, descriptive, and interpretative study is guided by constructivist inquiry (Guba & Lincoln, 1994). Therefore, the study is context specific. One measure of trustworthiness is the acceptance of the findings by the participants. The primary researcher of the current study acted as both participant-observer and facilitator of the classroom activities and discussions. At each stage of the semester, he communicated with the participating pre-service teachers concerning his understanding and interpretations of their stated beliefs and actions (i.e., triangulation of data processing). Another measure of trustworthiness is the provision of thick description. In this study, the participating pre-service teachers' voices and concerns are the focal points. To accommodate all the participants and make the assignments and activities meaningful and doable within the time constraints of a semester, the primary researcher paired them so that one pre-service science teacher and one pre-service

mathematics teacher worked together collaboratively to fulfill their common goal of a semester-long project. Furthermore, each pair would select another pair in the classroom to critique their project. The reciprocal peer critiques provided the participants with an opportunity to reflect, modify, and re-plan their projects and presentations. A third way of triangulation occurred between the two researchers. They met every other week to exchange ideas and share their ongoing understanding and interpretations of the data.

Data sources included the researchers' classroom observations and field notes as well as participating pre-service teachers' verbal and written responses to class discussions, reading assignments, and course activities. Data analysis occurred alongside data collection, which began with coding, a process Charmaz (2001) described as the critical link between data collection and meaning interpretation. Open coding, which was referred to as descriptive codes by Saldaña (2016), was assigned to identify primary themes of the data. This allowed us to explore the understanding of the participating pre-service mathematics and science teachers through a social justice lens. Once open coding was concluded, we moved on to the inductive sorting of codes, identifying recurrent codes, metaphors, and contradictions. The data were then integrated and sorted into categories according to links between the codes, with the focus on the participants' experiences and realizations as well as the challenges, problems, and possibilities of teaching and learning mathematics and science embedded in social justice contexts. We iteratively moved between data and the coding framework and refined codes into consistent and discrete categories. Along with the coding process, reflexive and analytical memos were written to "document and reflect on the coding process and code choices" (Saldaña, 2016, p. 41), which helped us achieve reflexivity on the data corpus and at the same time provide documentation and transparency about our methodology. Once coding was completed, important factors were identified as considerations in promoting the integration of mathematics and science content into social justice contexts.

Researchers' Role

As Dollard (1949) stressed, the researcher "must pay the price of intense awareness of self and others and must constantly attempt to define relationships which are ordinarily taken for granted" (p. 20). Researchers with different backgrounds might push or support participants differently. Coming from different ethnic backgrounds, the two researchers of the current study were acutely aware that their roles could influence the participants. As such, they both managed their roles cautiously due to their various social identities throughout the research.

The primary researcher, who was also the instructor of the course at the center of the current study and has teaching the course for over 10 years, came to the United States as a political refugee from Iran years ago and has been teaching at his current

institution for 25 years. His mediating role as facilitator in the participating pre-service teachers' conversations and his position as a researcher in the classroom called his attention to the importance of maintaining a reflexive lens on his relationship with the participants. Being an immigrant professor, he kept cautious not to let his unique race and social class influence his role as facilitator in the participants' conversations. As a veteran educator of this course, he was sufficiently capable of fully eliciting the participants' self-reflections, but he also regularly reflected on himself, trying not to shape participants' discussions with possible pre-assumptions or stereotypes. In this sense, he was an observer of himself. He shared his understanding and interpretations of the findings with the participating pre-service teachers and the other researcher on a regular basis (every two weeks) to ensure transparency and trustworthiness.

The other researcher, a third-year doctoral student of urban education, came from China. She had taught in high school settings for nearly 20 years in China before coming to the United States. As a former teacher in China where historical background and student demographics are very different from those in the United States, she was a complete "outsider." She was clear that her subjectivity might constrain her ability to see phenomena in the field and hear participants' conversations, so she constantly probed to gain a more precise understanding of any concepts whose meanings she did not feel fully certain of. As a qualitative researcher, she reflected constantly on her positionality and subjectivity, communicating her understanding and discussing her uncertainty with the primary researcher each time they met. Being both the documenter of events and co-constructor of the meanings, it was easy to slip from the role of documenter to the role of co-constructor; she balanced her roles and goals through timely and constant reflexive memos.

Findings

As the participating pre-service teachers engaged in classroom discussions, critical reflections on teaching and learning, as well as lesson plan presentations, several themes emerged. These included the importance of teaching mathematics and science through a social justice lens, the participants' realizations and conscious awareness, and the challenges, problems, and possibilities of teaching and learning embedded in social justice contexts.

