

Exploring Mathematics of the Sociopolitical Through Culturally Relevant Pedagogy in a College Algebra Course at a Historically Black College/University

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In collegiate mathematics, college algebra continues to be a barrier to graduation for students (specifically non-science, mathematics, engineering, and science majors). Each year, nearly half of enrolled students struggle to “pass” this course with a grade of C or better (Herriott, 2006). Using innovative constructed lessons geared towards African American students, this research study was designed to investigate the effects of a sequence of such lessons grounded in the principles of culturally relevant pedagogy on students enrolled in an introductory college algebra course at a historically Black college/university. Using critical race theory as a lens, along with culturally relevant pedagogy, this study explored students’ abilities to apply mathematics to address contentious and present-day sociopolitical problems through eight in-depth semi-structure student interviews. Further, findings also suggest the need for collegiate mathematics instruction to have more emphasis on cultural components to build students’ sociopolitical consciousnesses, because this is integral in helping students be able to think critically and use mathematics in their everyday lives. Students in this experimental course were able to discuss difficult issues, such as the pervasiveness of racism in America (DeCuir & Dixson, 2004) and the importance of cultural identity for African American students (Martin, 2009).

KEYWORDS: college mathematics, critical race theory, culturally relevant pedagogy, mathematics education

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Nationally, nearly 50% of students who are unsuccessful withdraw from service-level college algebra courses each year (Herriott, 2006). With the growth of diverse students in America and research that is often focused on *gap gazing*, which Gutiérrez (2008) defines as “document[ing] disparities in achievement between middle-class White students and students who are Black, Latina/Latino, First Nations, English language learners, or working class” (p. 357), we must research and invest in pedagogical approaches that are specifically geared towards students of color who stand to benefit most. Racially minoritized students face additional barriers to achieving in mathematics courses due to deficit perspectives and perceptions on perceived indications of what (and how) they can or cannot learn (Harper, 2010). Racially minoritized students are often regulated and oppressed under the guise of teachers “doing what is best for their students.” These views also help teachers rationalize that “certain students” are not capable of the critical thinking needed to engage in higher-order tasks; therefore, they must be explicitly told the information they need to learn. Under this mindset, the only way to “teach” students is through direct instruction (i.e., lecture), a method that is still the predominant mode of instruction in mathematics; yet, the failure rates for students who receive primarily direct instruction are 55% higher than students who are engaged in a more active learning approach (Freeman et al., 2014).

Deficit perspectives, traditional instruction, and low expectations are factors that help influence whether students take more advanced coursework in high school. When students are not advised to take more advanced courses, they are inadequately prepared for college. This often results in students being placed in college algebra, where failure rates are extremely high. There is a high need to help minoritized students in these service-level mathematics courses to improve outcomes for students (Boyce & O’Halloran, 2020; President’s Council of Advisors on Science and Technology, 2012). Using culturally based pedagogical frameworks has been shown to improve and combat negative learning experiences for students of color (Gutstein et al., 1997; Ladson-Billings, 1995a, 2014). To explore the effects of such pedagogy (in hopes to improve the outcomes for these minoritized students), this study utilized culturally relevant pedagogy (CRP) within a college algebra mathematics course taught at a Historically Black College/University (HBCU).

Literature Review

Underrepresented minority groups, including African Americans, Hispanics and Latinos(as/x), and others, make up about 30% the population in the United States (U.S. Census Bureau, 2017). There has been some research conducted (and currently being conducted) on how best to improve aspects of the education system to impact diverse groups of students and their teachers (Ladson-Billings, 1995a, 1995b; Martin

et al., 2017). However, much of this research has been conducted in grades K–12, with less focus at the college level.

Powell and Frankenstein (1997) curated the anthology *Ethnomathematics: Challenging Eurocentrism in Mathematics Education* in order to challenge the following statement on the notion of White dominance in the field of mathematics:

In the Eurocentric account, Europe (and “Europeanized” areas like the U.S.A.) has always been and currently is the superior Center from which knowledge, creativity, technology, culture, and so forth flow to the inferior Periphery, the so-called underdeveloped countries. (p. 1)

This hegemonically developed notion of how mathematics should be learned, taught, and who created mathematics is problematic on multiple levels. Thus, researchers are working to fight to end these and other similar notions that mathematics is naturally, and by definition, “neutral” with regards to culture and the teaching of it (Nasir et al., 2008). Mathematics is not culturally neutral. Thus, it is worthwhile investigating how an approach to teaching mathematics that embraces the culture of students affects students’ engagement with and performance in mathematics.

Social justice pedagogy is an equity-oriented practice that is conceptualized by what is and what is not fair and just with regards to the relationships between the individual and society (Baily & Katradis, 2016). This is measured by the explicit and implicit ideas of wealth distribution, opportunity, and social privileges based on one’s social status in society. Social justice is often referred to as something researchers and educators move towards, never quite reaching it, for “[i]t is in seeking to understand the ways in which we simultaneously accept/unaccept the other that we move closer to becoming agents of social justice” (Aguilar et al., 2016, p. 252). Practitioners and researchers interested in social justice have found ways to address inequitable learning opportunities. Some have done so by using CRP, which integrates the cultural identity of the students involved and academic rigor of the content being taught (Ladson-Billings, 1995a).

Theoretical Framework

By utilizing the tenant of sociopolitical consciousness (CRP) and challenging the notions of colorblindness, dominance, and the hegemonic nature of mathematics (critical race theory [CRT]), we are able to address anti-racism and social justice issues (SJP) through mathematics education. Thus, researchers are moving past socio-cultural views in attempts to “espouse sociopolitical concepts and theories, highlighting identity and power at play” (Gutiérrez, 2013, p. 37).

