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Contextualization of mathematics: which and whose world?

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Abstract
We frame teachers' contextualization of mathematics (CoM) as a classroom-based identity resource. We explore CoM in secondary classrooms in the segregated school landscape of the US, focusing specifically on schools that serve primarily low-income Black and Latinx students. We review literature that discusses commonly-cited affordances for CoM according to formative, affective, functional literacy, and critical literacy rationales and problematize those rationales relative to prior research. We analyze 58 lessons from 12 classrooms at 11 schools to reveal patterns in CoM relative to those commonly cited affordances. The formative, affective, and functional literacy rationales were frequently evident. Teachers draw largely on generic human experiences and marketplace contexts, positioning students as consumers or employees. There were few instances of CoM naming racism or inequality, and our analysis further reveals blind spots in these efforts. Our discussion considers the implications of these patterns.

Keywords Mathematics education · Secondary education · Real-world contexts · Equity

Contextualization of mathematics (CoM) denotes a teacher's discursive turn—in posing a task, explaining a process or idea, telling a story, offering an analogy—that does not consist exclusively of mathematical objects. In communicating situations that warrant mathematical solutions and by delineating *how* mathematics is used, by *which* actors, and to pursue *what* goals, CoM is a "carrier of cultural values" (Bright, 2016, p. 6). Analyses of CoM in formal curricula are often revelatory (Smith & Morgan, 2016; Wijaya et al., 2015). Yet, in the United States (US), teachers are known to adapt published curricula and create their own task statements (Choppin, 2011; Gainsburg, 2008; Remillard & Heck, 2014). Thus, our study explores CoM as enacted by middle and high school teachers, separate from any specific, text

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resource. As we will argue, CoM reflects the depth of teachers' recognition of students' prior knowledge and breadth of expectations for students' futures.

We conducted our study in a large US city, in middle and high schools whose students are primarily low-income and Black or Latinx. Schools of this profile tend to be under-resourced and located in historically looted and chronically under-served neighborhoods (Gutiérrez, 2016). Our goal is to better understand CoM in this context, especially in light of the overwhelmingly white teaching force in the US and tendency toward deficit views of communities of color and essentialist understandings of culture (Adiredja, 2019).[1] Although the nature of the politicization of race, mathematics education, and their intersections have unique features in the US, we expect that our research will resonate broadly.

We begin with an overview composed of four rationales for CoM and supplement that overview with perspectives that complicate those rationales. Then, we present a conceptual framework, based on Skovsmose's paired notions of *background* and *foreground*, that explains the significance of CoM. We present empirical findings about the CoM offered in 58 lessons from 12 classrooms under study. Our discussion considers our findings relative to the literature, with particular attention to this school context.

1 Literature review

1.1 Rationales for contextualizing mathematics

Four general rationales underlie the common practice of contextualizing mathematics: CoM (1) supports the learning of mathematics (we refer to this as *formative*), (2) motivates students to learn mathematics (*affective*), (3) supports the teaching of how to solve essential everyday problems (*functional literacy*), and (4) is integral to teaching mathematics for social justice (*critical literacy*).

1.2 Supports the learning of mathematics (formative)

Several theories of learning and instruction, like constructivism (Dewey, 1925; Piaget, 1972) and Realistic Mathematics Education (Freudenthal, 1971), emphasize CoM as instrumental for learning. These theories advocate for CoM in terms of situations concrete or familiar to learners, which can serve as "foundations" on which "mathematical skyscrapers" can be built (Carraher & Schliemann, 2002, 149). A premise is that students hold reasoned, but often inefficient, informal problem-solving strategies that classroom learning can shape into formal, more efficient, or generalized approaches (Reinke, 2020). Pedagogical orientations that highlight the role of culture in learning (Ladson-Billings, 1997; Matthews, 2003) call attention to how CoM's formative potential often goes unrealized, especially when teachers know little about their students and their communities, a point to which we return below.

1.3 Learners enjoy CoM (affective)

A second perspective is that CoM motivates learning by piquing learners' attention and inviting participation (González, 2017). Here too, the affective perspective values CoM in

[1] About 79% of teachers in US public schools are white (U.S. Department of Education 2019).

support of the goal of learning mathematics, guiding teachers towards what might please or interest their students. Often, teachers try to entice participation in mathematics with CoM, "through association with pleasant sights, tastes, textures, sound and social experiences" (Pierce & Stacey, 2006, 214). Teachers, many times, personalize CoM with students' names or perceived interests (Bates & Wiest, 2004; Wager, 2012; Walkington et al., 2013). Of course, any group of students has diverse interests. As we discuss below, teachers need to know their students well enough to be able to identify what might please or interest them without having to rely on assumptions or stereotypes.

