"RETURNING TO THE ROOT" OF THE PROBLEM: IMPROVING THE SOCIAL CONDITION OF AFRICAN AMERICANS THROUGH MATHEMATICS EDUCATION

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Abstract

The underachievement and underrepresentation of African Americans in STEM (Science, Technology, Engineering and Mathematics) disciplines have been well documented. Efforts to improve the STEM education of African Americans continue to focus on relationships between teaching and learning and factors such as culture, race, power, class, learning preferences, cultural styles and language. Although this body of literature is deemed valuable, it fails to help STEM teacher educators and teachers critically assess other important factors such as pedagogy and curriculum. In this article, the authors argue that both pedagogy and curriculum should be centered on the social condition of African Americans – thus promoting mathematics learning and teaching that aim to improve African communities worldwide.

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Accentuating Social Transformation: A Mathematics Curricular Approach
Driving Purpose behind African-American STEM[1] Education

Historically, scholarship on the STEM (science, technology, engineering and mathematics) education of African Americans has focused largely on the achievement disparity between African Americans and their non-African-American peers. (Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Lewis & Collins, 2001; Lewis, Pitts, & Collins, 2002; Lubienski, 2002; Maple & Stage, 1991). Some researchers have criticized this approach as a one-dimensional treatment that pathologizes African-American youth and emphasizes their perceived failure. (Martin, 2009; Norman, Ault, Bentz, & Meskimen, 2001). Even the growing body of research examining success and high achievement among African-American learners (Berry III, 2008; McGee & Martin, 2011; Thompson & Davis, 2013; Thompson & Lewis, 2005) is, to some degree, a response to this prevailing discourse of African-American pathology. With disparity firmly established as "the problem" of African-American STEM education, much of the scholarship in this area has been aimed at leveling the disparity.

As researchers, we have focused so intently on leveling disparity by focusing on relationships between teaching and learning and factors such as culture, race, power, class (Martin, 2006; Weissglass, 2002; DiME, 2007), learning preferences (Hilliard, 1989; Malloy, 1997), cultural styles (Malloy, 1997; Moody, 1998) and language (Orr, 1987). While such efforts certainly have value, they fail to question whether "leveling disparity" is beneficial for African-American STEM learners. We have tacitly accepted the idea that the purpose of STEM education as articulated by STEM education reform efforts (e.g. National Council of Teachers of Mathematics, 2000; National Governors Association Center for Best Practices, 2010; National Research Council, 1996) is in the best interest of African-American STEM learners. Thompson, Mutegi, and Davis (in review) challenge the assumed benefit of leveling disparity by

(a) identifying a set of assumptions about disparity that drives the work of some STEM education researchers, and (b) arguing for nation building as a driving purpose for the STEM education of African[2] people.

The study by Thompson, Mutegi, and Davis (in review) began when Thompson questioned the purpose behind STEM education disparity scholarship. She asked, "Why is it important that we have more African Americans in mathematics? Blacks are overrepresented among NBA players and underrepresented among NHL players. What makes this a problem? Can't society function well if different groups of people gravitate to different professions or occupations?" To answer this question, she interviewed three, highly regarded mathematics

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[1]According to the H.R. 1020 (114th): STEM Education Act of 2015, STEM education means education in the subjects of science, technology, engineering, and mathematics, including computer science. Activities related to STEM education may incorporate one or more of the STEM disciplines. For this reason, we refer to mathematics education and/or science education as STEM education.
[2] We operate from a Pan Africanist perspective. As such, we regard the social, historical, and cultural challenges facing African Americans to be localized manifestations of social, historical and cultural challenges that face people of African descent throughout the diaspora. In this spirit, we invoke the term "African" to characterize people of African descent regardless of where they happen to be on the planet. When we invoke more specific terms, such as "African American," it is to reflect the characterization used by other authors or to distinguish a particular group of African people from the global African family. This treatment is consistent with our other work in this area (Mutegi, 2011, 2013).

education researchers. The experts she interviewed were well-published authors whose work evinced a long-term commitment to increasing the representation of African Americans in STEM. Two open-ended questions guided her interviews. The first question was, "In your opinion, why should educators be concerned about the underrepresentation of African Americans in mathematics?" The second question was, "What are some benefits of having African Americans pursue mathematics careers?"