Culturally Relevant Pedagogy. CRP has teaching mathematics for social justice at its heart. It looks beyond notions of functional mathematical literacy and concerns

itself with gaining mathematical knowledge and skills that are necessary for participating in society as it is now and pushes towards critical mathematical literacy. This emphasizes the development of knowledge, practices, and discourses for transformative purposes (Tan et al., 2012). These transformative purposes come from Freire (1968/1970), who reminds us that education should provide opportunities to understand, challenge, and re-create preconceived understandings of the self and the world. With CRP, the goals are clear: to afford students who have been historically marginalized the opportunity to achieve. The effect of teaching with students' culture has been shown to have a substantial increase in self-confidence and self-efficacy (Enyedy & Mukhopadhyay, 2007; Hubert, 2014), effectively replacing feelings of failure and alienation that is all too common with the subject of mathematics and students of color (Tate, 1995).

CRP is founded upon three tenets: academic achievement, cultural competence, and sociopolitical consciousness. Academic achievement concerns itself with student learning, focusing on what "students actually know and are able to do as a result of pedagogical interactions with skilled teachers" (Ladson-Billings, 2006, p. 34). Cultural competence involves aiding and empowering students to recognize and honor their own cultural beliefs and practices while also acquiring access to wider cultures. Sociopolitical consciousness focuses on students becoming more conscious and aware of sociopolitical issues not only on a national or a global level, but perhaps even more so on a local level. The focus of this research paper and subsequent literature review will be on the third tenet (sociopolitical consciousness).

Sociopolitical Consciousness. Possibly the least addressed of the tenets of culturally relevant pedagogy is sociopolitical (or critical) consciousness. This section will show how researchers attempt to unveil the policies and practices that are happening in the world outside (and sometimes inside) the classroom. William Tate (1995) stated that this type of pedagogy is beneficial because it enables students to pose their own questions as they relate to their communities and how they feel they are negatively impacted. Therefore, students are in charge of their own learning, and CRP allows students "to see the world from the perspective of others" (Tate, 1995, p. 170). Students can incorporate the problems facing many African American communities to make mathematical learning more relevant to themselves as shown in this dimension.

Power Through the Sociopolitical. Gutiérrez (2013) charges us to make transparent the realities that are plaguing us so that we can empower our students to rise beyond the current dynamics that are at play in mathematics education and in our society. Teachers must continually be educated and attend professional development so that they can see their mathematics classrooms as a smaller part within a large social and political history. They need support to challenge discourses that seek to instill inequality through the use of high-stakes standardized test scores as the only

measure for learning. This involves developing more than just the “[pedagogical content] knowledge of mathematics, pedagogy, and learners, but also the political knowledge and experiences necessary to negotiate the system and develop working networks with other educators who share their emancipatory visions” (Gutiérrez, 2013, p. 62).

During a series of professional development sessions in the Bahamas, teachers wanted to enhance their abilities to “(a) foster critical mathematical and critical consciousness, (b) build on informal mathematical and cultural knowledge; and (c) utilize empowerment orientations toward students’ culture” (Matthews, 2003, p. 61). The institute hoped to marry CRP with a heavier emphasis of social justice pedagogy (Gutstein et al., 1997) to reflect on the use of mathematics in schools and the world, explore enhancing algebraic mathematics instruction, and encourage using students’ cultures as a tool in mathematics class. Some teachers were more successful than others. The teachers who were successful relied on the relationships built between their students and themselves. Teachers also built on students’ mathematical and cultural knowledge simultaneously through rich mathematics explorations. Through these explorations, students’ critical-thinking capabilities were expanded through mathematics, and connections to the government and other societal entities were investigated as context within their mathematics courses (Matthews, 2003).

Social Justice Pedagogy in Action

Some teachers have found success in infusing project-based curriculum with CRP (Gutstein, 2003; Gutstein et al., 1997; Westheimer & Kahne, 1998). Lynn (1999) interviewed African American teachers of predominantly African American students about their successful practices with this demographic. These teachers were sought out due to their liberative-styled instruction. With most being elementary teachers, they commented on the pervasiveness of racism in America (DeCuir & Dixon, 2004), the importance of cultural identity for African American students, and the intersection of class and race (Crenshaw, 1989, 1991). Aligning with CRP, this style of teaching (liberatory), according to Lynn (1999), consists of the following:

- a) teaching children about the importance of African culture [cultural competence],
- b) encouraging and supporting dialogue in the classroom [constructivist methods],
- c) engaging in daily self-affirmation exercises with students [cultural competence], and
- d) actively and consistently resisting and challenging authorities who advocate practices that are hegemonic and counter-emancipatory [sociopolitical consciousness]. (p. 619)

Teachers can choose to see the connections between mathematics teaching and social justice in the form of activism (Gutstein et al., 1997). This study uncovered that teaching for social justice and using CRP is not removed from teaching standards. In fact, they overlap. Both social justice and teaching standards understand and advocate for teachers using students' cultural knowledge as platforms for instructional activities and require a place for critical thinking. There is an important distinction that exists between thinking critically in mathematics (necessary for mathematical aptitude) and viewing knowledge critically in general (necessary for effective social change; Gutstein, 2003; Gutstein et al., 1997). Teachers should continue to make connections between families in order to create and foster a sense of community in which students will see their culture in their work in order to build "a curriculum of empowerment and as a way to promote cultural excellence" (Gutstein et al., 1997, p. 733).

CRT: Challenging Colorblind Mathematics Perspectives

Increasing mathematical knowledge and ability is certainly a goal of this body of research, and so is affording historically marginalized students the opportunity to succeed. If students see no links between the subject they are trying to learn and their lives and future goals, then they will not respond to it. Sticking to the status quo and continuing not to teach mathematics with a cultural perspective will continue to exclude people from cultures from outside the dominant majority because they just simply will not be interested in it (Nasir et al., 2008). As Herzig (2005) states, "some individuals may reject mathematics not out of a sense of choice but because they feel that mathematics has rejected them" (p. 253). Thus, the transition to the inclusion of these practices can be enhanced through listening and learning from students and other adults who are invested in making the students' learning environments productive and conducive to developing students' identities of themselves and the world.