1.4 Mathematics for essential everyday problem-solving (functional literacy)

For the formative and affective perspectives, CoM functions in service of a goal of learning mathematics, either as a conceptual anchor or as a motivator. An alternative reverses the direction of the relationship between mathematics and CoM, so that it is mathematics that supports engaging with contextualized problem-solving (Blum, 2015). The functional literacy perspective positions mathematical knowledge as instrumental for later problem-solving, oftentimes of the essential but everyday variety. Curriculum, evaluation, and policy documents tend to emphasize this rationale, positioning mathematics as needed for "engaged and reflective 21st century citizens" (e.g., Organization for Economic Cooperation and Development, 2018, p. 25). CoM is then the basis of developing those competencies.

Despite the prevalence of the discourse of mathematics as essential for civic participation, that preparation is realized narrowly through a "commercial-administrative mathematics" (Harouni, 2015a, 30). Harouni (2015b) offers an historical analysis linking current school mathematics to the resemblant mathematics taught in 16th century Europe in schools for future merchants and accountants. Since the present curriculum omits more complex financial situations, school mathematics today "has been gradually and deliberately reduced to" a kind of "consumer mathematics,...just enough for shopping or for working as a petty bureaucrat, a soldier, or a cashier (Harouni, 2015b, 70)." Teachers in the US, at all school levels, tend to prefer CoM around consumer practices, because they view these as neutral and widely relevant (Bright, 2016; Gainsburg, 2008; Lee, 2012; Simic-Muller et al., 2015; Wager, 2012). Rare is what Harouni (2015b) calls *artisanal mathematics*, or creative interactions with instruments and materials, an absence Harouni attributes in part to the fact that presentation formats available in schools ("textbooks, worksheets, word problems") are "completely inadequate for the learning that creative labor requires" (63).

1.5 Teaching mathematics for social justice (critical literacy)

Apple (1992) distinguishes critical from functional literacy. Critical literacy in mathematics signifies: understanding power relations, identifying gaps in opportunities and resources, participating in social movements, and contributing to struggles towards justice, all aided by the use of mathematics (Frankenstein, 2009). Gutstein (2006) proposes teaching mathematics for social justice, built on synergies among critical literacy, as defined above; community knowledge, or the extensive cultural understandings people hold; and classical knowledge, or abstract school mathematics. CoM is essential to this orientation, as it essentially bridges the classical with the community and critical knowledge. Gutstein (2006) argues that it is through the connections among critical, community, and classical knowledge, that teaching for social justice expands students' mathematical identities and adjusts their views of mathematics, from "seeing it as a series of disconnected, rote rules to be memorized and regurgitated, to a powerful and relevant tool for understanding complicated, real-world phenomena" (30).

We have presented an overview of four rationales that undergird CoM, often in axiomatic terms. These rationales can overlap, are difficult to disentangle, and can shift in priority. Characterizations of a given context as "relevant" or "authentic" are multi-faceted and could signal any or all among familiarity, emotional connection, practicality, or social urgency. For example, the literature includes affective orientations to CoM, at times, that base relevance in terms of assumed familiarity (González, 2017), at other times, in terms of what is deemed to be practically relevant to students (Hernandez-Martinez & Vos, 2018), and at yet other times in terms of what is considered culturally relevant (Meaney et al., 2013). Teaching mathematics for social justice is less common, a gap we attribute to how such themes are less prevalent in curricular materials, more context dependent, and often regarded by teachers as controversial and therefore risky (Simic-Muller et al., 2015). The commonality of CoM notwithstanding, the literature elucidates a set of complexities.

1.6 Complexities of the four rationales for CoM

1.6.1 Formative potential can be undermined

Some prior research challenges the formative potential of CoM by demonstrating how it can distract, rather than anchor, learners. At times, learners might have difficulty interpreting story situations when communicated in written form (Walkington et al., 2012). Formal approaches might seem unnecessary relative to existing, nuanced knowledge (Enyedy & Mukhophadyay, 2007). Moreover, teachers' general tendency towards abstraction implies suppression of aspects of CoM that would be resourceful (Chapman, 2006; Depaepe et al., 2010). That is, as part of a tradition in school mathematics of CoM based in pseudo-contexts (Boaler, 1993b), teachers oftentimes intend for learners to put aside contextual reasoning (Verschaffel et al., 2000). Increased authenticity encourages students to engage with the contextual domain so to realize its formative affordances (Baranes et al., 1989; Palm, 2008).