The mathematics education researchers interviewed gave three reasons for the necessity of increasing the representation of African Americans in mathematics. These were (a) to establish an African-American presence in STEM fields that will dispel myths surrounding the intellectual capabilities of African Americans; (b) to increase the level of African-American contribution to the technological advancements of this country; and (c) to create a level of critical thinking among African Americans as a means towards social change. These reasons serve to lay bare implicitly held assumptions about the purpose of African-American STEM education scholarship. They reveal a perceived need for people of African descent to gain social acceptance and to make national contributions through their STEM work.

In response, Thompson et al. (in review), suggest that STEM education could also (and perhaps more effectively) be driven by a "liberatory agenda" with the goal of building and improving "the status of Black people globally." Drawing from the work of Kwame Akoto (1992), they characterize this effort as "Nationbuilding." We have found that the work of Thompson et al. as well as that of Akoto resonates strongly with STEM education research on social justice. Our objective in this paper is to draw from the spirit of scholars like Thompson et al. and Akoto, to describe how social justice-oriented STEM education might look in practice, specifically in the area of mathematics education. To accomplish this objective, we will first provide an overview of social justice mathematics scholarship. We will then detail one of the curricular approaches drawn from this body of work. The curricular approach detailed (Mutegi, 2011) provides guidance for modifying traditional STEM content (specifically in the area of science) to meet the purpose of educators committed to nationbuilding and social justice. We conclude by demonstrating the application of that model to the mathematical study of combinatorics.

Historical and Contemporary Perspectives of Social Justice in Mathematics Education

In mathematics education, scholars have a long history of trying to achieve social justice. A review of this history reveals that varied perspectives have been used to discuss social justice approaches in mathematics education. The major focus of social justice approaches is to illustrate the social and political dimensions of mathematics and mathematics education and to challenge the perceived neutrality, objectivity and cultural neutrality of mathematics (Vithal & Skovsmose, 1997). Historically, the main terminology used by scholars to discuss social justice approaches in mathematics education were "critical mathematics" (Frankenstein, 1987) and "teaching mathematics for social justice" (Gutstein, 2003). Marilyn Frankenstein and Eric Gutstein are considered leading scholars in the development of social justice perspectives in mathematics education. These scholars have drawn on Paolo Freire's theory to advance social justice approaches in mathematics education. In particular, Frankenstein (1983) asserts:

> Applying Freire's theory to mathematics education directs our attention to how most current uses of mathematics support hegemonic ideologies, how mathematics education

> also reinforces hegemonic ideologies, and how critical mathematics education can develop critical understanding and lead to critical action. (p. 327)

Aligned with this perspective, Powell and Frankenstein (1994) challenged the Eurocentric perspective that pervades mathematics to advance the concept of ethnomathematics to achieve social justice. Even though Frankenstein and Powell contributed intellectually to ethnomathematics, d'Ambrosio (1985) is often considered the "father of ethnomathematics." Ethnomathematics seeks to connect culture and mathematics (d'Ambrosio, 2001). Vithal and Skovsmose (1997) suggest that ethnomathematics primarily involves cultural and social issues. There are four strands of ethnomathematics (a) challenging the traditional history of mathematics, (b) examining traditional cultures of mathematics for colonized people, (c) exploring groups' everyday use of mathematics, and (d) examining the relationship between ethnomathematics and mathematics education.

Gutstein (2007) indicates "the goal of teaching (mathematics) for social justice [is] that students become agents of social change and join in, and eventually lead, the struggles to remake our world for peace and justice" (p. 116). According to Gutstein (2007), teaching (mathematics) for social justice is accomplished through interplay of the three C's – community knowledge, critical knowledge and classical knowledge. Community knowledge is defined as the compilation of knowledge that is brought to a central location such as school. In particular, it "involves several different but related components of knowledge and culture [and] refers to what people already know and bring to school with them" (p. 110). Critical knowledge is comprehension concerning the sociopolitical environment of an individual's current and extensive reality. More specifically, it entails "knowledge about the sociopolitical conditions of one's immediate and broader existence" (p. 110). Classical knowledge is the acquisition of the systematic rituals of classroom, abstract learning.