The driving force behind much of CRP literature in this literature review is summed up by Martin (1997): "[e]xposing the links between mathematics and social [awareness] should not be seen as a threat to '[academic] mathematics' but rather as a threat to the groups that reap without scrutiny the greatest material and ideological benefits from an allegedly value-free mathematics" (p. 169). Offering students proven and valuable methods to a new view on mathematics should not come as a threat to anyone, for enriching the mathematical educational experience for students of varying backgrounds that do not reflect that of what is shown on posters and in textbooks through the use of culturally relevant teaching has positive effects on those students (Ascher, 1991).

Colorblind ideology allows people to look beyond race and reinforce the mindset that everyone is the same, thereby invalidating racial identity and cultural experiences. As a challenge to colorblind ideology, CRT allows us to utilize its

undergirding tenets to critique the colorblind perspectives when teaching mathematics at the collegiate level. CRT addresses race, racism, and power structures in the United States. For this study in particular, the permanence of racism and Whiteness as property are the focus. CRT posits two notions: (a) the permanence of racism, which states that race is permanent and a constant that controls social, political, and economic mobility in our society, and (b) Whiteness as property, which states that “the law’s construction of Whiteness defined and affirmed critical aspects of identity; of privilege; and of property,” making it easy to exclude African Americans (Harris, 1993, p. 1725; see also Delgado and Stefancic, 2017). These factors allow for limited opportunities and numerous educational injustices, especially in mathematics.

Mathematics as an educational content area is not racial, but historically the instruction of mathematics is embedded in racism (Joseph et al., 2017). CRT allows us to challenge conversations regarding mathematics, and African American students are centered around the underperformance and access these students have. In particular, they have disparate access to advanced courses and certified teachers at early ages, which disenfranchises these students mathematically, thus maintaining a culture of White supremacy (Bullock, 2017). In collegiate settings, professors are not typically hired based on their pedagogical skill sets but rather on their research ability, thus contributing to poor achievement, poor instruction, and negative ideals towards mathematics amongst African American students and privileging the White experience (Joseph et al., 2017). Additionally, through mathematical knowledge (specifically statistics), we can see how racism contributes to inequity amongst African Americans in our society.

CRT posits that the idea of property allows Americans to gain power; in education, intellectual property such as access to certain technologies, certified teachers, and advanced courses are in fact limited resources that every student does not have access to (Bullock, 2017). Quality education is given to those who have access and is situated around specific nuances of housing and socioeconomic status (Bullock, 2017; Joseph et al., 2017). For example, diversity in teaching mathematics may differ at a private school with board certified teachers compared to a public school where new teachers are hired to instruct mathematics (Bullock, 2017). In collegiate settings, some of these same disparities exist when it comes to class size, access to teacher assistants or tutors, and other resources that can assist with achievement. Deep engagement in culturally relevant mathematic pedagogy not only allows students to develop social awareness and find value in mathematics, it also challenges the current narrative that mathematics is White property and provides a way for African American students to connect their own experiences to instruction.

Methods

The purpose of this study was to investigate the effects of a series of lessons grounded in CRP on students in a college algebra course. To this end, the research question that was explored was the following: *How are college algebra students able to critique discourses of power using mathematics as a tool?*

Study Context

This study took place at a large HBCU located in the southeastern United States during the Fall 2018 semester. Students were enrolled in one of two sections of College Algebra I at Bernard St. Stephen State University (BSSSU [pseudonym]). Nestled amongst an urban Black neighborhood that is recognized by the National Register of Historic Places, BSSSU resides in the middle of an urban community with deep roots focused on African American heritage, history, development, and educational advancement that contributed to the growth of the HBCU.

Course Context

This three-credit hour course, College Algebra and Trigonometry I, has been historically taught using traditional approaches and is vastly procedural. Topics include linear, quadratic, higher order, exponential, and logistic functions. Most students will end up taking only one additional mathematics course to satisfy general education requirements at BSSSU, either College Algebra and Trigonometry II (for majors that are more science, technology, engineering, and mathematics-focused) or Elementary Statistics (non-science, technology, engineering, and mathematics focused majors). There is a non-credit hour course that students can place into (Introductory College Algebra), but most students begin in College Algebra and Trigonometry I.

Participants

Participants included 25 students—overwhelmingly, many of the students were African American (96%) and female (76%). A total of eight students agreed to participate in semi-structured student interviews (Table 1). The student sample that was selected to participate self-identified as either all African American (six women and one man) or of mixed heritage (one woman, half-African American and half-White). All of these students were first-year students, and one was a non-traditional student (who was not admitted to BSSSU directly from a high school). The age of these participants was between 18 and 19, except for the non-traditional student, who was 36 at the time of the study.

Table 1
Interview Participant Information

Name (Pseudonym)	Race	Gender	Age	Year	Major	Final Grade
Tiffany	Black	Female	18	First Year	Nursing	A
Asia-La'Rae	Black	Female	18	First Year	Nursing	A
Pamela	Black	Female	18	First Year	Elementary Education	A
Matthew	Black	Male	18	First Year	Business Administration	A
Ahshante	Black	Female	18	First Year	Social Work	B
Lindsey	Black/ White	Female	18	First Year	Nursing	B
Jamie	Black	Female	18	First Year	Business Administration	B
Kanisha	Black	Female	36	Junior	Business Administration	C

Intervention

Four lessons were designed and developed to be grounded in CRP and for the specific population of students—primarily traditional college students attending an HBCU in the southeastern region of the United States (see Table 2). These lessons were vetted for their alignment with CRP using Matthews, Jones, and Parker's (2013) Culturally Relevant Cognitively Demanding task rubric. These lessons were implemented during the final three (of five) units in the college algebra course at BSSSU. Beginning with a problem statement that would guide the focus of the lessons, students had various opportunities to explore the statement through mathematical exploration using data sets, mathematical manipulations, and information from the internet. Students were also encouraged to draw from their own prior knowledge and past experiences of various topics to help make meaning.