1.6.2 The unlikeability of CoM

The affective rationale claims that CoM motivates learners because of interest or pleasure related to the associated context. Yet, some studies show that students often dislike CoM and find it less accessible than abstract mathematics (Brantlinger, 2014; Schukajlow et al., 2012), and that teachers consider CoM to be disliked and to be more difficult (Reinke & Casto, 2020). For example, even though the students in Nathan and Koedinger's (2000) study were more successful with story problems, their high school teachers erroneously predicted that they would be more successful with solving abstract equations. In aggregate, these studies qualify the premise that students prefer and enjoy CoM, unless the selected contexts relate to students' own experiences.

1.6.3 Transfer of school-learned strategies is questionable

As with the formative and affective rationales bearing complexity, various studies complexify the functional literacy perspective on CoM as well. Transferring mathematical understanding from one context to another, even within the classroom, is not trivial (Herbert & Pierce, 2011). People often do not transfer school-learned strategies (Boaler, 1993a; Carraher et al., 1985) and tend to choose solutions depending on the context in which they are solving the problem (Rubel, 2007). Adults use alternative algorithms rather than school-taught ones, in work and everyday situations (Hoyles et al., 2001; Jurdak & Shahin, 2001; Lave, 1988). Mathematics teachers, too, can experience difficulty using mathematics they teach but to solve problems set in everyday contexts (Gazit & Patkin, 2012). These studies attribute gaps in knowledge transfer to a tradition in school mathematics around pseudo-contexts.

1.6.4 Dilemmas around CoM for social justice

The literature elaborates tensions about CoM as part of teaching mathematics for social justice, alongside its affordances for learning (Felton-Koestler, 2015; Gonzalez, 2009). For example, since the mathematics curriculum is usually ordered around carefully sequenced concepts and procedures, school mathematics likely does not correspond with how a thematic investigation inherently involves a nonlinear web of ideas and disciplinary perspectives. Some studies note reluctance from teachers because of a perception that social problems do not have clear-cut solutions or that students will not be interested (Mamolo, 2018; Simic-Muller & Fernandes, 2020). Furthermore, CoM around social justice can inadvertently reinforce deficit notions about students and families (Larnell et al., 2016) via teachers' "blind spots to race, racism, and racialization," (27), a caution we return to when discussing our findings.

We have presented an overview of rationales that support CoM as well as evidence that complicates those rationales. Next, we turn to consider CoM in relation to the "nested contexts" at play; that is, as nested in school contexts (Beswick, 2011, 384). Here, we are interested in CoM in schools where teachers are primarily part of the white power-majority and students are from minoritized groups. Next, we offer a conceptual framework that justifies the significance of our study, especially with respect to this school context.

2 Conceptual framework

We follow other researchers in mathematics education and draw on Bernstein's (1996) theories to understand CoM as pedagogic discourse (Dowling, 1996, 1998; Gellert & Jablonka, 2009; Meaney et al., 2013). CoM is an element of the collection of rules—the *pedagogic device*—that recontextualizes everyday practices into school mathematics. Recontextualization begins with de-location, the teacher's selection of an everyday discourse or part thereof, and proceeds through its re-focusing into school mathematics. What teachers recontextualize into school mathematics is significant —patterns in CoM can reify, elaborate, or disrupt existing systems of power.

Skovsmose's (2005a, 2012) notions of *background* and *foreground* are useful. Background denotes what a person has "done and experienced (such as the situations the person has been involved in, the cultural context, the socio-political context and the family tradition)" (2005a, p. 6). Foregrounds, in contrast, represent those perceived "opportunities, which the social, political and cultural situation provides" (2005a, 6). People's backgrounds and foregrounds are neither static nor singular but are multiple and expand or contract with experience. We view CoM as an identity resource, in the extent to which it relates to background and contributes to the shaping of foreground.

2.1 Attending to background as identity resource

The extent to which CoM reflects learners' backgrounds is significant. Contexts will naturally be differently familiar to students (Boaler, 1993b; Cooper & Dunne, 1998; Taylor, 2004). Yet, alternative ways of reasoning might not be anticipated or valued by teachers, meaning that prior experience can become a disadvantage (Brenner, 1998). Furthermore, those from marginalized groups are often outsiders to a culture of school mathematics that has communicated to those on the inside how much (or more typically: how little) attention to pay to a problem's context (Cooper & Harries, 2007; Lubienski, 2000). Prior research stresses that when disjoint from learners' backgrounds, CoM can further disadvantage those from already marginalized groups (Sullivan et al., 2003; Tate, 1995).

