SOCIAL JUSTICE DRIVEN STEM: ACHIEVING EQUITY GOALS THROUGH INTEGRATED MATHEMATICS EDUCATION

Frances K. Harper
University of Tennessee – Knoxville
francesharper@utk.edu

Deepa Deshpande
University of Tennessee – Knoxville
ddeshpan@vols.utk.edu

This study investigated how integrating social justice issues, STEM practices, and mathematics may support equity in mathematics education. We analyzed video of four lessons focused on inverse trigonometry and disability rights from a STEM project-based geometry class. Using an established observation protocol, we identified themes related to access and participation in coherent and cognitively demanding mathematics, student voice, and opportunities to develop positive mathematics identity. Findings provide insights into project and lesson structures that support balancing mathematics and social justice goals across STEM projects and point to additional considerations of equity not fully captured by the existing observation protocol.

Keywords: Equity and Diversity; Geometry; High School Education

Calls for integrated STEM education in K-12 schools have increased in recent years, and strategic STEM education plans often identify project-based learning (PBL) as one approach to integrated STEM education (e.g., Chief Education Office, 2016; STEM Leadership Council, 2018). These STEM education plans argue that full integration of STEM education in K-12 learning is necessary to ensure all students, particularly those from economically disadvantaged in STEM fields. Simultaneously, efforts to use mathematics to critically investigate social justice issues increasingly offers another approach to integrating mathematics and other learning goals (e.g., Esmonde, 2014; Keith McNeil & Fairley, 2016). Some mathematics education scholars argue that teachers face a moral and ethical imperative to transform mathematics classrooms into spaces for the development of critical social awareness and social transformation (Stinson, 2014). Both of these approaches to integrating mathematics with other content areas and topics overlap in their goals to make mathematics learning more accessible and equitable for those students who have been systematically and historically marginalized in mathematics.

Envisioning integrated models for mathematics education may hold promise for addressing longstanding inequities in mathematics. This study investigates the intersection of STEM PBL and social justice in mathematics classrooms with students from economically disadvantaged backgrounds and minoritized racial/ethnic groups. In integrated mathematics lessons, however, balancing mathematics learning goals with other goals (e.g., social justice, STEM) presents significant challenges for teachers (Bartell, 2013), and little is known about whether or not students actually experience these integrated lessons as more equitable (Harper, in press). Thus, the possibility exists that attempts to integrate social justice goals and STEM might further exacerbate equity issues. We aim to investigate the potential for integrating social justice and STEM goals into mathematics education by asking: does (and if so, how does) the integration of social justice mathematics with STEM PBL support goals for equity in mathematics education?

Theoretical Framework

Historically, research towards equity in mathematics education has prioritized achievement and access. *Achievement* relates to tangible outcomes on measures such as standardized tests or course-taking patterns, and *access* relates to tangible resources such as high-quality mathematics teaching and rigorous, coherent mathematics curricula (Gutiérrez, 2012). Achievement and

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

access reflect dominant dimensions of equity in mathematics education because of the widespread, historical attention these aspects have received and because of the acceptance of their importance in mainstream mathematics education research. In addition to these dominant dimensions of equity, we include a focus on under-recognized and under-explored dimensions of equity, identity and power, in this study (Gutiérrez, 2012). Students develop their mathematics *identities* based on dispositions and beliefs about their ability to learn, do, and use mathematics (Martin, 2006). Because school mathematics traditionally marginalizes certain ways of knowing, students must negotiate their personal (racial, ethnic, gender, etc.) identities as they develop their mathematics identities, but students of Color and students who are economically disadvantaged rarely have opportunities to see themselves as competent mathematics learners, doers, and users (Gutiérrez, 2012; Martin, 2006). Alternative ways of knowing in mathematics challenge traditional *power* structures in mathematics classrooms, and a more complex conception of equity attends to issues of social transformation such as whose voice is heard and what mathematics reveals about social justice issues (Gutiérrez, 2012). Identity and power represent critical dimensions of equity in mathematics education because attention to identity and power reflects a more recent sociopolitical turn in mathematics education (Gutiérrez, 2013). We adopt this framework for equity, which attends to both dominant and critical dimensions, and aim to describe what these dimensions look like in classroom interactions among teachers and students. Namely, we sought to answer the following questions: (1) How does access to mathematics content and the emphasis on student identity and power vary across a social justice-oriented, STEM project in a mathematics classroom?; and (2) What dimensions of equity within a social justice-oriented, STEM project-based classroom are not captured by current frameworks for observing mathematics classrooms?