Importance of Teaching Mathematics and Science Through the Social Justice Lens

The data analysis revealed a consensus that teaching mathematics and science embedded in social justice contexts would make learning purposeful, interesting, and engaging. The participating pre-service teachers stated it is important to challenge the false Eurocentric viewpoint that has dominated mathematics and science education in the United States for a long time.

Traditionally mathematics and science have been taught from a Eurocentric or Western perspective. This is not fair for every student and especially unfair to underrepresented and minority students. This narrative does not tell the truth and can lead those students to believe that mathematics and science are not part of their own cultural background or their own selves. This is quite untrue. Mathematics and science are a part of every culture and part of all humankind. Teaching from a Eurocentric perspective limits the student's opportunities to learn about diversity, mathematics, and science from a different perspective. I believe that teaching content from a multicultural perspective embedded in social justice contexts will engage all students and create a classroom where all students can thrive. (Cory,¹ an African American male teacher)

The pre-service teachers mentioned the importance of teachers' awareness of their own bias and prejudice, which they thought would create a more inclusive classroom for their students belonging to underrepresented cultures. They concluded that this cultural awareness would allow students to find their own identities in the classroom.

While I had a decent understanding of multicultural education, I was not expecting to find out that so much stuff had been taken from other cultures and written off as a European discovery. The incredible achievements that the Babylonians and the Egyptians made many years before any European would begin thinking about such things were something that I had never realized before. Despite my awareness, I too fell into the Eurocentric trap. I just accepted what I heard, never really caring about where the theories came from. It was not until I came into this class and read more about how long this Eurocentric takeover has been going on that I realized just how strong this cultural impact is. It is important to make the classroom a beacon for cultural and historical education so that every student will know how important their cultures are to the development of the modern world, which helps them find their identities in the classroom. (Sophia, an Eastern European female teacher)

The participants also stressed how vital it is to teach from the social justice perspective. They indicated that this approach to teaching would allow students to better understand the world around them. They discussed that making mathematics and science relevant and personal to students would enable them to learn how to apply the learned content to the real world, which is much more important and meaningful than rote memorization of facts.

Social justice in the curriculum is not just a suggestion; it is a must for students and teachers alike. The important point is that social justice will enrich lessons, making them more influential and extend beyond the classroom. Students who feel empowered through lesson plans will have the confidence necessary to apply their knowledge to social issues. Without teaching mathematics and science in a way that highlights these issues, students lose out on a critical part of their education and teachers lose possibly the most important aspect of education: to empower their students. (Emma, a Native American female teacher)

¹ All names are pseudonyms.

Data analysis further suggested that the participating pre-service teachers had repeatedly proposed access and equity in mathematics and science learning in their classroom discussions, presentations, and writings.

We as educators should not be the gate closers in education. We should be the gate openers for our students instead. This allows our students to play a part in the world around them. Understanding the meaning behind numbers helps students spot injustices in their own communities. A deeper understanding of mathematics and science also enables students to defend their reasoning behind their points of view and beliefs. This skill can improve the confidence of the students, help find their voices, and show them that they can change the world around them. This makes mathematics and science alive and gives real meaning to the subjects. (Benjamin, a Middle Eastern male teacher)

As the participants gradually became aware of and tried to avoid their own biases, they became more convinced that teaching mathematics and science through a social justice lens would result in more engaging, meaningful, and democratic classrooms. By empowering themselves with social justice awareness for teaching, they became more prepared to design lessons geared toward their students' empowerment. Below are three examples of lesson plans developed by pre-service teachers that relate to social justice goals and objectives. These three lessons were selected to show various aspects of teaching mathematics and science through a social justice lens, including health care justice, environmental justice, and pandemic-related justice. The first lesson relates to social justice through its focus on the health care issues that arose during the AIDS epidemic:

This lesson is designed for a mathematics classroom when students are learning to graph and solve different forms of equations or when students are learning about using exponential equations. The lesson would follow students' ability to graph and solve exponential equations. Since the AIDS epidemic can follow the logistic style of equations, the lesson is meant to include a focus on an important social issue that impacts so many and that so many have no idea about it. The video engagement activity helps to start discussions on the topic of HIV, with 3 True or False statements that are commonly misconstrued. This fuels the fire of curiosity of what students really know, what misconceptions they have, and what they might be interested in knowing or learning. The personalized approach allows students to focus on researching what is interesting to them while filling out a worksheet to gain the knowledge of basic HIV facts as supported by the [State] *Science Standards* as well as the mathematics they have been learning. The follow-up lesson for tomorrow will include modeling various exponential equations and solving different components of the equation. We will look at different epidemics that occur in our society and have student teams to choose one scenario to model in the classroom, ending with a short research paper assignment to discuss the cultural and social effects of what would happen if the epidemic scenario were to occur in our state. (Noah, a Western European male teacher)