Table 2
Table of Lessons

Mathematical Content	Guiding Question/ Problem Statement
Linear Functions	What does incarceration look like in this county and the US? Does race play a role?
Quadratic Functions	How are sexually transmitted diseases and cuffing season related to each other?
Exponential Functions	How do poor people bank? What does college loans/debt look like at HBCUs?
Exponential and Logarithmic Functions	How are demographics in the US changing?

Data Collection and Analysis

Semi-structured interviews were a crucial data collection tool in this study to explore students' views and perceptions gleaned from participants in the course. This semistructured interview used broad, open-ended questions that allowed for flexibility to let the respondents open up about what they were thinking yet also allowed consistency amongst participants (Merriam & Tisdell, 2016). These interviews were separated into two main sections. The first part contained questions related to the course and how students thought and reacted to the content, more specifically, the delivery and interactions with and about the content. The second part of the interview was focused on students' abilities to think about real-world situations and come up with opinions. The goal with these situations were to see how students could use mathematics to help them conceptualize the issue and support their argumentation with the mathematics students were describing. Of these three scenarios, two were focused on the sociopolitical construct of CRP. These scenarios were surrounding minimum wage and police shootings and killings of unarmed Black Americans. The third scenario was around planning for social events. This scenario was used to further investigate students' mathematical thinking through a culturally relevant situation.

Voice recordings of the interviews were transcribed verbatim, with indications of any elongated pauses or breaks in communication documented along with turns, which were marked by changes with the speaker at each timestamp (Ochs, 1979). Transcripts were shared with participants to make sure that what was recorded

aligned with what the participants tried to portray. ATLAS.ti 8 was used to analyze the interview data.

Data-driven coding (DeCuir-Gunby et al., 2011) took place through line-by-line analysis of transcripts. Statements were coded through the use of open coding in order to conceptualize what was said by respondents (Strauss & Corbin, 1990). After open coding, axial coding was conducted to collapse codes into larger categories through constantly comparing codes with each other and developing categories from pools of concepts discovered in the data. Constant memoing took place to capture the researcher's thoughts during this process (Charmaz, 2006).

Findings

When pedagogy has a goal of building students' sociopolitical consciousness, it is charged with equipping students with the knowledge to view social and/or political actions that are happening in their local communities, nationally, and globally through a critical lens (Ladson-Billings, 1995b, p. 476). The experiences, as reflected by students in this course, revolved around themes related to *recognizing* (that a problem exists), *caring* (empathizing with groups of minoritized people), *critiquing* (established systems and structures), and *acting* (towards finding solutions). These themes were observed in both parts of the interview. Part one included questions about the course, and part two included questions surrounding scenarios involving a topic/issue and the use of mathematics to help explain that scenario.

Interview Part One: Questions About the Course

Recognizing. Several of the students who were interviewed expressed a feeling of shock when they were asked what they thought about the lessons. The lesson that really shocked the students with some of the raw facts and figures was the lesson on incarceration and linear functions because they were able to see and recognize the *pervasiveness of racism* that exists in our society. Tiffany said, "the incarceration one is like... wow! Is that many people in jail!?? Like, Black people at that! It's very informational, all that. I didn't know that before."

Connecting what was learned in this class with other things, Matthew had the following to say about the topics in the course.

Matthew: The changing populations in race in America and then the incarceration [were the lessons that addressed my culture in this class]. Today, a lot of people see African American, you automatically think bad sometimes. We talked about in these lessons, well... people made comments about how they always going to jail and stuff; drugs, you see a lot of people getting killed, police brutality, and stuff like that. I think we're already at a disadvantage, so for us to fix that, it would take us all to come together as one and everything. But as to what was talked about in the class, I do believe the Black racial population and incarceration were very important things that are important [to know] today for us.

Matthew acknowledged that some of the topics that were discussed in class involved issues that are salient to him and his cultural community (African American). Ahshante also agreed with this sentiment when she was responding to the question of how discussing these topics in a mathematics class made her feel.

Ahshante: Well, we basically grown, so it's not like it was too much because it's something that needed to be talked about and still needs to be talked about and pushed for. If you don't talk about it... you don't want to make a mistake, or you want to be aware. You want to be cautious. So, I think all of them was good. Like it is not just about one thing. It's about everything. All the topics should come with this education, and school. That's what we are now. We need to learn about this stuff and a class seems like a good place for it—at least the way we did it, mixed in with the math.

Discussing these topics for these students was something they felt was needed, because these topics reflected what was currently going on in society and thus were affecting their day-to-day lives. The culturally relevant topics influenced not only their lives, but also people who looked like them and were a part of their same culture.

Caring. When learning about these sociopolitical topics throughout this course, students often expressed varying degrees of empathy for the populations of people that were being discussed. With this, students began to use the mathematical lessons to create their own *intellectual property*. After the course was over, and throughout the lessons themselves, students thought heavily about the issues that were being discussed with the mathematics.

Jamie: [These lessons] made people in the class think not just about like what the equations was or whatever math we were doing but how it could affect us. So, they basically depict what can happen in the future if this continue to happen—happen to us and other people.

Feelings of wanting to prevent and/or help alleviate some of the issues that were talked about (specifically incarceration and banking choices by poor people) came up in several of the interviews. Take Lindsey's response when she was asked about the role culture should play within a mathematics course. She stated the following thoughts deeply rooted in her background and her feelings about incarceration and how it has played a role in her life.