Classrooms communicate "explicit and implicit racialized and gendered notions of who does and does not belong" (Nasir & Vakil, 2017, p 378). One way that such notions are constructed and communicated is through the extent to which CoM reflects students' backgrounds. This is, of course, far from straight-forward. For example, the common practice of personalizing CoM around assumed interests could rely on stereotypes and alienate students. Even though unintentionally, teachers act as "local gatekeepers who police boundaries that act to deny access to quality education of particular students" (Barton et al., 2020, p. 3). We see the extent to which CoM communicates recognition of students' backgrounds as a regular mechanism of gatekeeping in mathematics classrooms.

Equity pedagogies, including Culturally Relevant Pedagogy (CRP, Ladson-Billings, 1995, 1997) and Culturally Responsive Pedagogy (e.g., Averill et al., 2009), argue that culture should be a vehicle for learning and frame attending to students' backgrounds as essential. Even though stated national priorities affirm commitments to equity, CRP remains outside of the mainstream, despite its benefits for African American youth in particular (Bonner, 2014; Clark et al., 2013; Flint et al., 2019; Hubert, 2014). We attribute this, in part, to CRP's incompatibility with trends towards standardization. Moreover, CRP demands considerable investment from teachers, teacher educators, and schools, beyond the political and social will that seems available. These factors likely contribute to why teachers tend to generate CoM relative to their own experiences or based on their assumptions about the cultural practices of others, rather than on first-hand knowledge (de Freitas, 2008; Gainsburg, 2008; Matthews, 2003; Wager, 2012). Adult experiences often dominate, even though as aptly reflected by Chu (Chu & Rubel, 2010): "My students do not pay income taxes, and the hypothetical incomes they researched for years before they were even born were anything but 'relevant'" (p. 64).

2.2 Shaping foreground as identity resource

CoM is significant in terms of its contributions to the shaping of students' foregrounds as well. Sfard and Prusak (2005) theorize learning as a process whereby people narrow gaps between "actual identities," the stories about who they are at present, and "designated identities," or the stories about who or what they might later become (p. 18). Through CoM, teachers communicate what mathematics is used for, how, and by whom. This means that CoM sources additional designated identities; that is, the kinds of people students might later become, pursuant to specific goals and relative to mathematics. On one hand, by providing an expanded set of designated identities, CoM could challenge existing social hierarchies. As an example, mathematics textbooks were redesigned in the late 20th century to represent women's work more fully, outside of their work in the home. The CoM came to include broader options for women's foregrounds.

On the other hand, by constraining or contracting certain students' foregrounds or *designated identities*, CoM might reify existing hierarchies. In countries with so-called ability-based differentiation, CoM is often distributed such that "there would be education for leadership and education for 'followership' (Apple, 1992, p. 424)." CoM for those "lower attainers" tend to be guided by functional literacy, emphasizing shopping, employment, and time management (de Freitas, 2008; Bright, 2016; Gainsburg, 2008; Jablonka, 2007; Smith & Morgan, 2016). When a functional literacy perspective of mathematics dominates and CoM is oriented around generic, everyday problem-solving, this practice could be regarded as motivating class-based aspirations (Bright, 2016), through a kind of "civilizing' process" (Apple, 1992, p. 423). Dowling's research in the UK shows, for example, that textbooks for students tracked as low-ability emphasize CoM, in contrast with the mostly abstract form of the textbooks for those considered "high-ability." Dowling (1996) cautions that the preponderance of CoM for the former signifies inequitable access to mathematics under an illusion about the actual utility of mathematics. Those identified as "low-ability" are, Dowling and Burke (2012) argue, "confined to a domain neither in mathematics or anywhere else other than in the classroom" (p. 98).

In the US, where low-income status is largely correlated with race, African American and Latinx children are more likely to be perceived by teachers and schools as less capable in mathematics (Faulkner et al., 2014; Morton & Riegle-Crumb, 2019). Thus, a tendency to orient CoM around functional literacy could be regarded as preparation for serving the bottom of that hour-glass economy,[2] toward being "more obedient, more effective and efficient workers" (Apple, 1992, p. 423), and not toward being "changers of society" (Smith & Morgan, 2016, p. 38). In Gainsburg's (2009) study, teachers echoed that students tracked as "lower-ability" need "everyday, concrete, consumer-related" contexts. Those students considered to be "more advanced," on the other hand, "should be exposed to, or were naturally interested in, more sophisticated, abstract, academic contexts" (p. 277). One teacher commented that in the "lower-level" classes, students need to learn to balance their checkbook or make change, whereas in the "higher-level" classes, "you're the guy in charge" (Gainsburg, 2009, p. 278).

