



# Bank Street Occasional Paper Series

Occasional  
Paper  
Series

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Volume 2019  
Number 41 *Critical Mathematical Inquiry*

Article 8

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March 2019

## Mathematics for Whom: Reframing and Humanizing Mathematics

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### Recommended Citation

Yeh, C., & Otis, B. M. (2019). Mathematics for Whom: Reframing and Humanizing Mathematics. *Occasional Paper Series, 2019* (41). DOI: <https://doi.org/10.58295/2375-3668.1276>

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## Mathematics for Whom: Reframing and Humanizing Mathematics

### Cover Page Footnote

We would like to thank Jamaica Ross and her fifth grade classroom for the opportunity to learn with and from them.

# Mathematics for Whom: Reframing and Humanizing Mathematics

*Cathery Yeh and Brande M. Otis*

## Introduction

Schools are “inherently cultural spaces where different forms of knowing and being are being validated” (Nasir, Hand, & Taylor, 2008, p. 206). Every decision a mathematics teacher makes, “[w]hich properties of arithmetic, which formulas in algebra, which theorems in geometry, and in what context, and for what purpose” (Kumashiro, 2004, p. 96), sends powerful messages about what is valued and whose knowledge and experiences are deemed important.

Mathematics is traditionally seen as the most neutral of disciplines, removed from the arguments and controversies of politics and social life. We join an emerging group of mathematics educators, researchers, and activists to contend that mathematics is political (Frankenstein, 1983; Gutiérrez, 2013; Gutstein, 2008; Yeh, 2018a). Mathematics has been used as a weapon to legitimize capitalist interests, producing stratified achievement levels and positioning some children and families of color at the bottoms of social strata (Ellis, 2008; Yeh, 2018a). How children perform in mathematics is not a reflection of innate ability, disposition, or soft skills, but instead is a product of the organization of schooling, shaped by cultural, historical, and political roots (Ellis, 2008; Nasir, et al., 2008; Yeh, 2018a).

As educators committed to a more humanizing pedagogy, we see education as a site of social reproduction *and* as a potential site for transformation. Schools can be places in which students’ ideas and identities are honored and leveraged, and education can, among other things, help bring equality and justice to an unjust world (Freire, 1970). As critical mathematics educators, we see mathematics as a tool to understand and critique the world, and mathematics education as a tool to deconstruct power structures that continue to marginalize certain groups. Transformative pedagogy involves educators developing curriculum that draws from students’ knowledge and experiences and supports the development of both sociopolitical consciousness and mathematical competencies (Freire, 1970; Gutstein, 2007).

In this paper, we share a process in which we, as mathematics teacher educators and education researchers, have worked in collaboration with K–6 teachers and students to analyze the purported neutrality of mathematics textbook word problems and to consider ways to use mathematics to analyze social inequities in the world. In the sections that follow, we describe the framework that grounds our development of justice-oriented mathematics curriculum and share an example of how textbook analysis can serve as an entryway to investigations that raise students’ awareness of social issues while developing their power as mathematics thinkers and doers. Drawing from these experiences of creating and teaching mathematics projects, we end with a discussion of the complexities, challenges, and possibilities of creating justice-oriented mathematics curriculum in elementary-school settings.

## **What's the Hidden Message in Mathematics?**

Schools teach us more than just reading, writing, and arithmetic; they send powerful messages to students about what is valued and whose knowledge and experiences are deemed important (Jackson, 1968; Nasir et al., 2008). In this paper, we consider the concept of the hidden curriculum, which has come to be understood as the transmission and reproduction of culture—the norms, values, beliefs—conveyed in both the formal educational context and daily school interactions (Giroux & Penna, 1979; Jackson, 1968). Typically unrecognized and unchallenged, the hidden curriculum is one of the means through which structures of power and privilege are maintained.

Mathematics education is rarely considered for its role in the reproduction of dominant ideas, beliefs, and norms. All artifacts encode systems of power, and mathematics texts themselves serve as transmitters of hegemony (Bright, 2016). Mathematics education is a powerful apparatus, inscribing different rules of participation and status and contributing to the taken-for-granted logics that grant authority to some while undermining the authority of others (Gutstein, 2006; Moses & Cobb, 2001; Skovsmose & Valero, 2001; Yeh, 2018a). Mathematics education centers instruction around a narrow set of goals, including individualistic gain, employment, economic competitiveness, and national security and promotes norms and discourses that contribute to ongoing inequalities in our society (Ellis, 2008; Yeh, 2018a; Yeh & Rubel, under review).