In more recent times, the language Frankenstein and Gutstein use to discuss critical mathematics and teaching mathematics for social justice has evolved. Critical mathematics is now referred to as "criticalmathematical literacy" (Frankenstein, 2012) and teaching mathematics for social justice is often referred to as "teaching and learning mathematics for social justice" (Gutstein, 2003, 2006, 2012). Frankenstein's and Gutstein's social justice frameworks provide a lens to re-examine African-American STEM education. In particular, what is the nature of STEM education that positions African Americans to use their knowledge of their community in conjunction with critical knowledge of sociopolitical issues to learn classical knowledge of mathematics to effect social change? It is our contention that the mathematics education for Africans must be grounded in their community knowledge and developed in response to the current social conditions of Africans throughout the Diaspora.

"Returning to the Root" of African Tradition

One of Gutstein's collaborators, Tate (2005) framed his social justice scholarship on African-American students. While Gutstein has created social justice mathematical tasks focused on African-American issues (e.g., racial profiling, home buying while Black, etc.), his work has not exclusively focused on African-American students. It also focuses on Latino/a students. Tate is one of the first mathematics education scholars to amass a body of scholarship focused on race, racism, Afrocentricity, social justice and the lived realities of African-American students in mathematics education (Tate, 1993, 1995, 2013). From a research, theoretical and conceptual perspective, Tate connected and centered Afrocentricity and social justice pedagogical approaches in African-American students' mathematics education. He reported information about their cultural and community knowledge and experiences learning mathematics. Tate's use of Afrocentricity represents the "power of returning to the root of African tradition" (1995, p. 172).

Operating in a similar paradigm, Anderson's (2005) contribution to social justice focused on the Africans contribution to mathematics. In doing so, he challenged the dominant European perspective of mathematics (Anderson, 1990; 2005). Anderson advocates for students to learn about African peoples' contribution to mathematics and help students to understand that white men were not the only people to make contributions to mathematics. In fact, he contends that students should know that Europeans studied in Africa to learn mathematics from Black people.

Building on Tate (2005) and Anderson's (2005) Afrocentric perspectives of mathematics, Martin and McGee (2009) advanced a liberatory perspective of mathematics education for African-American students rooted in Afrocentricity. While their use of liberation is not unique in mathematics, as Powell and Frankenstein (1994) also advanced notions of liberatory mathematics, Martin and McGee's perspective is unique in that they identify African-centered thought and practice as key tools for achieving liberation for African Americans. The use of the term liberation is a reframing of social justice rooted in the history and traditions of African Americans' fight for freedom.

Introducing critical race theory into the mathematics education social justice discourse, Terry (2010, 2011) focuses on the most underserved and underrepresented population: African-American males. He engaged African-American males in social justice oriented mathematics using socially, culturally, and contextually relevant topics, data and pedagogical approaches. Using critical race theory's notion of counter storytelling, Terry developed and called for the use of mathematical counterstories as a social justice pedagogical approach to engage Black males. He argues that African-American males are looking for opportunities to critically examine issues, data and mathematics that directly relate to their lives.

Continuing in the tradition of using critical race theory, Larnell, Bullock, & Jett (2016) seek to broaden the possibilities of social justice scholarship in mathematics education. More specifically, these scholars use a critical race perspective to shed light on the role and operations of race, racism and racial injustice within the teaching and learning mathematics for social justice discourse. Larnell and colleagues use select tenets of critical race theory to offer new perspectives and conceptualizations of teaching and learning mathematics for social justice. Racial realism, interest convergence, critique of liberalism, intersectionality, and counter-storytelling are the tenets of critical race theory that Larnell and associates use to expose "blank and blind spots' with respect to race, racism, and racialization" (p. 27). Furthermore, Larnell et al suggest that incorporating critical race theory into the teaching and learning of mathematics for social justice discourse illuminates the necessity to address intersectionality and complexity of multiple forms oppression and injustice impacting groups.

Summary

Based on the available literature, it can be argued that social justice approaches in mathematics education started with ethnomathematics and critical mathematics. The literature also reveals that the history of social justice approaches in mathematics has not exclusively focused on African Americans. This scholarly area has focused on diverse cultural groups. The exclusive focus on African Americans has mainly come from the scholarship of African-American scholars (Martin & McGee, 2009; Terry, 2010, 2011).