Lindsey: So, when I'm doing math, now I'm thinking of these real-world situations—like this is actually happening, you know. How can I help prevent that? Like, think about the incarceration [lesson]. I knew a lot of people that have gotten locked up for no reason... well, to me for no reason. I know a lot of people that do dirty things and don't get locked up, and I feel like it's just because of the color of their skin. Yeah, I take the incarceration thing a little far. I just feel really bad for them because race has a lot more to do with them being locked up than their actually petty crime.

The empathy that Lindsey exhibited was for people of color who themselves were in the incarceration system. She, and others interviewed, really connected with people in the situations that were brought up during these class discussions during the CRP lessons. Like other students, Lindsey was able to see how mathematics was connected to racism within her own community,

Kanisha took a different approach with the empathy she was exhibiting. It was not directed towards a particular group of people like some of the other statements were above. She wanted people, specifically White Americans, to show empathy towards African Americans. Kanisha took note of how *Whiteness as property* guided what statistics are shared in America. She believes that CRP conducted at predominantly White institutions could be a potential conduit to perform such a task to illicit such a response.

Kanisha: A lot of times, even in the predominantly White schools, a lot of times they show; rather, they wouldn't show about statistics about the White becoming smaller in number [exponential lesson about rising population of minorities in America]. They wouldn't show this. But I think like in their life in general, a lot of White kids don't get the information that they need, so they're only stuck with what they know, but this is reality, you know. This is OUR reality; the incarceration is reality. I mean I think it would give them a better outlook on us as Black people too. There could actually be something wrong with a system that is incarcerating us more often than them, even though they more than outnumber us in overall population.

Critiquing: Incarceration. Throughout all the interviews, the most comments were on the CRP lesson centered around incarceration. Perhaps it was because this was the first lesson that was presented to the students or it was an issue that students were invested in. Kanisha had the following to say as it relates to incarceration.

Kanisha: As Black adults and young adults, you know, we need to know certain things especially about incarceration and its role in life... like this is our life! Pretty much. That's what they're doing is putting it as a part of our life. It's all racism. Incarceration is part of my culture too, but not my culture per se, like not directly towards me, but it is a part of Black culture. Like I said it's how they see us. It's our life. It's worse the prisons are filled with us because of the crime rate or the so-called crime rate that they put us in. Yeah, that is definitely a part of our culture. Sad but true. Show them the graphs and the numbers and they'll rethink somethings—probably not though.

Using that lesson as a launching pad for her thoughts, Kanisha began to think about what students did in class and wondered if looking at the statistics, making this her own intellectual property, would lead to a change in the system of incarceration, crime rates, and arrests made by law enforcement.

Health

The topic of health really got Jamie talking and deeply reflecting on her own personal home life with her family and issues dealing with health and insurance. She began her statements discussing the sexually transmitted disease contraction lesson (in relationship to quadratic equations), and this discussion progressed into one about the overall well-being and health of African Americans. This then evolved into a discussion about what she believed to be the true heart of the matter: expensive health insurance premiums, connected to the *pervasiveness of racism* in medicine.

Jamie: I guess the STD patterns. African Americans have a hard time telling their doctors that they have something that they can't get rid of. So that's the same thing with just regular illnesses in general, like diabetes, high cholesterol. Because we are, we're not too known about going to the hospital and looking after our health because that's [not] the main priority. But we as African Americans need to keep ourselves in check whenever it comes to these types of things. A lot of times, we weren't taught these things. This leads to an even bigger issue of what I would really want to talk about is good health care for just for all different types of races. It's too expensive, and a lot of people can't afford it. If we got data on these types of diseases and compared when people actually come in to get help based on whether they had insurance or not, and plotted it on graphs and showed them the equations, I would hope that would change some things.

These discussions held with Jamie and Kanisha were extremely enlightening in what students were already passionate about, or had previously thought about these issues, and how they connected what was done in these classes on these “experimental” lesson days.

Acting. Discussions from reflecting upon the mathematics that students learned (the content) led them to focus on the issues (the context) and how it affected them. These reflections were often quite deep, and students had been constantly thinking about these sociopolitical contexts since speaking about them during the specific lesson classroom period.

Lindsey: A lot of my family has been locked up, and I can, I see the difference. Like something that the people that raised me [African Americans] would do that would get them locked up, but something that if my mom's side of the family [Caucasian] did, it probably would get them a slap on the wrist. I like the fact that I can see it from both sides and perspectives, but it's just messed up, and I wish I could just do something about it.

Kanisha echoed this feeling of “wanting to do something” about the reality of the situation as well. She also wants other African American students to feel the same way because of the reality of this pervasive issue in society.

Kanisha: The only thing that really made me feel some type of way is, I believe, would have been that incarceration one. Just to know like this is real. Like just introducing it to the Black students because it deals with Black people. It makes them, or it should make them, even look like for their future like, “I don't want to be a statistic. I don't want this to be me,” you know. The total prison population went down a little in that time period, but we're still the majority. But it's like: okay, as a Black student what can I do? What can I do so I'm not that statistic? What can I do to help my community so we can bring down the number?

This idea about finding the next steps or “taking action” is something that was explored in the final part of the interviews with students. They were asked to reflect upon several situations and indicate how they could potentially use mathematics to explore the situation, if they thought it could be explored with mathematics, what mathematics was being used, and how it was being used.

Interview Part Two

In the final portion of the interviews, students were given three scenarios (two sociopolitical and one culturally relevant) where they were asked first for their opinion about the topic, then second if mathematics could be used to help either explain the situation or bolster their stance on the topic being asked about. The topics included whether the federal minimum wage should be increased from \$7.25 to \$15, social gathering decisions (attending parties), and the killing of unarmed Black Americans by police officers. In these discussions, students were able to identify how racism existed based on mathematical situations and utilized the knowledge they gained in class to share how mathematical concepts influenced the decisions they made, as well as cultural and community issues.