Building from the work of critical pedagogy (Freire, 1970; McLaren & Kincheloe, 2007) and critical mathematics scholars in the field (Bright, 2016; Frankenstein, 1995; Gutstein, 2006), we argue that mathematics literacy for all students should be more than an economic necessity—it should be a necessary prerequisite for democracy (Moses & Cobb, 2001; Skovsmose & Valero, 2001). When students use mathematics to describe and make sense of real-life contexts, they improve their decision-making skills and develop problem-solving abilities (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). More importantly, mathematics can be taught in a way that deepens students' understanding of society and prepares them to be critical participants in a democracy (Gutstein & Peterson, 2005).

## **Classical, Community, and Critical Knowledge**

We do not believe that mathematics education should be limited to helping students develop mathematics literacy as traditionally understood; rather, the goal is to conceive of mathematical knowledge as the ability to use mathematics to analyze, critique, and transform oppressive structures—that is, as “knowledge for liberation from oppression” (Gutstein, 2006, p. 211). We use Gutstein's (2006) community, critical, and classical knowledge bases (3Cs) as the framework within which we develop mathematics curriculum.

Classical knowledge refers to the traditional mathematics knowledge typically taught in schools. It is the formal, in-school, and often abstract knowledge taught in textbooks and assessed in standardized tests. Community knowledge refers to the informal knowledge students already know and bring to

school with them; it is the knowledge that resides in individuals and in communities and that is often left out of school curriculum. Community knowledge can be referred to as students' funds of knowledge (Gonzalez, Moll, & Amanti, 2005) or indigenous knowledge (Mack, 1990). Critical knowledge refers to students' understanding of their sociopolitical context. It includes knowledge about why things are the way they are and about the historical, economic, political, and cultural roots that shape one's immediate and broader existence. This knowledge builds from Freire's critical literacies of "reading the world" (Freire & Macedo, 1987). In Freire's (1970) early work on literacy campaigns with Brazilian farm workers, he discussed culture circle sessions in which farmers studied codifications (representations of daily life through cases, stories, and photos) and reflected on their meaning. These sessions allowed culture circle members to examine their lives from different perspectives, to deepen their understanding of their present life situations, and to transform community knowledge about the everyday world—knowledge that has often been normalized—into critical knowledge about the same situation.

### **Critical Mathematics with K–6 Students**

There is a growing commitment to teaching mathematics for social justice in various settings (e.g., middle school and high school classrooms, remedial high school courses, adult education classes, and pre-service and in-service teacher education programs); yet there is little work on critical mathematics in elementary school settings (Bartell, 2013; Frankenstein, 1983; Gutstein, 2006; Gutstein & Peterson, 2005). Students' early experiences with mathematics have lasting effects on students' perceptions of themselves and of mathematics and mathematics competence (Boaler, 2015; Martin, 2006; Nasir et al., 2008). In addition, recent literature in critical mathematics suggests that students demonstrate positive changes in their perceptions of mathematics and its utility after they use mathematics as a vehicle to understand and uncover structural inequities (Brelías, 2015; Gutstein, 2003; Gutstein, 2006). Therefore, it becomes increasingly important to engage younger students in diverse applications of mathematics and provide opportunities to engage in this sort of social inquiry early in their educational careers.

Our desire to engage in textbook analysis with elementary-age students is informed by our own work as educational researchers and as teacher educators (Yeh, 2017; 2018b; Yeh & Rubel, under review). We have examined hundreds of mathematics textbook word problems; the process of analysis has increased visibility of the tradition of silence with regard to sexism, heterosexism, classism, and consumerism that is typically reified through mathematics texts and has made it "unhidden" (Yeh, 2017; 2018b; Yeh & Otis, in progress). Interrogating word problems in terms of assumptions and values as well as in terms of whose experiences the problems valorize has allowed the teachers we have worked with to then undertake a process of reframing, pushing back against stereotypes, and interrogating the problem's implicit values. We believe that elementary school students too can be engaged in this process of developing consciousness about word problems and reframing them, a process whereby students can reframe mathematics texts to be better mirrors of their identities, experiences, and values as well as those of others (Gutiérrez, 2007).

We turn now to a short example of textbook analysis with linguistically and ethnically diverse elementary-age students in an urban<sup>1</sup> public school setting. The authors worked in collaboration with Ms. Jamaica Ross, a fifth-grade teacher in Long Beach, California, to develop a lesson to analyze the purported neutrality of the word problems in their mathematics textbook. The collaboration builds from an established partnership in which Ms. Ross and the first author are part of a family and educator advocacy organization for supporting gender-expansive and transgender children and youth.