We continue to advance social justice perspectives and approaches to mathematics by building on this history. We contribute to this existing body of literature by illustrating the application of socially transformative science curriculum as described by Mutegi (2011) to mathematics education. We use this model for several reasons. First, this model focuses explicitly on addressing problems plaguing African people all over the world. Second, it seeks to position learners of African descent as agents of change in their community. It also seeks to inform African learners about the system of racism (white supremacy), help them to recognize how it impacts their academic and social development, and prepare them to struggle for power against this system. This model of socially transformative curriculum argues that we should engage students of African descent in critical discourse about their social conditions and their use of scientific knowledge to change those conditions.

Understanding Socially Transformative STEM Curriculum

The model of socially transformative science curriculum described by Mutegi (2011) draws heavily from (and reflects the commitments of) critical pedagogists (e.g. Allen, 2004; Freire, 1970; Macedo, 1993). The overriding purpose of this approach is to position learners of African descent to (a) become aware of systemic racism, (b) understand how it is established and maintained, and (c) work to change it. According to Mutegi (2011), this purpose can be accomplished when teachers plan curricula that help learners of African descent to attain mastery in each of five areas. These are: content, currency, context, critique, and conduct. Mastery of *content* positions students to better understand the content. It empowers students to answer what- when- where- and how-type questions about the topic. The second area of mastery is *currency*. Mastery of currency positions students to better understand how the topic is related to human beings. The third area of mastery is *context*. Mastery of context positions students to better understand how the topic is related to people of African descent. The fourth area of mastery is *critique*. Mastery of critique positions students to better understand how the topic is related to systemic racism. The final area of mastery is *conduct*. Mastery of conduct positions students to use their emerging knowledge to effect social change. These areas of mastery and the questions they inspire are tools that teachers can use to create or modify curriculum with the intention of teaching for social justice.

Accentuating Social Transformation: A Curricular Approach

Throughout the K-12 pipeline, the National Council of Teachers of Mathematics (NCTM) and the Mathematical Association of America (MAA) advocate for combinatorics to be in sync with the mathematics curricula being used in schools (National Council of Teachers of Mathematics, 1989, 2000). However, the mathematics curriculum in schools serving large populations of African-American students rarely or most times never expose them to combinatorics or any other advanced mathematics content (Ladson-Billings & Tate, 1995; Lubienski, 2001, 2002; Oakes, 1990; Strutchens & Silver, 2000; Tate, 1997) that can be used to improve the conditions of African communities locally and globally. Nkwanta, Hill, Swamy and Peters (2011) provided high school teachers in Baltimore city public schools with a week-long professional development workshop focused on connecting mathematics and biology and to help them integrate computations into biology courses. More specifically, Nkwanta and associates used the workshop to:

> use lattice walks and RNA secondary structures as a way of introducing teachers to enumerative combinatorics integrated with molecular biology… By demonstrating and explaining the importance of integrating mathematics and biology, an objective was to give teachers a sense of how mathematical concepts could be applied to certain adverse health conditions. For example, considering adverse health conditions such as asthma, cancer, diabetes, HIV, and AIDS, it was demonstrated in the workshop that enumerative combinatorics could be used as a tool to help predict RNA structures for the development of more favorable health conditions (p.82).

The health conditions Nkwanta and associates identify significantly impact African communities all over the world. In this article, we use the model of socially transformative STEM curriculum to describe how combinatorics can be used to address the HIV/AIDS epidemic impacting African communities locally and globally.

In their articulation of mathematics literacy as a civil rights issue, Moses and Cobb (2001) point out that,

> the importance of algebra [in the U.S.] has emerged with the new technology. It didn't have to be algebra… In France, geometry is the driving force of the math and technology education. So, there's nothing that says it has to be algebra. There's nothing that says it has to be geometry. (p.14)

Similarly, in K-12 schools across the country, there is nothing that says combinatorics cannot be taught to African-American students to help them improve conditions impacting their community locally and globally. An alternative approach is needed to teach African-American students to use their knowledge of combinatorics and other mathematical topics to improve the conditions of African communities worldwide.