Patterns in CoM shape the ways students view mathematics relative to their foregrounds. Sealey and Noyles (2010), for example, studied schools in the UK of contrasting socioeconomic levels to see how students might view the purpose of their mathematics education. In the middle-SES school, students emphasized its process relevance for their future education or professions, but in the low-SES school, students remarked on their sense of its practical relevance. In the high-SES school, in contrast, students noted its professional relevance. For those students, "mathematics is a power subject, giving access to higher paid careers and economic security… They can become the controllers of the mathematized world that they aim to inherit" (Sealey & Noyles, 2010, p. 250).

Our framing of CoM as an identity resource—in the ways it reflects students' backgrounds and contributes to the shaping of students' foregrounds—invites questions about CoM in classrooms. We use the four rationales justifying CoM (formative, affective, functional literacy, and critical literacy), along with their complexities, as an analytical lens. Then, our conceptual framework of CoM as an identity resource helps to attribute significance to our

[2] The hourglass economy refers to a shape created by an income distribution that includes a group at its top with very high incomes, and a group at the bottom with very low incomes, but few middle earners.

empirical observations, through the ways CoM reflects learners' backgrounds and shapes foregrounds. Relative to this particular school context, of mainly white teachers and African American and Latinx students from low-income families, we ask: How often do teachers contextualize mathematics and for what kinds of mathematics? When a teacher contextualizes mathematics, what contexts are used and why?

3 Methods

To answer these questions, we use data drawn as part of a year-long (2012–2013) professional development (PD) project. Rubel recruited middle and high school teachers as participants through a professional organization. The PD consisted of a summer program and ten meetings across the year around these goals: teaching mathematics for understanding, centering instruction on youth, and teaching mathematics for social justice. Contextualizing mathematics played a significant role, in an emphasis on how contexts support learning as mathematization (Freudenthal, 1971), but through the lens of cultural competence (Ladson-Billings, 1995), meaning that contexts need to be familiar to learners for their formative affordances to be realized. The PD guided teachers in various activities designed for them to learn about their students' interests, families, histories, and communities. The PD sessions included collaborative problem-solving around CoM for functional literacy (e.g., using exponential functions to model a car loan) as well as critical literacy (e.g., analyzing probabilities of winning local lottery games relative to the high presence of advertisements in low-income neighborhoods). Participants' instructional practices were influenced to some extent by their participation in this PD (see Rubel, 2017; Rubel & Stachelek, 2018), but the current study does not look at teacher learning. Rather, this study focuses on a particular practice (contextualizing mathematics), without attribution to learning in this PD.

Twelve teachers from 11 secondary schools volunteered to participate in the PD and associated study. The teachers taught algebra (7 teachers; Remedial Algebra, Algebra I, Algebra II), geometry (3 teachers), and 6–8th grade mathematics (2 teachers). Most (10/12) identified as White; two teachers of color identified as Latina and Afro-Caribbean respectively. All schools predominately served Black and/or Latinx students from low-income families. Rubel was the lead researcher at the time of data collection (and facilitator of the PD); McCloskey joined for secondary analysis. As former classroom teachers, our researcher positionality is, in some ways, as insiders. Yet, we acknowledge the inevitable blind spots that come with our standpoints as people who benefit from white privilege.

3.1 Data collection and analysis

A team led by Rubel observed each teacher five times for a total of 58 observations.[3] We arranged observations ahead of time, evenly spaced over the length of the school year. One or two researchers observed lessons, debriefed with the teacher immediately after each lesson to clarify his or her lesson goals and next steps, and then wrote fieldnotes and archived lesson materials (handouts, images of text projected during the lesson). The research team produced a

[3] Single observations of two teachers were missed because of school cancellations.