### A Peek Inside a Classroom

The example that follows highlights an activity that took place in Ms. Ross's class in a school serving low-income Black and Latinx populations. For years, Ms. Ross has been using literacy practices to develop students' critical sociopolitical consciousness while following the school's standards-based English Language Arts curriculum. Specifically, her class engages with literature that explores the social construction of difference, identities, privilege, and power. However, prior to engaging in the activity discussed below, her class had not yet explored *mathematics* as an extension of their conversations around diversity/inclusion. The lesson we describe here centered around critiquing mathematics textbook word problems and leveraging the textbook analysis to begin investigations of social issues. In addition, we provide classroom artifacts (photos and video recordings) and descriptions of this classroom's first attempt at analyzing word problems.

### Intentional Word Problems

This process begins with Ms. Ross's class analyzing the mathematics curriculum, specifically their grade-level textbook word problems. We started with a series of problems in the fifth-grade *Math Expressions* (2015). We selected the following word problems to connect with the class's current read-aloud of *George* (Gino, 2015). *George* is a novel by Alex Gino that shares the story of a 10-year-old transgender fourth-grader and her struggles with acceptance among friends and family. In addition to presenting a list of word problems from the Math Expressions unit that might lead to a discussion on genderism, we intentionally included word problems that highlight different representations of fractions (linear, set, and area models):

1. *Amie used  $\frac{7}{9}$  yard of ribbon in her dress. Jasmine used  $\frac{5}{6}$  yard of ribbon in her dress. Which girl used more ribbon? How much more did she use?*
2. *A fifth-grade class is made up of 12 boys and 24 girls. How many times as many girls as boys are in the class?*
3. *Ms. Hernandez knitted a scarf for her grandson. The scarf is  $\frac{5}{6}$  yard long and  $\frac{2}{9}$  yard wide. What is the area of the scarf?*

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1 The term urban takes on multiple meanings in public discourse and in educational research. Here, urban denotes a place with a high population density, and urban schools have two distinguishing characteristics. First, urban schools serve a diversity of students across racial, linguistic, and socioeconomic backgrounds. Second, urban schools are part of a large school district characterized by bureaucratic leadership structures, an emphasis on standardized testing, and high teacher turnovers.

SAY	MEAN	MATTER
<p>1) Amie used <math>\frac{7}{9}</math> yard of ribbon in her dress. Jasmine used <math>\frac{5}{6}</math> yard of ribbon in her dress. Which girl used more ribbon? How much more did she use?</p> <p>2) A fifth grade class is made up of 12 boys and 24 girls. How many times as many girls as boys are in the class?</p> <p>3) Ms. Hernandez knitted a scarf for her grandson. The scarf is <math>\frac{5}{6}</math> yard long and <math>\frac{2}{9}</math> yard wide. What is the area of the scarf?</p> <p>Source: Fifth grade Math Expressions Fractions and Decimals Unit</p> <p>Questions or Wonderings I have.....</p>	<p>What does this mean? How do I interpret this? Read between the lines!</p>	<p>Why does this matter? Why does it matter to me or others? What are the implications?</p>

Figure 1. Say-Mean-Matter-Graphic Organizer

### What Does This Say?

Ms. Ross used the close reading strategy *Say-Mean-Matter* and a graphic organizer in order to help students question the word problems, search for deeper meanings, and make connections between the text and their lives (see Figure 1). We began our initial analysis of the word problems with the question, “What does it say?” This first layer of analysis—eliciting from students what the text says, which words are actually used—attends to classical knowledge. The focus here is on the meaning-making and sense-making of the problems.

Students were asked to look closely at the mathematical text and explain the problems. We encouraged students to use words, drawings, and numbers as well as their native language as they developed their explanations. Power and status are communicated in how we allow and encourage students to engage in the mathematics, and language and opportunities for multi-modality play a critical role in discourse and student access (Moschkovich, 1999; Razfar, Khisty, & Chval, 2011).

Examining the three word problems led to conversations exploring fraction and measurement concepts. For example, the knitted scarf problem led to a discussion comparing the characteristics and units of measure of area and volume. Students also discussed different methods of problem solving based on what made sense to them in relation to the context of each problem.