The analysis will not primarily look at the specific responses that students gave regarding their opinions on the topics or the specific mathematics that students were using; rather, the analysis is focused on *how* students were using the mathematics that they were employing during their commentary. It is important to note that students were not asked to do any mathematical calculations during this portion of the interview. They were asked *if* mathematics could be used and to explain *how* they would use it if they had access to information they thought was necessary to fully explain their thinking and reasoning.

Minimum Wage

The first topic students were asked to respond to dealt with the sociopolitical topic surrounding minimum wage. Students were prompted with the following statement: “*There are some jobs in the university, especially those for students, where some people are making minimum wage at \$7.25 per hour. People have been talking*”

about raising the minimum wage to either \$10 per hour or even \$15 per hour.” After the prompt, students were asked if they believed that the minimum wage should be increased and why they thought this way, followed by a second question in which they were asked the following: “*In order to support their argument and position, in what ways could mathematics be used, if at all.*” Students used mathematics in three main ways to describe their thoughts about minimum wage to justify that a problem actually exists, to compare and contrast situations between groups of people, and to explain how a change in wages affects an entire system.

Recognizing: Justifying a Problem Exists. The first theme that showed up during analysis was one where students used mathematics to justify that a problem existed by describing and modeling a person’s situation. Several students described how they would use iterative calculations, linear equations, and ratios to show how by not increasing minimum wage, people would not have their basic needs met.

Asia-La’Rae believed that the minimum wage should be increased because she felt that as an 18-year-old, single, non-parent college student it is impossible to make a living on \$7.25 per hour even with the few bills she has to pay every month. She found it highly improbable that people with families and children could manage to make that living situation work. When asked how she could use math to help explain the reasoning behind her opinions, Asia-La’Rae described calculating a living wage dependent upon the number of children a person has and comparing someone’s current finances over a month and looking at that to show that a person making minimum wage cannot make enough money to meet their basic needs.

Students used mathematics to justify that a problem existed and proposed that raising the minimum wage would help alleviate that problem (although Asia-La’Rae would love to see that number be even higher). While doing the CRP lessons, students had to work with data that they used to help explain the existence of a problem just as these students were doing with this sociopolitical topic of setting a minimum wage.

Caring: Comparison of Situations. Students also gave responses using mathematics that allowed them to compare groups of people based on differing situations. Students reflected on their own situation, where they found themselves earning minimum wage, and compared this with the potential to earn above minimum wage. For this use of mathematics, students proposed using equations, such as profit functions, to show comparisons.

Tiffany believed that the minimum wage should be increased because college students had limited options to work beyond the normal hours of operation on BSSSU’s campus and due to the rising costs in tuition and fees. She felt that if students are trying to be responsible and contribute to their own educational expenses, the only way for that to happen is for them to be able to make more money in the

time that they are able to. She stated the following as her explanation of her use of mathematics in helping her craft an argument for her supposition.

Tiffany: So, definitely [I need] information from the Internet and like make a graph of like the people that are making minimum wage, like by the end of the year how much are they doing. And they also do like their living expenses their car expenses like every bill and stuff that they had to pay. And then the people that's making above minimum wage, how much they're also making their expenses, and everything like in the same situation like saying living expenses cost and everything is the difference in making \$7.25 and making above \$7.25.

She believed that showing the difference in the yearly net gain for people making minimum wage and those making above minimum wage would itself justify increasing the minimum wage from \$7.25 to \$15 (or “somewhere around that number”).

Pamela also used a similar argument; however, her belief was that the minimum wage should not be increased, because, as she puts it, “a McDonald’s worker should not get paid the same as someone with a college degree.” She proposed showing this difference in yearly net gain or savings to high school students as a warning to show them that getting a college degree would afford you a lifestyle that you would probably want to live.

Looking at profit functions was a key part of the experimental lesson based on health and flu shot maker/distributor companies. These students particularly used the principles of that lesson and their knowledge of how “life works” to formulate an argument—to different audiences—of the projected outcome of different groups of people based on hourly wages.

Critiquing: Explaining How a Change Would Affect a Larger System. Finally, students crafted arguments for and against raising the minimum wage using mathematics to justify their responses that revolved around explaining how such a large increase in minimum wage would affect not only the people receiving said increase, but also everyone else working within this environment/system. Generally, the students that used this argumentation disagreed with most students in that increasing minimum wage from \$7.25 to \$15 should be done.

Both Matthew and Lindsey used mathematical principles of optimization through inequalities and graphs of these functions and systems of equations to demonstrate and explain their reasoning. Matthew believed that in order to accommodate such an increase in the minimum wage, schools and (other work places) would have to lay off people because they would not be financially able to support giving raises to a vast number of people. He stated the following in support of his position on the topic.

Matthew: I don't know how much money the school has to give out, but from what I would think, I would say no because if you do that, you wouldn't be able to hire a lot of people. Some people's hours may get cut short. Maybe that's when it could be shown using a graph; it'll probably be quadratic-looking because the higher the salary, the less people could be hired. Also, look at if you do raise it, how much money is left for the school to use for different things for stuff that we need, like athletics and stuff like that. You would see a lot of the important stuff is going down and then you just put two and two together and then you'll see that you need to keep minimum wage what it is.

Lindsey (much like Pamela) stated that people working at fast food restaurants should not make more money than emergency medical technicians, whom she felt/knew that some of them did not even make between \$10 and \$15 per hour. She did not go as far as to say these people should not get raises at all but believed it should not be higher than \$10 per hour.

Lindsey: You would have to see how much you have to distribute out to the people that you're paying and raise it out to a certain extent to where everyone gets paid the same. So, like where you're not breaking the budget you have to pay everyone. So, you would have to incorporate how many employees you have, how many hours they work, and then figure out okay if we pay them \$8 an hour, we pay everyone on campus as jobs like this \$8 an hour, and they work this amount we have enough money to pay all of them instead of like, oh, we're just gonna give you \$10 an hour and then not have enough money to pay everybody.