Research Design and Methods

This study drew on a subset of data from a larger study that examined how students took up, negotiated, shifted, or resisted an innovative approach to coupling equity-minded mathematics instruction with STEM PBL across an academic year. The study took place at a STEM-themed magnet school, in a low-income area of a small Midwestern city, whose mission emphasizes technology-driven (1:1 student-to-computer ratio) PBL. The study occurred in one ninth grade geometry classroom in which the teacher integrated various equity-oriented instructional approaches, including integrating social justice and mathematics topics, into STEM PBL in mathematics. Of the 16 consented research participants, six are young men (4 white, 1 Black, 1 Latino), and ten are young women (9 Black; 1 Asian American). The teacher participant is a White woman who was in her fourth year of teaching. She and the first author collaborated on social justice mathematics for three years, and the teacher sought various other professional development opportunities (e.g., technology, equitable collaboration).

The research design was rooted in ethnographic and critical traditions of educational research (Anderson-Levitt, 2006; Skovsmose & Borba, 2004). The first author observed 93 total class sessions as a participant-observer. Data included video and audio recordings, field notes, and photographs from seven major projects and two mini-projects (all teacher-designed), as well as interviews assessments with students This study examined only video data from a mini-project in late April focused on inverse trigonometry and disability rights (hereafter, the mini-project).

Mini-Project Overview

Across four days, students worked in pairs to determine whether or not ramps at the school were compliant with regulations set by the *Americans with Disabilities Act* (1990). The primary mathematics goal focused on learning to use inverse trigonometric functions to find an unknown

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

angle when two or more side lengths of a triangle are known. The primary social justice goals focused on understanding the meaning and need for the *Americans with Disabilities Act* (ADA) and reflecting on whether persons with disabilities had fair access to and within the school. Students utilized technology and engaged with some aspects of design work, but the integration of STEM practices was more limited in the mini-project than in the major projects. The design aspects of the project involved collecting measurement data from physical ramps at the school and creating scaled drawings of ramps. Although students had an option to use dynamic mathematics software to model ramps, all students elected to draw by hand. Technology use mostly involved word processing, calculators, and researching ADA history and regulations. As the final mini-project artifact, students wrote letters to the principal about their investigation, making recommendations for school improvements using recently acquired funding. Although there were distinct goals for mathematics learning, social justice learning, and STEM practices, various activities throughout the mini-project and the final letter required integration across these goals and practices.

Data Analysis

Because achieving equity goals in mathematics education depends upon particular relationships between teacher and student behaviors, we sought to operationalize access, identity, and power based on observations of the entire class – teacher and students – throughout the mini-project. We did not consider achievement because pre- and post-assessment data reflected progress over the entire year, not over individual projects. We used the Teaching for Robust Understanding of Mathematics (TRU Math) Rubric (The Algebra Teaching Study and Mathematics Assessment Project, 2014) to describe how access to mathematics content and the emphasis on student identity and power varied across the mini-project. We chose this rubric because it was designed to capture overall activities and interactions (i.e., not distinguishing between teacher and student behaviors) along five dimensions, which the rubric developers claim comprehensively describe powerful mathematics classrooms (Schoenfeld, 2014). The identification of these five dimensions as key aspects of mathematically powerful classrooms (i.e., "classrooms that produce students who do well on tests of mathematical content and problem solving" (Schoenfeld, 2014, p. 406)) was based on cumulative research in mathematics education suggesting that access to coherent and cognitively challenging mathematics, an emphasis on mathematical sense making, and equal participation are necessary aspects for students' mathematics success. These dimensions of powerful mathematics classrooms, and thus the TRU Math Rubric, map onto ways equity in mathematics education has historically been theorized (Gutiérrez, 2012), making this rubric a particularly good starting point for considering whether social justice, STEM, and mathematics integration achieved equity goals. More specifically, we used the TRU Math Rubric to operationalize *access* as the extent to which participation in coherent and cognitively demanding mathematics was available to students and *identity* and *power* as the extent to which student voice, thinking, or contributions drove the mathematics and gave students an opportunity to develop a positive mathematics identity. Table 1 gives an overview of the five dimensions included in the TRU Math Rubric and shows how we mapped each dimension to the theoretical constructs of access, identity and power.