The second example focuses on environmental justice and requires critical analysis of climate change, its impact on our living conditions, and what can be done to change this situation. It is presented as follows:

The goal of this lesson is for students to understand the issue of climate change: what causes climate change, what impacts it has on our environment, and what we can do to help reverse the effects of climate change. The objective of the lesson is for students to investigate the issue of climate change through a PowerPoint presentation and a whole-class discussion. Students will also be able to identify the effects of climate change. They will also use a KWL chart to document what they already know about climate change prior to the lesson, what they want to know about it, and what they have learned after the lesson is complete. At the end of this lesson, students will brainstorm ideas and move toward a team-based project of their choice to apply their knowledge. The significance of this lesson is the students' awareness of how Global Warming is affecting people of every part of the world (i.e., of diverse backgrounds). More locally, the factors contributing to Global Warming are being manifested (e.g., Pollution of Cuyahoga River, unsustainable private and public practices, etc.). It is also important for students to learn this lesson to meet the [State] Learning Standards and pass the State Test. (Mary, an Asian female teacher)

The third lesson plan example concerns the current COVID-19 pandemic, which is impacting the lives of people almost all over the world, particularly the lives of minorities, people of color, and low-socioeconomic status populations. As a response to this current social issue, one pair of the pre-service teachers initially selected a topic concerning the ongoing pandemic. However, due to many unknowns regarding the nature of the virus and the lack of a viable vaccine for controlling the spread of the disease at the time of the study, they decided to change their topic to a similar but very well-known disease, as their lesson plan aimed at involving their students in critical thinking about health care justice. Below is how they presented it:

This lesson is the start of a new mathematics unit and also a review of the concepts taught in this school year and previous years. Students have learned various mathematics graphs, but this lesson will go into more detail and cover some new graphs. The pre-assessment will be used to see how much they remember what they have learned and what they have not yet learned. During the lesson, students will be given data concerning the chickenpox virus to learn about the scientific process for data processing and presentation. They will work in groups to find a way to represent the data and then present their graphs to the class. Each group will have different data representing a different aspect of chickenpox. They will need to tell the class their group's original hypotheses about a unique issue, what they think the given data means as depicted in their graphs, and their opinions about social concerns and future issues regarding chickenpox based on the data. Students will work cooperatively and respect different perspectives. The follow-up activity after this 40-minute class will occur on the following day. During the next class, students will continue working on their graphs and their worksheets and will also prepare to speak in front of the class. Presentations should have smooth transitions and each group member should have a chance to present a different aspect of the information. Once all the presentations are complete, one class period will be dedicated to a test that

includes scientific inquiry, statistics, and graphs. Additionally, each student will fill out a “peer evaluation” for each member of their group. This evaluation will show how well the group worked together. (Lucas, a Latino male teacher)

Social consciousness through critical reflections provided the pre-service teachers with opportunities to carry out their situated instructions in their own classrooms during their student-teaching. These above praxes (i.e., dialectical relationships between actions and reflections) are clear examples and testaments of the importance of teaching mathematics and science embedded in social justice contexts.

Participating Pre-Service Teachers’ Realizations and Conscious Awareness

Throughout the semester, the participating pre-service teachers realized several issues concerning teaching and learning mathematics and science, such as racial justice, gender equity, the importance of teacher-student relationships, and the notion of caring and belonging in education.

A major realization that has come about from observing patterns in mathematics and science education is the marginalization of female contributions in those fields. Female students need to see themselves reflected in those fields when learning. But because the history of female contribution is omitted or because females are underrepresented in teaching the historical contexts of mathematics and science, there is a gender disparity within the STEM fields. I further realized that science and mathematics do not lack female contributors; rather, typical K-12 science and mathematics education simply failed to acknowledge these contributors. (William, a Western European male teacher)

The female pre-service teachers in the classroom came to the realization that women are underrepresented in mathematics and science education and that there is a large gender gap in science, technology, engineering, and mathematics (STEM) fields for several reasons. Their reflections also revealed these trends in their own educational life.