Social Transformation through Combinatorics

Mutegi (2011) drew from the work of critical curriculum theorists to develop a model for science curriculum that positions students of African descent to improve their social condition. Here we will illustrate the applicability of Mutegi's approach to mathematics education by providing an example of a curriculum unit on combinatorics. As mentioned, the first area of mastery is *content*. Mastery of content empowers students to answer questions such as, "What is combinatorics? How does combinatorics work? Where is combinatorics used?" The mathematical content presented to students of African descent about combinatorics must get them to see that the study of combinatorics includes permutations, enumeration, combinations, arrangements, and formulas. It must equip them to see that combinatorics is one of the oldest branches of discrete mathematics that is deemed an essential concept for solving problems using computer methods and is regarded as the mathematics of systematic counting (National Council of Teachers of Mathematics, 1989, 2000; Sriraman & English, 2004).

The second area of mastery is *currency*. Mastery of currency empowers students to answer questions such as, "How and where is combinatorics used by humans? How does the application of combinatorics impact mankind in daily life?" Instructional dialogue on combinatorics could equip African-American students to explore (a) the global importance of computers nationwide, (b) the importance of computers for international warfare (c) computer scientist use of combinatorics to advance modern technology, (d) medical professional use of combinatorics to match symptoms with proper medicine, (e) scientist's use of combinatorics to find a cure for diseases (e.g. HIV/AIDS, cancer, etc.), and (f) industrial use of combinatorics for modernizing manufacturing distribution.

The third area of mastery is *context*. Mastery of context empowers students to answer questions such as, "In what ways is combinatorics important to people of African descent? How has it been used by African people historically or in modern times? In its application, how does it impact the daily lives of African people?" The context of instructional dialogue on combinatorics could prepare African students to understand how combinatorics could be used in service of African people. For example, it could be used as STEM professionals of African descent work to (a) find a cure for HIV/AIDS, malaria, asthma, cancer, and other health problems experienced by African people, (b) develop businesses for African people to capitalize on their inventions (e.g. traffic lights, blood preservation, and polymers), and (c) create housing and buildings for businesses in African communities in order to develop an economic base.

The fourth area of mastery is *critique*. Mastery of critique empowers students to answer questions such as, "How can my understanding of combinatorics help me to better understand the mechanisms by which systemic racism is established and maintained?" The instructional discourse surrounding these questions would engage African students to use their knowledge of combinatorics to investigate systemic racism as a result of (a) denying African students access to courses and knowledge of combinatorics and other higher level mathematics topics that can be used to improve the conditions (e.g. housing, health, etc.) of their community and develop an economic foundation for African people, (b) high rates of health problems (e.g., heart disease, cancer, HIV/AIDS, etc.) affecting African people and the lack of medical care to remedy their health problems or find a cure for the global HIV/AIDS epidemic, and (c) the lack of economic stability in African communities globally.

The fifth area of mastery is *conduct*. Mastery of conduct empowers students to answer questions such as, "How can I use my understanding of combinatorics to improve the social condition of African people? Instructional dialogue about African-American students conduct should equip them to use their knowledge base to (a) work with scientists (e.g. biologists, etc.) to locate better or more stable SL12 and SL3 components of HIV-RNA sequence to aid African people in their efforts to find a cure for the global HIV/AIDS epidemic, (b) develop businesses to distribute African peoples inventions (e.g. traffic signal, peanut products, etc.) to become self-sufficient, and (c) work with computer scientists, engineers, and architects to create housing and buildings for businesses in African communities in order to develop an economic base.

Concluding Comments

The five areas of mastery (i.e., content, context, currency, critique and conduct) are drawn from Mutegi's (2011) description of socially transformative science curriculum. In this article, we juxtaposed this work against similar work in mathematics education to develop an alternative curricular approach to prepare African people to address the social realities of their community. This curricular approach builds on the work of several scholars who accentuate "what to teach" and "why we teach" (Anderson, 1990; Martin, 2007; Tate, 1995). In particular, the proposed curricular approach meets the purpose of educators committed to nationbuilding and social justice in that the approaches are viewed and contextualized in ways aimed at changing the lives and mathematics education experiences of peopled of African descent. To ignore the potential of the proposed curricular approach to inform efforts to meet the needs of African-American STEM learners "is to be like the man who was looking for a lost coin two blocks away from where it was lost because the light was better at the new spot. If he were to continue in that way, the problem would never be solved" (Hilliard, 1974, p. 44).

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