Table 1: A Map of Dimensions of Equity to the Dimensions of the TRU Math Rubric

Access	**Mathematics**	*The extent to which the mathematics discussed in the observed lesson is focused and coherent, and to which connections between procedures, concepts and context are addressed*

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

(dominant dimensions)	**Cognitive Demand**	*The extent to which classroom interactions create and maintain an environment of productive intellectual challenge that is conducive to students' mathematical development*
	Access to Mathematical Content	*The extent to which classroom activity structures invite and support the active engagement of all of the students in the classroom with the core mathematics being addressed*
Identity & Power (critical dimensions)	**Agency, Authority, & Mathematical Identity**	*The extent to which students have opportunities to conjecture, explain, make arguments, and build on one another's ideas in ways that contribute to students' development of agency, authority, and identities as doers of mathematics*
	Uses of Assessment	*The extent to which the teacher solicits student thinking and instruction responds to those ideas, by building on productive beginnings or addressing emerging misunderstandings*

Each author independently analyzed video recordings using the TRU Math rubric to: (1) identify segments by participation structure (whole class, group work, or individual work); (2) divide segments by participation structure into five minute or less segments; and (3) rate (1 – low level, 2 – mid level, 3 – high level, 8 – not enough information, and 9 – not applicable) the activities of each segment along the five dimensions described in Table 1 by using unique rubrics corresponding to each participation structure (for full rubrics see Schoenfeld, A. H., Floden, R. E., & the Algebra Teaching Study and Mathematics Assessment Project, 2014). Each recording was approximately one hour in length and was split into fourteen segments on average. We used spreadsheets to record the participation structure, duration, TRU Math rating for each dimension, and brief memos about observations on each segment. We ensured reliability by meeting and comparing our ratings and memos for each segment and resolving differences through discussion and rewatching that segment together until we reached consensus.

Findings

Across the mini-project, we observed three classroom participation structures: whole class activities (36.49% of total time across four days), group work (28.3%), and individual work (31.37%). Note that 3.85% of total class time was identified as not applicable and is shown in gray in Figures 1 and 2. Whole class activities included launch of activities (18.62% of total time across four days), teacher exposition (6.94%), and whole class discussion (23.15%). Table 2 summarizes mini-project activities and their durations.

Table 2: Summary of Mini-Project Activities and Their Duration

	Activity Summary Participation Structures	Time (min)	% of Lesson
Day 1	Warm-up by solving equations using inverse operations Launch, Individual work, Discussion	11.75	23.8%
	Introduction to using inverse trigonometric functions to solve for unknown angles in right triangles Launch, Exposition	5	10.2%
	Inverse trigonometry task, adapted from the CPM (2013) *Core Connections: Geometry*, Lesson 5.1.3, involving hypothetical wheelchair ramps Launch, Group work	32.5	66.0%

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

Day 2	Connecting math practices necessary for project to evaluation rubric Launch, Individual work, Discussion	32.95	58.9%
	Measuring base, height, and/or hypotenuse of selected ramp in school Launch, Group work, Exposition, (N/A)	22.95	41.1%
Day 3	Revising measurements, producing scaled drawings, calculating angles of measured ramps Launch, Group work, (N/A), Exposition	46.4	83.0%
	Writing letters to summarize findings and make recommendations Individual work, Exposition	9.5	17.0%
Day 4	Reflection on evaluation from previous project Launch, Individual work, Exposition	5.9	11.6%
	Writing letters to summarize findings and make recommendations Launch, Individual work, Exposition	33.2	65.4%
	Discussion of meaning/importance of ADA law and equity concerns raised through this investigation Launch, Discussion	11.7	23.0%

Access to coherent and cognitively demanding mathematics content

Figure 1 shows the average TRU Math Rubric scores for three dimensions for each participation structure across the four days of the mini-project. Duration of participation structures are drawn to scale, with whole class activities in blue (light blue for launch, dark blue for exposition, and blue for discussion); group work in green; and individual work in orange.