Another important realization mentioned by several pre-service teachers was the importance of teacher-student relationships and the sense of belonging. As one of them put it:

The degree of students’ engagement in the classroom is related to their sense of belonging at the school. Students with a low sense of belonging, often marginalized students, are at risk of disengaging and falling behind their peers. If the school system does not attempt to remedy the cause behind this sense of belonging, it could have lifelong impacts on the students. Research shows harmonious teacher-student relationships can increase students’ sense of belonging. The sense of belonging is crucial for the development of adolescents as they go through many changes socially and intellectually. The needs of students of these marginalized groups must be met for their overall improvement in content areas and furthermore, in their professional life. (Isabella, an African American female teacher)

The participating pre-service teachers also asserted the significance of caring communities for equitable education. Some of the teachers shared their classroom interactions with their high school students. For example, a teacher shared her classroom teaching activities that were based on a community project and meant to help students understand the concept of percentage in mathematics:

From this class, I learned to check my biases at the door before going into my own classroom, which helped me view students equally without discrimination. As a teacher, this is a very important quality, helping me build my classroom into a caring learning community. Once my students were doing a project based on their communities' needs. At first, I asked them about their concerns in their communities, and then each student chose a concern and wrote down their thoughts about it. The students then looked up the percentages of different concerns and compared them with their peers'. This helped them understand the meaning of percentage and the method of calculating it. (Mia, a Latina female teacher)

Project-based learning was very common for these participating pre-service teachers to use as a teaching strategy to help their students. For example, they would focus on topics initiated by students and try to guide and facilitate their completion of the projects. As the students were engaged in project-based activities, they were learning significant integrated mathematics and science content within the contexts of their communities.

Challenges and Possibilities of Teaching Mathematics and Science Embedded in Social Justice Contexts

Data analysis revealed that the current school structure and culture, the existing curriculum, state-mandated tests, limited resources, and the lack of meaningful teaching experience were all challenges the pre-service teachers stated that they faced or might face in the future as they attempt to teach mathematics and science in social justice contexts. For example, one major obstacle is called the *culture of silence*, which occurs when a teacher is not fully committed to overcoming the structural systems of inequality in education. It is critical that teachers strive to achieve full awareness of the five social factors—race, social class, gender, culture, and disability status. It is also important that teachers reflect on cultural and linguistic diversity to gather necessary information to develop culturally responsive instruction. Teaching mathematics and science for social justice should instill students with new knowledge that encourages them to become social change agents. Some of our participating pre-service teachers were not comfortable confronting the challenges of injustice and inequality in urban settings. For example, one of them presented this:

While I think it is beneficial to connect the content to student life, I feel like that discussing these topics, especially in urban areas where there are typically high concentrations of poverty, might be too personal for some students and may result in them feeling

ashamed, embarrassed and even angry. I am uncertain as to if it will work in a middle school classroom where some students already feel self-conscious. (Katie, a Native American female teacher)

These feelings of uncertainty and being passive in the face of the “hot topics” surrounding the educational community were expressed by several participating teachers. However, this perspective was challenged by most of the pre-service teachers during classroom discussions. As one of them put it:

Something I have realized over the semester is the difficulty in actually teaching mathematics in a way that integrates history and social justice into the classroom. This is because it is not the way I was taught growing up and is new to me and many of my colleagues. But I have also realized the importance of teaching in this way because it will open a door for the low-status adolescents in urban settings to become both aware of the historical background of the learning materials and actively engaged in community-based activities that are of interest or importance within their daily life. (Charlotte, a Western European female teacher)

Another teacher supported the above statement by saying that sometimes being uncomfortable confronting challenging issues is positive rather than negative. He stated this:

I enjoy this course because it opened my eyes and changed my thoughts about education. I believe that mathematics and science are best taught from a multicultural perspective. I do not think it is easy to implement this approach into a classroom, but I believe those uncomfortable feelings would motivate and help us to overcome all the difficulties. I also believe our efforts are worthwhile for the better education of our students. (Liam, an African American male teacher)

Despite all these challenges, obstacles, and problems, most of the participating pre-service teachers were convinced that it is worth fighting to teach mathematics and science in the context of social justice.

Discussion

This study examined 26 pre-service middle and secondary school teachers’ experiences and reflections on teaching and learning mathematics and science from a social justice perspective as they took a semester-long course concurrently with their student-teaching. The findings of the study suggest that a semester-long discussion, critical reflection, and lesson plan development provided the participating pre-service teachers with opportunities to question their own learning experiences in mathematics and science classrooms and to become active members of transforming learning communities. Moving away from traditional ways of teaching mathematics and science toward developing engaging mathematical and scientific content embedded in

social justice contexts requires the transformation of consciousness, which is consistent with the findings of previous research (Bartell, 2013; Felton-Koestler, 2017; Myers, 2019). This transformation is more than changing teaching strategies; it is a change in ways of knowing and reading the world through critical lenses to become change agents.