Similar to the previous theme of *Caring: Comparison of Situations*, students who used this theme of explaining the ramifications of such an increase in minimum wage used the reasoning used during the health lesson and combined it with the discussions that were had throughout that lesson to help them craft an argument to support their position on minimum wage.

Planning

The second topic students were asked to respond to was less sociopolitical in nature but related to the culture of living on an HBCU college campus, and one that the researchers initially thought students would say did not involve mathematics at all. This topic was surrounding the decisions people make to attend or not to attend a Homecoming party (or some other social gathering) at a college campus. Students were prompted with the following statement: "*Remember the class after Halloween, people went to a lot of different Homecoming parties the night before. Is there mathematics involved in deciding which party to go to?*" Responses given by students were interesting in that no one said "no;" rather, they explained what application of mathematics they use or what they would use in such situations. Responses revolved around the concepts of modeling fun and modeling profit.

Recognizing: Modeling Fun. Most students gave responses that involved the reason for wanting to go to a party to begin was first, and foremost, enjoying themselves and having a good time mingling with their peers. Lindsey embodied the responses from most students, except she hit on every point that was discussed in all others' responses. She was extremely keen on this question due to her high involvement and participation in the CRP lesson delivered on the class period after Halloween (which also coincided with Homecoming). She stated the following in response to this question.

Lindsey: There are many equations involved! The first involves the population of the party and the amount of space available. If there's way too many people, it's going to get shut down. I went to a party Halloween night, and we had to choose between the Q-party and a block party. The Q-party was down the road, and we knew everyone was going to go to the Q-party, because it's a Q-party... who's not going to go?!? So, everyone's gonna be there, so you gotta think about this space cuz it was at a house, so the space around the house and all the people inside the house and then eventually the party was gonna get shut down cuz every Q-party gets shut down. ... Another equation is the type of fun can we have. Like we already knew there's gonna be smoking, underage drinking—it's Halloween and homecoming. It's like, are we gonna be able to get out in time? Are we gonna get caught up? That's another equation. How fast we can fun if something crazy pop off, like a fight or gun shots—and remember this is depending on the first equation with space and people. This may be an exponential function because we'd probably be able to run fast at first, then slow up as we got tired. [Laughter]. Um, ok... then we got to think about the block party, which we had to think about the time walking there, which was 25 minutes, which was another factor. So, it was 25 minutes to walk there, and not that many people know about it, so hopefully it's gonna be laid back, you know we can just chill, listen to music, do what we do. So, we decided to go to the block party cuz even though it was a farther distance, we figured since it was a farther distance everyone's gonna be a little bit too messed up to walk that far, so we decided to go to that one for the factors of less people times a farther distance. The block party seems quadratic with all the two factors multiplying that gave us a better answer in the long run since we didn't have to think about the other stuff that a Q-party brings with it.

This quote was extracted from Lindsey after she originally did not know how to respond—which was frequent for her. She would often have long pauses of silence, followed by blocks of fruitful statements after simply needing a rephrasing of the question and some time to think. Lindsey brought together many of the experimental lessons that were discussed throughout the course, including linear functions, quadratic functions, and exponential functions. To say it like Pamela phrased it, Lindsey thought about this topic using equations, “but typically most people do this without thinking about the specific math or equations. People just make decisions without thinking its math, but it can be if you want it to be. Almost anything can be!”

Recognizing: Modeling Profit. Jamie thought through this scenario as if she were the one throwing the actual party and not going to one (counter to the intended

perception of the scenario). Using the quadratic profit-revenue function discussed during the CRP lesson on health, she explained how several factors would determine the constraints of a certain party they would try to throw and its chances of being successful.

Jamie: Yeah [party planning involves math] because it depends like how many tickets you sell. So, like say if there is one party everybody talking about, “oh, we gonna go to this, everybody is going to go to this.” But after presales you raise the price at the door. So, like if you start with a \$5 presale, you start with \$10 until 10:00 or 11. Then the price will go up more around midnight. You can only raise the price so much to make sure you get the most number of people possible because people won’t pay but so much, And all this depends on the size of the house the party is in.

This discussion focused on making money from throwing a party with variables about the total number of tickets, space, and advertising. Other students also made responses for this situation of throwing a party. Responses in this theme used mathematics and described it using concepts that were experienced in the CRP lessons, which helped students make a more compelling argument to support the points they were trying to make.

Deaths of Unarmed Black Americans by Police

The final topic discussed at the end of the interview was focused on issues surrounding the killing of unarmed Black Americans by police officers in the United States. Students were prompted with the following statement: “*As I am sure you are familiar with news stories about unarmed Black Americans being killed by police officers in America, what are your thoughts about this?*” After students gave their thoughts on the topic at hand, they were then asked, “*Who, if anyone, has the power to affect change or impact such shootings?*” The final question was, “*How, if possible, can you use mathematics to address this situation to help you enhance your arguments?*” Responses on these final questions revolved around major themes as to how students were using the mathematics to show the severity of the problem (using statistics) and then projecting what would happen if the pattern continued.

Critiquing: Describing the Severity of the Situation. The way that students began using mathematics to help their arguments on why the shooting and subsequent killings of unarmed Black Americans was problematic (which everyone agreed was a major issue that makes them feel an array of emotions) was to show how this was an issue. All students began down this path of discussion and described how they needed to gather the data and statistics that has been collected. Lindsey had the following to say.

Lindsey: I feel like, using statistics and showing like stuff has happened in the past and like the ratio Black men being—I'm trying to remember because I just did a project on this [for another class]. Ummm... I think Black men are ten or fifteen times more likely to be shot and killed by an officer than White men. They're (I think) one in sixteen are more likely to be abused by officers. So, I think just using statistics and showing them the numbers and that, this is real. Even though, you know, "one of your homeboys just got shot," yeah. It's more than just your homeboy. There's people out here everywhere getting shot and killed by police for no reason, so I feel like showing the statistics to both sides [Black people and police officers]. I feel that it would help both sides.