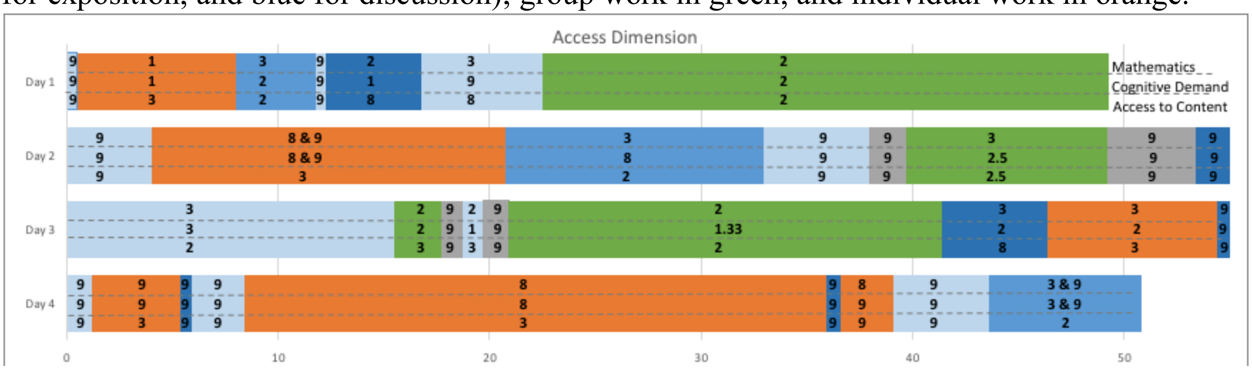

Figure 1. Access Dimension. Average TRU Math Rubric Scores for Mathematics, Cognitive Demand, and Access to Mathematics Content by Participation Structure

Taken together, the three dimensions shown in Figure 1 provide insights into how participation in coherent and cognitively demanding mathematics (i.e., access), as well as STEM practices and social justice content, varied by participation structure and day. Average scores (calculated by averaging scores across segments for the duration of each participation structure) for the "access to content" dimension suggest that, overall, broad (i.e., equitable) participation was achieved (score of 3). In some cases, uneven participation was observed, but the teacher made efforts to achieve equitable participation (score of 2). The average scores for the "mathematics" and "cognitive demand" dimensions provide information about the nature of that participation, respectively, the coherence/meaningfulness of mathematics and the level of cognitive challenge involved in participation. Although overall average scores of 2-3 were common for these dimensions, we noticed some variation by participation structure and day.

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

During group work on Day 1 and 3, the mathematical content students engaged with was largely skills-oriented (solving for an unknown angle using inverse trigonometry) with some connections to the meaning of inverse (in Day 1) and to the context of the ramps (Day 1 & 3) ("mathematics" score of 2), but the teacher largely drove these connections ("cognitive demand" score of 2). On Day 2, however, students had an opportunity to engage with explanation of mathematics practices/content as they collaborated to measure a ramp within the school ("mathematics" score of 3). The ramp students selected could not be measured in a straightforward way because it was two combined ramps (i.e., involved a switchback) and was adjacent to stairs. As students worked to decide how to define and measure the height and base of each ramp, they (rather than the teacher) took on the cognitive challenge involved with explaining and justifying their mathematical thinking ("cognitive demand" score of 2.5).

Unlike in group work, whole class and individual activities often focused on coherence and connections in mathematics ("mathematics" score of 3), but the teacher was the primary driver making these connections ("cognitive demand" score of 2). Exceptions included the launch on Day 3 in which students' were challenged to make sense of their ramps measurements by connecting to mathematical ideas and the context and the final whole class discussion (Day 4) in which students undertook the cognitive work of making connections between the mathematics and the social justice issue ("cognitive demand" scores of 3). Further, scoring the "mathematics" and "cognitive demand" for whole class and individual activities presented challenges (indicated by scores of 9: not applicable and 8: not enough information). In some cases, these dimensions were not applicable because the activities did not involve mathematics content. For example, launches and teacher exposition commonly scored 9 because these activities focused on logistics (e.g., how to complete an activity) without any attention to mathematics content. In other cases, however, the challenge of using the rubric to rate segments arose because of the interdisciplinary and integrated nature of activities. For example, rating these dimensions during individual letter writing was challenging because it was impossible to discern students' mathematical thinking from their thinking about writing and the social justice issue. Further, topics of discussion were not always explicitly connected to mathematics (e.g., whole class discussion on Day 4).

Emphasis on student identity and power

Figure 2 shows the average TRU Math Rubric scores for two dimensions for each participation structure across the four days of the mini-project. Duration of participation structures are drawn to scale, with whole class activities in blue (light blue for launch, dark blue for exposition, and blue for discussion); group work in green; and individual work in orange.