### Making Meaning

In the second level of analysis, Ms. Ross asked students to consider what the text means, generating interpretations that tap into their community knowledge. Most students have never been asked to consider the hidden curriculum embedded within mathematics textbooks. Cultural hegemony works to normalize the experiences portrayed in textbooks. We have found that most students read these word problems, at this level of analysis, without seeing that there are limitations with regard to whose lives are represented in them (Yeh & Otis, in progress). This in itself is particularly problematic in that the contexts in which word problems are embedded are not representative of the lives of all people—or in fact of most people.

Mathematics texts carry rich complexity and contextualization. Students bring into the classroom diverse histories and their own rich complexity and contexts within which they see and make sense of the problems they encounter, thus leading to differing interpretations and discoveries. To ensure multiple voices are heard, students are given time to think about the meaning on their own, then share their ideas in pairs, and later share them with the whole class. In doing so, the class as a whole is provided with multiple opportunities to see the problem through differing perspectives. We have found that responses are always diverse, as students bring in different lenses through which to view and interpret the text (see Figure 2).

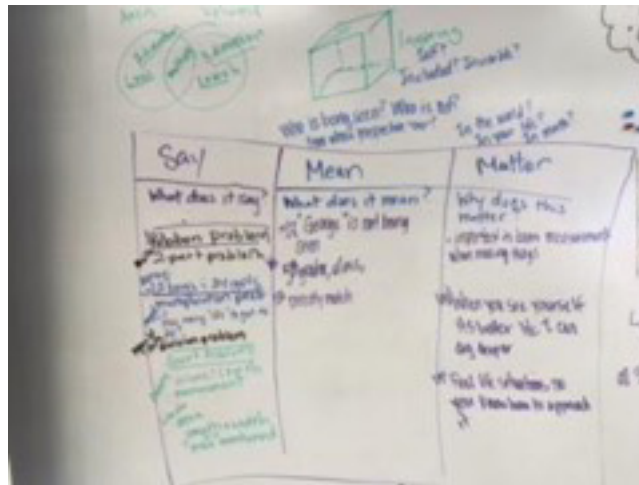


Figure 2. Whole class Say-Mean-Matter

### Why This Matters

The heart of our conversation rests in the third column of the graphic organizer, “Why does this matter ... to me, to mathematics, to the world?” These questions have been central in helping us see that all word problems are carriers of cultural values and privilege certain worldviews. We center observations on identifying perspectives and points of view in the text and look for the “silences” in them (e.g., What prior knowledge and experiences [aside from mathematics] are needed to solve the problem? Whose lived experiences are not included?). We then consider how the narrative or its consequences might be different if a given character were different. In the example problems above, the students considered the implication of having a character be a boy instead of a girl, or vice versa.

Throughout this practice, we recognized the importance of student participation and dialogue surrounding the question of “Why does this matter?” Through think-aloud sharing and student participation, students learn from each other, and we can better understand student thinking around mathematics.

Click this link for a clip of how Ms. Ross starts the discussion of why word problems “matter”: <https://youtu.be/csDtaVqvkJw>. Notice how Ms. Ross wrote down each student’s idea on the board and would consistently ask a follow-up question. The norm in her class is that a student initiates an explanation and then others contribute to and build on that explanation. Since any group of people, including students, has diverse histories and experiences, this norm encourages differing interpretations and discoveries that



can overlap or even contradict. Analysis followed by group discussion, therefore, enables multi-vocality and provides alternate discourses that would likely be unavailable if individuals conducted the analysis alone. To provide some context (see Figure 3), below are observations and questions that arose from the problem set:

- What constitutes “boys’ things” and “girls’ things”?
- Word problems with girls’ names provide context related to looking pretty, being helpful, and being a homemaker.
- Word problems with boys’ names focus on sports and competition.
- Playing sports is seen as a boy’s thing while playing house is seen as a girl’s thing.
- Are certain things—toys, games, activities, etc.—the sole and primary preserve of either girls or boys?
- Are there word problems about ribbons, cooking, or knitting that use a boy’s name?
- Do these word problems really matter in real life? Do they represent mathematical calculations needed to engage in daily life?