She then goes on to discuss her personal feelings and emotions and how practical steps could be taken with this information that involves both African Americans and police officers. Focusing on the statistics is the way Lindsey saw how mathematics could be used. Others also began with this usage of the subject and took it a step further by explaining how if the problem persists, then they could project these effects using mathematical representations of the data.

Acting: Projecting and Exploring Trends. Several of the interview participants commented on how they would use the statistics gathered to display the data visually in hopes of compelling change.

Matthew: Umm... I would make a graph showing the past few years. First, I would put how many people who are like, do an estimate of how many Black people died within the last, say, 10 years, and then continue that equation to project in the future. I would show this to people, police, to show that if they don't change, these numbers would probably continue to increase. It'll probably be linear because I feel the number goes up more and more each year—not a lot, like exponents, but consistently.

Using principles explored in class, students were able to verbally describe what they wanted to use and how to use it, which comes to mathematical exploration. For these students, the predictive modeling was important, and they felt it would be the primary reason for catalyzing change—to stop the continued killing of unarmed Black men by police officers.

Students really mirrored their arguments in the same way that the CRP lesson on incarceration was presented and explored. First they explored data that had been collected on the issue, then they used linear equations and functions to explain what is currently happening with this data set. Finally, by extrapolating responsibly and relatively close in the future to show that if all other factors held constant, they could know what to expect. Perhaps the most sociopolitical topic discussed during the CRP lessons, this topic was one that students stated they enjoyed because of how it really allowed them to see how mathematics could be useful and helpful in the "real-world."

Discussion

Students were able to use the critical-thinking and examination skills that were practiced and utilized in these exploratory lessons in the contexts of other sociopolitical and cultural situations that had not been directly explored in the course. Mathematics and emotions were utilized in a variety of ways to advocate for a certain position. The complex nature of these positions and the mathematics used are advantageous for students who most likely will not take another mathematics course; however, they will be able to utilize these skills in their various fields of study and as a part of becoming productive members of society.

Recognizing, Caring, Critiquing, and Acting

Although higher education is a very diverse setting, the teaching practices within it, especially in mathematics, are still very limited and are embedded in White supremacy, thus making it difficult for Black students to establish mathematics identities (Joseph et al., 2017; Larnell, 2016). Thus, through a CRT lens, the findings in this study challenged the pervasiveness of racism that exists within mathematics instruction, while the intervention itself allowed students to engage in a critical examination of racism in America while they built their intellectual property mathematically. Through this approach, students not only became more knowledgeable about the content matter, they became community advocates of issues that they are faced with daily. The themes that transpired during student interviews embodied one of the following: recognizing that a problem existed, caring, critiquing, and acting. Students described how they felt after the lessons, often stating that they either did not know about certain issues or were just shocked to see the numbers in relation to them. Once they expressed or emphasized the situation, some empathized with the groups of people that were being discussed. After caring about and empathizing with various people for myriad reasons, students moved to a more critical approach with their statements. Students began to critique various institutional systems, including incarceration, education/college loan providers, and healthcare—all topics that had culturally relevant lessons built around them. Some students wanted to seek to change the various systems they had just critiqued. These discussions led to the scenarios (two sociopolitical and one culturally specific) where students voiced their opinions and concerns. Again, students used these same themes of recognizing, caring, and critiquing to explain how they would potentially act on these issues. Students were able to use the experimental lessons they had been a part of in various ways. One way was by using the mathematics that was learned. Another way was using the structure of the experimental lessons themselves to explain what they would do.

The ability to utilize mathematics in such a way that students find it useful and see its applicability in their day-to-day lives is a strong benefit for the advocacy of

such critical mathematics pedagogy (Tate, 1995). It is important to mention again that most of these students will not take another mathematics class, and that is something most of them are all too excited about. Students were able to discuss difficult issues, such as the pervasiveness of racism in America (DeCuir & Dixson, 2004), the importance of cultural identity for African American students (Martin, 2009), and the intersection of class and race (Crenshaw, 1989, 1991) through the use of mathematics. This occurred during the classroom activities themselves but also during the interviews when they were asked to take stances or discuss their opinions on various topics. Evidence from this study shows that students were able to examine inequalities in various areas of life and expound upon their critiques of various issues in their local, state, and global community—such as the goal for this type of pedagogy (Gutstein, 2003; Ladson-Billings, 1995b; Milner, 2017).

Implications for Future Research and Practice

Teacher training programs must lead the charge in developing the next generation of culturally relevant pedagogues. This study has helped lay some groundwork at the collegiate level in showing that greater positive student outcomes were held at this level of education. This call for teacher educators extends to graduate programs in mathematics as well as mathematics education programs. To better serve and meet students where they are to get them where we want them to be, using the culture of students was shown to be a great start, as it allowed them to take ownership of their mathematics education and transform it into their own intellectual property. The education of students who take service-level mathematics courses like college algebra need this pedagogy to get them more interested and have a better outlook about mathematics and its utility in the real world.

For teachers who are already in the classroom, teacher educator programs should provide professional development on CRP. Showing in-service teachers the foundations and how to use students' cultures in non-trivial and innovative ways to enhance their teaching practices will benefit already good teaching practices and make them better.

Conclusion

Historically, students taking college algebra and other introductory mathematics courses have struggled to “pass” these courses (Herriott, 2006). When looking at what is taking place in collegiate mathematics classrooms, culture and the interests of students continue to lack a place within the day-to-day activities of classes, even if the courses are designed to be student centered and rely less on teacher-as-lecturer. In this study, it was shown that by incorporating these cultural facets of students'

lives through CRP, we can challenge current mathematical practices, which can lead to positive effects on student outcomes. Students gained not only the ability to relate mathematics to their everyday lives, but they also gained space to show their knowledge and understanding of what they have learned. This understanding also extends to their own communities and how they perceive themselves in the world.

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