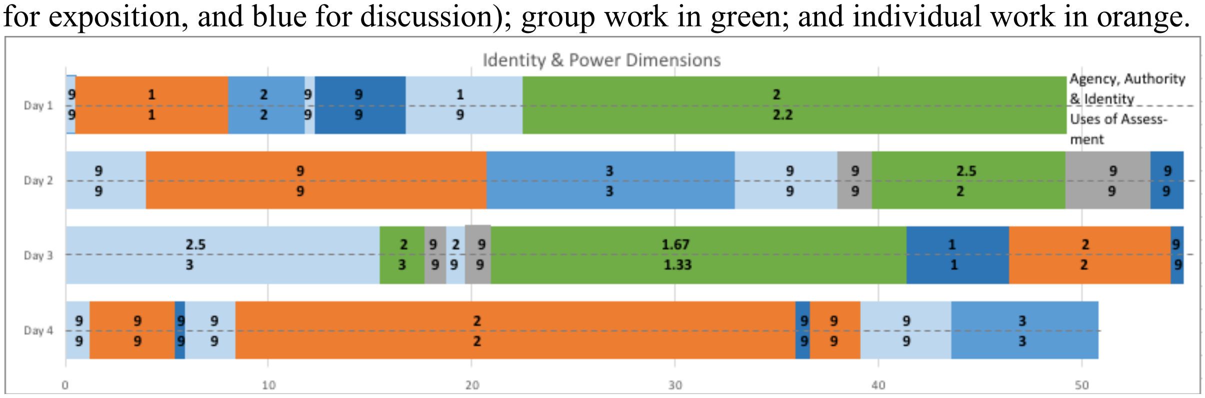

Figure 2. Identity and Power Dimensions. Average TRU Math Rubric Scores for Agency, Authority, and Identity and Uses of Assessment by Participation Structure

Taken together, the dimensions in Figure 2 provide insight into the extent to which student voice, thinking, or contributions drove the mathematics (i.e., power) and gave students an opportunity to develop a positive mathematics identity. Overall, during group and individual work, at least one student had an opportunity to talk about mathematical content, but the teacher drove conversations and determined mathematical correctness. Students were not supported to build on each other's thinking ("agency, etc." score of 2), and the teacher did not necessarily build on student ideas (e.g., lead students in the "right" direction) ("assessment" score of 2). In whole class activities on Day 2, 3, and 4, however, students had an opportunity to explain their thinking, with other students building on those ideas, the teacher ascribing ownership to those ideas ("agency, etc." score of 3) and instruction building on those ideas ("assessment" score of 3). These instances corresponded to high levels of mathematical coherence/connections and cognitive demand (scores of 3) but uneven participation ("access" score of 2; Figure 1).

Discussion and Conclusion

With increasing recognition of mathematics' important relationships to other disciplines, attempts to integrate other topics (e.g., social justice, STEM) into mathematics education will necessarily require that teachers spend instructional time focused on topics that are not explicitly mathematical. In efforts to integrate social justice goals and mathematics goals, concerns about balancing the focus on mathematics and other goals are not new (Bartell, 2013). A major concern is that time taken away from a direct focus on mathematics may exacerbate inequities in mathematics (Harper, in press). This study provides insights into how particular project structures might support balancing mathematics goals with social justice and STEM goals.

Although aspects of the mini-project focused on skill-oriented mathematics, non-mathematical topics, or project logistics, the activities that scored poorly on measures of coherent and cognitively demanding mathematics seemed to have served an important purpose in the overall scope of the mini-project. The work that students did on Day 1 and the first half of Day 2, combined with the integration of STEM practices in the second half of Day 2, likely prepared students to engage in coherent, cognitively demanding mathematics as they measured ramps and made sense of those measurements by connecting to mathematical ideas (from Day 1) and the context at the beginning of Day 3. Although subsequent mathematical work was largely procedural and letter writing was not always focused explicitly on mathematics, scores of participation were highest when students worked in pairs or individually on their letters to integrate mathematics, social justice, and STEM learning from across the mini-project. In other words, *all* students engaged with the intended mathematics, social justice, and STEM ideas, at least to some degree. Further, the final whole class discussion provided some insight into the integrated and equitable learning that occurred through this letter writing process. Although participation was somewhat uneven in this final discussion, the project culminated with high levels of coherent, cognitively demanding mathematics and student voice and authority with meaningful connections to the social justice issue.