Teaching mathematics and science from an integrated perspective embedded in social justice contexts served the pre-service teachers a sense of purpose. It allowed them to present academic content in meaningful ways by making connections between students' interests and state standards. By developing, preparing, and delivering activities grounded in project-based pedagogical contexts, the pre-service teachers were able to better understand the contributions of underrepresented groups and diverse cultures in the development and evolution of mathematics and science. Moreover, classroom discussions and critical reflections regarding culturally responsive teaching were essential for them to address the unique learning needs of students in diverse classrooms. This is how university courses help prepare pre-service teachers for their future teaching.

Collaboration and support, critical reflection, and personal relevance are important elements for pre-service teachers to adopt in preparation for mathematics and science instruction embedded in social justice in their classrooms. Marginalized students have already fallen behind historically and will continue to do so unless major changes are made in the way STEM courses are taught. Sociocultural and sociopolitical perspectives must be introduced into the classroom to encourage students who have been hindered from engaging in mathematics and science that they too have a voice about. Without the effort of teachers to learn their students' needs, students will be further alienated to the point where they feel they have no discourse in their study. These pre-service teachers, although convinced regarding the vitality of culturally responsive pedagogies, may face significant challenges, problems, and obstacles as they start teaching their own classrooms within the existing school structure and culture. However, as many of the participating teachers stated, it is worth fighting, and perseverance will help them achieve the integration of social justice into their classroom activities. As one of the participating teachers expressed:

We must not make our students feel as though they have no voice in the classroom; we must give them that voice. We must give them the voice they need so as to instill changes they want within their communities. The only way that voice can be found is through the integration of cultural-historical perspectives in the classroom. Without this crucial element in instruction, the problem of marginalized students falling behind in STEM education will only become even worse. (John, a Latino male teacher)

With classrooms becoming increasingly diverse, it is the duty of educators to make sure students from all backgrounds feel included both in the physical classroom and in the content being taught. There are deep sociocultural, sociopolitical, and

sociohistorical contexts surrounding mathematics and science content that need to be integrated. Although traditional lectures may be easier to accomplish, the job of teachers is not to look for easy ways to conduct classes but to ensure educational standards are met and that students establish the conceptual knowledge being taught as well as critical thinking skills necessary to tackle issues they will face in their lives. There might be some degree of pushback, but this work can be highly rewarding and entirely achievable as pre-service teachers tend to be more involved in real-world problem contexts and new mathematical and scientific methods (Aguirre, 2009; Ensign, 2005; Mistele & Spielman, 2009; Rodriguez, 2005).

Conclusion

The problem of systemic injustice in our society is deeply rooted in the notion of identity and power. This problem cannot be solved from the same mindset where it originated. In the context of education, there ought to be a shift of mindset from considering preparing students to live in the existing world to considering preparing them to reconstruct those current social systems and to remove obstacles experienced by minorities, women, and others (Secada, 1989). The implication of this transformation is significant. It denotes that school reform cannot be actualized without active participation in and reconstruction of school systems by teachers and students. They are the beacons of hope and the beacons of change. Due to the intricate connections between education and economic, political, and social power structures in society, which contribute to inequity in both schools and society (Apple, 1992; Kozol, 2005), achieving social justice in mathematics and science education remains a huge challenge for educators. However, if mathematics and science teaching and learning are situated within sociocultural and sociopolitical contexts combined with viable organizational support, there is hope.

Teaching through a social justice lens is not a methodological issue but a process that requires teachers to adapt to the particular contexts they and their students belong to (Cochran-Smith, 1999). Learning to teach mathematics and science from a social justice lens is a “lifelong undertaking” and a complex process that requires effort, perseverance, and reflection (Darling-Hammond, 2002, p. 201). It also requires teachers to see it as such (Gutiérrez, 2009). Although a one-semester university course cannot make learning to teach for social justice “happen,” such efforts increase our understanding of the broader goals of mathematics and science education. This study contributes to the process of educating pre-service teachers for the implementation of social justice into their mathematics and science instruction and the development of their new conscious awareness. More importantly, this study is a story of hope. We hope the study encourages future professional development programs and future studies on both pre-service and in-service mathematics and science teachers’ engagement in social justice issues.

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