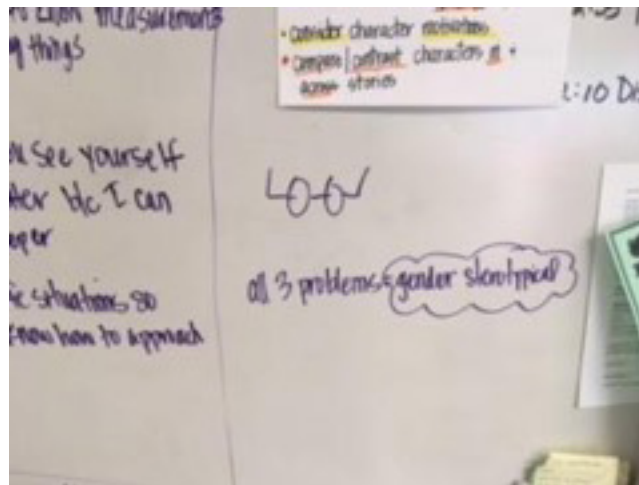


Figure 3. Student input

### Students’ Mathematical Investigations

The initial analysis of the word problems allowed students to interpret and assess the ways that gender and sexuality norms are relegated and naturalized by the context made available in the word problems and served as a springboard for students to work in groups and engage in their own mathematical investigations. Students followed their analysis of the word problems in the fractions and decimals chapter by posing their own questions about the contexts for those problems. These investigations provided material for a meaningful experience with basic concepts of data analysis: asking questions and gathering and organizing data in order to make an analysis (National Council of Teachers of Mathematics, 2000).

Analysis of patterns across all word problems in the curriculum helped students to identify a consistent message about gender normativity—the idea that there is only one way to be a boy and another, different way to be a girl. While there were a few instances of a problem context that challenged gender stereotypes (e.g., David’s dad baked a dozen cookies to share with David, his sister, and his mom), textbook problems continued to perpetuate heterosexism. Mathematics textbooks seldom contain problems involving non-nuclear families (e.g., two moms or a single dad) or problems including scenarios beyond those featuring opposite-sex relationships, such as male-female dances.

However, we want to note that it is not enough to simply have students notice these patterns; it is also necessary to question why certain things (e.g., toys, activities, careers) are perceived as being only for girls or only for boys and what the implications of these assumptions are. Learning is about disruption, including supporting students in redefining their understandings of sexuality, sexual orientation, and gender by bringing the oppression that results from labeling and categorization to the forefront of classroom dialogue. *Why does this matter? Who does this privilege? Who is silenced?* (See the following video clip of a student discussing why it is important for people of all genders to see themselves in stories: <https://youtu.be/H3MPuhE5mms>.)

Why does genderism matter? Conventional borders around sex, gender, and sexuality maintain marginalization and oppression. The current trend in the United States regarding definitions of gender and corresponding laws about school bathrooms is toward construing gender only as equivalent to one’s sex “as assigned at birth.” Such legislation is currently being introduced across the United States, although these laws effectively deny many students from feeling comfortable in school and make them vulnerable to harassment and physical violence.

Ninety percent of gender-nonconforming students indicate that they have received negative remarks about their gender expression, and more than half reported being subject to gender-based physical violence in the past year (Kosciw, Greytak, Palmer, & Boeseen, 2014). Even students who are just perceived to be gender nonconforming are significantly more likely than their peers to be harassed and assaulted at school (Kosciw et al., 2014). Examining the meaning of this set of data became a natural opportunity for the class to use mathematics as a tool to understand the role of genderism in school-based violence and to develop new mathematical knowledge on percentages. Physical tools were used to help students develop understanding of percentages building from the students’ existing understanding of the base-ten system. The physical representation, using square tiles to model what 90 percent of a group of 10 people or of 20 people would mean (see Figures 4 and 5), provided a kinesthetic model of the data to facilitate student interpretation and sense-making of school-based violence.

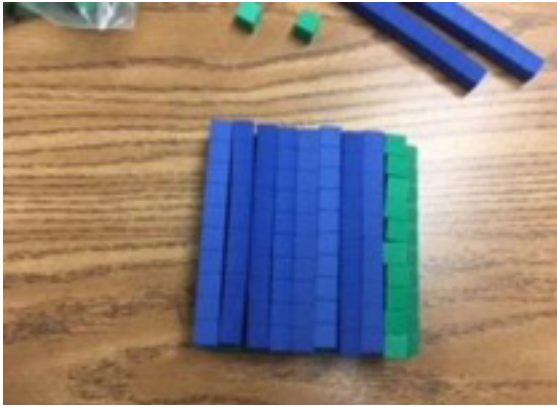


Figure 4. Groups of 10



Figure 5. Using square tiles to show 90 percent

## Reframing Mathematics

One of the most pervasive themes that emerged in analyzing word problems with children or teachers was the failure of word problems to depict realistic and relatable applications of mathematics (Yeh & Otis, in progress). Instead, math curriculum word problems often created superficial scenarios as a context for teaching the seemingly more highly valued mathematics. Take the following example found in a fifth-grade mathematics textbook:

*“Jeff likes cooking with fruit and vegetables. He needs to know how much they weigh. This is what he found:*

*A tomato weighs between 1 ounce and 4 ounces.*

*An apple weighs between 4 ounces and 8 ounces.*

*A kiwi fruit weighs between 2 ounces and 4 ounces.*

*A banana weighs between 3 ounces and 6 ounces.*

*A carrot weighs between 2 ounces and 5 ounces.*

*A grape weighs between  $\frac{1}{4}$  ounce and 1 ounce.*

*An orange weighs between 5 ounces and 10 ounces.*

*A plum weighs between 1 ounce and 3 ounces.*

*Jeff buys half a pound of grapes. What is the greatest number of grapes he can get? Explain how you got your answer. (16 ounces = 1 pound)”*

Ask yourself, how could this problem apply to my daily life? When would a person weigh a single grape? Why does this problem matter? This leads to the last step: reframing. Part of examining word problems in this way involves asking our students to help us reframe word problems so that they’re more relevant and realistic. Student groups collaboratively rework and reframe the problems into more relevant, socially

just scenarios. This process provides opportunities for students to examine the often unnamed layers of power, positionality, and privilege that form the context of mathematics scenarios in textbooks and then to use these insights to consider ways to challenge and disrupt current narratives of mathematics that are removed from lived experiences.

Follow this weblink to view three groups' recreated word problems and their justifications for changes: <https://youtu.be/zeLEpdMnabk>. In our experiences with students, their reframings—similar to the recreated word problems seen in the video—often focused on shifts in the identity of the protagonist so that the word problem better represents the diversity of children and families in our schools and community: *Juan is cutting ribbon to make a pink bow or Molly's dad knits a scarf for his husband*.

### **The Journey of Teaching (and Learning) Mathematics for Social Justice**

Recent events in US politics have led to a renewed urgency to examine the role of education in the lives of our children. Educational inequities are systemic and pervasive. Education, including mathematics education, is implicated in various forms of broader interpersonal dominance and ideological struggles. Institutional tools that implicate mathematics, like standardized tests, prescribed curricula, and curricular tracking systems, perpetuate inequities in mathematics and have led to increased pressures of accountability and performativity for teachers—making the process of teaching mathematics for social justice both challenging and rejuvenating.

One of the greatest challenges in learning to teach mathematics for social justice is the negotiation of mathematical goals and social justice goals. In our desire to support and foster students' sociopolitical and critical consciousness, it is always necessary to ensure that our students use, apply, and learn new mathematics (Bartell, 2013; Gutstein, 2006). As such, we have found that it's important to not only examine curriculum text, but also to closely examine our own implementation of math lessons. Critical mathematics education should not only raise students' awareness of social issues, but also develop their power with mathematics and their sense of themselves as mathematics thinkers and doers. In our work as teacher educators, we ask our teachers to consider how lessons, from their design to their implementation, can leverage the community and classical mathematical knowledge students bring to class and to find ways to connect students' funds of knowledge (Gonzalez et al., 2005) to new mathematics concepts.

As teacher educators, we have had the privilege to work with hundreds of pre-service and in-service teachers. Although mathematics education is one of the powerful institutional discourses that help to create and maintain prejudice, many educators, students, and school professionals consider textbooks and curricular materials to be objective transmitters of truth (Yeh, 2017; 2018b; Yeh & Rubel, under review). Teachers and students typically do not question the context of word problems presented to them. Instead, they initially accept the text as truth, and they often view mathematics and mathematics teaching as universal, neutral, and uninfluenced from the social realm. Only after some period of time do they feel compelled to engage with the question, "Why does this matter?"

Cochran-Smith (2004) uses the metaphor of traveling—or walking the road—to make the case that the work of social justice in education is "an ongoing, over-the-long-haul kind of process" (p. xvii). Education, including

mathematics education, is intricately linked to power structures that perpetuate inequities in both schools and society (Bartell, 2013; Frankenstein, 1983). Mathematics learning experiences in most schools still require students to perform mathematics using algorithms that are not their own, in a language different than their native tongue (emergent bilinguals are now the fastest-growing student population in the United States) and to solve mathematics problems irrelevant to student interests and experiences (Aquino-Sterling, Rodríguez-Valls, & Zahner, 2016; García, Kleifgen, & Falchi, 2008). As such, we've found this work to be a collective journey in which we walk with teachers and students to "unlearn" the mathematics we have experienced as students and to relearn the possibilities to teach mathematics for social justice.

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