Finally, this study provides insights into additional considerations that are likely important for achieving equity goals through integrated mathematics education. Namely, models for powerful mathematics classrooms, and the observation protocols designed to capture dimensions of those classrooms, do not account for the ways that non-mathematical aspects of social justice-oriented STEM PBL support access to coherent and cognitively demanding mathematics (as discussed previously) and how those non-mathematical aspects may foster additional aspects of power and identity. The framework used in the current study only captured power as student voice and authority and focused only on mathematics identity. In this study, the level of engagement with and passion for discussing the social justice issues during the whole class discussion on Day 4 are not reflected in the current analysis. Because students negotiate their personal (racial, ethnic, gender, etc.) identities as they develop their mathematics identities (Martin, 2006), attempts to frame equity in observations of mathematics teaching and learning must also incorporate a way to identify opportunities for students to bring other salient identities into the mathematics space through integrated mathematics education. For social-justice, STEM PBL specifically, this might involve adding an additional dimension that identifies the extent to which students use mathematics and/or STEM practices as analytical tools to understand and transform social justice issues (i.e., power) and how students see those issues as important and relevant to them (i.e., personal identity). Considering the level of engagement with disability rights that students came to recognize as relevant and important through this mini-project, non-mathematical discussions present an important opportunity to understand how students see their other identities as salient in mathematics when that mathematics is integrated with social justice and STEM. Looking ahead towards integrated mathematics education demands that we re-imagine what dimensions are necessary for powerful mathematics classrooms so that those classrooms support broader equity goals.

References

Anderson-Levitt, K. M. (2006). Ethnography. In J. L. Green, G. Camilli, P. B. Elmore, A. Skukauskaite, & E. Grace (Eds.), *Handbook of Complimentary Methods in Educational Research* (pp. 279–295). Muhwah, NJ: Lawrence Erlbaum Associates.

Bartell, T. G. (2013). Learning to teach matheamtics for social justice: Negotiating social justice and mathematical goals. *Journal for Research in Mathematics Education*, *44*, 129–163.

Chief Education Office (2016). *STEM education plan: Driving individual, community, and state prosperity*. Salem, OR: Chief Education Office. Retrieved from http://education.oregon.gov/wp-content/uploads/2016/11/STEM-Education-Plan-Final_CEdO_Nov_2016.pdf.

CPM Educational Program (2013). *Core Connections Geometry.* Sacromento, CA: CPM.

Esmonde, I. (2014). "Nobody's rich and nobody's poor...It sounds good, but it's actually not": Affluent students learning mathematics and social justice. *Journal of the Learning Sciences*, *23*, 348–391.

Gutiérrez, R. (2012). Context matters: How should we conceptualize equity in mathematics education? In B. A. Herbel-Eisenmann, J. Choppin, D. Wagner, & D. Pimm (Eds.), *Equity in discourse for mathematics education: Theories, practices, and policies* (pp. 28–50). New York: Springer.

Gutiérrez, R. (2013). The sociopolitical turn in mathematics education. *Journal for Mathematics Research Education*, *44*, 37–68.

Harper, F. K. (In press). A meta-analysis of teaching mathematics for social justice in action: Promises and problems of practice. *Journal for Research in Mathematics Education*.

Keith McNeil, C., & Fairley, C. (2016). Developing sociopolitical consciousness through Lorraine Hansberry's A Raisin in the Sun: An interdisciplinary project. *Teaching for Excellence and Equity in Mathematics*, *7*, 22–35.

Martin, D. B. (2006). Mathematics learning and participation as racialized forms of experience: African American parents speak on the struggle for mathematics literacy. *Mathematical Thinking and Learning*, *8*, 197–229.

Schoenfeld, A. H. (2014). What makes for powerful classrooms, and how can we support teachers in creating them? A story of research and practice, productively intertwined. *Educational Researcher*, *43*, 404-412.

Schoenfeld, A. H., Floden, R. E., & the Algebra Teaching Study and Mathematics Assessment Project. (2014). An introduction to the TRU Math document suite. Berkeley, CA & E. Lansing, MI: Graduate School of Education, University of California, Berkeley & College of Education, Michigan State University. Retrieved from http://map.mathshell.org/trumath/tru_math_rubric_alpha_20140731.pdf.

Skovsmose, O., & Borba, M. (2004). Research methodology and critical mathematics education. In P. Valero & R. Zevenbergen (Eds.), *Researching the socio-political dimensions of mathematics education: Issues of power in theory and methodology* (pp. 207–226). Dordrecht, The Netherlands: Kluwer Academic Publishers.

STEM Leadership Council. (2018). *STEM strategic Plan: An integrated K-12 STEM proposal for Tennessee*. Nashville, TN: Division of College, Career, and Technical Education, TN Department of Education. Retrived from: https://www.tn.gov/content/dam/tn/education/ccte/ccte_stem_strategic_plan.pdf.

Stinson, D. W. (2014). Teaching mathematics for social justice: An ethical and moral imperative? *Journal of Urban Mathematics Education*, *7*(2), 1–5.

Hodges, T.E., Roy, G. J., & Tyminski, A. M. (Eds.). (2018). *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.