Table 1 Distribution of CoM segments across school year by teacher

Teacher	Round 1 Sept.	Round 2 Oct.	Round 3 Nov.	Round 4 Feb.	Round 5 Mar.	Total
T1	2	2	1	1	1	7
T2	n/a	0	0	4	26	30
T3	3	0	1	2	0	6
T4	0	1	1	1	0	3
T5	1	0	1	1	0	3
T6	2	3	2	2	1	10
T7	0	0	4	1	5	10
T8	1	6	8	2	1	18
T9	0	1	4	1	1	7
T10	0	1	0	10	0	11
T11	2	3	2	0	7	14
T12	1	n/a	0	0	0	1
Total	12	17	24	25	42	120

Table 2 Distribution of observed lessons by mathematical topic and occurrence of CoM

Mathematical topics (listed by frequency)	Number of lessons *without* CoM	Number of lessons *with* CoM
Geometry, measurement, analytic geometry	8	13
Linear relationships, equations, inequalities	3	7
Statistics and data analysis	0	8
Radicals	4	0
Ratio and proportion	0	4
Polynomials	3	0
Algebraic expressions and operations	0	4
Other: combinatorics, logic, modeling, optimization	0	4

narrative description of each lesson with lesson-level analytic memos pertaining to CoM. Our data sources are these narrative lesson descriptions and the archived lesson materials.

For this analysis, we first identified lessons with any CoM. Teachers largely created their own CoM, in some cases excerpted from external resources. Sometimes the CoM constituted the lesson's main task, meaning that the CoM was engaged for the lesson's duration. In other instances, lessons included multiple CoM segments as singular, brief exercises (as many as 20 in a lesson). In yet other instances, CoM segments were not mathematical tasks at all, but instead, the basis of a teacher's analogy, such as T6 drawing an analogy between a triangle's altitude being perpendicular to its base and how patients stand straight up for a height measurement as part of an explanation. We treated these as individual CoM segments, even though their duration was widely varied. Most (69%) of the observed lessons included CoM, resulting in 120 CoM segments. Table 1 summarizes CoM by teacher and chronological round. Every participating teacher included CoM in at least one observed lesson; nine of the teachers did so in all or most of their five observed lessons.[4] Table 2 summarizes each lesson's mathematics topic according to whether the lesson included CoM.

[4] Most lessons contained 1 or 2 CoM segments: six of the lessons (taught by 4 teachers) had substantially more segments (6, 7, 8, 9, 10, 20). T2's lesson with 20 is the only extreme outlier. We have chosen to retain this lesson in the data set because this lesson was representative of the broader patterns.

Table 3 Preliminary coding process with examples

Analytic question	Examples
Who is named as actors or participants?	*"Beyoncé Knowles joins a dinner party…"* T8 [Beyoncé]
What activities or pursuits are named?	*"Use small tiles to design a 9" × 9" model floor-tile, and then scale that model to cover a floor"* T6 [design, home improvement]
What designated identities are indicated?	*"You own a company that makes cardboard boxes…"* T11 [company owner]
Where does the activity or story take place?	*"The Lincoln Stop of the Eastbound train…"* T7[a nearby, public transportation place]
Why is mathematics being used—to reach what goal(s)?	*"A store called Tech Savvy offered you a job selling computers. The offer is for $200 per week with $50 per computer sold. Before you make your decision, you receive another phone call from a store called Expert Tech. They try to lure you away from working at Tech Savvy, with the following proposal: $280 per week with $40 per computer sold. Which job should you choose?"* T1 [choose job offer by evaluating which offer has better salary]

Table 4 Designated identities with frequencies of 5 or more

Designated identity	Example	Freq.
Retail consumer or sales	"Suppose you work in an electronics store. You earn 6% commission on every item you sell. How much commission do you earn if you sell a $545 sound system?" (T10) "The original price for a snowboard was $124.99. Because they were not selling well, they were discounted to $74.99. What percent discount is the store offering?" (T9)	15
Generic human	"A trail mix recipe calls for 2 tbsp chocolate chips for every 5 tbsp of cereal. What is the ratio of choc chips to cereal? If I want 42 tbsp of trail mix. how many chocolate chips do I need?" (T6)	13
Athlete or leisure	"Joey kept track of the number of free throws that his team shot in practice and the percentage that they made in the next game. He displayed his findings on the scatterplot below. Draw a trend line." (T2)	10
Artist, builder, construction, designer	"Ms. L wants to paint a rectangular wall that is 9.75 feet by 8.2 feet….Which of the following is the best estimate for the wall's area?" (T6)	6
Low-earning, unspecified worker	"After college, Julia is offered two jobs: $20,000 salary with $2,500 raise per year, $25,000 salary with $2,000 raise per year. How many years will it take her to make the same amount at the two jobs?" (T2)	6
Bank customer: savings and loans	"Two investment accounts: Diena at 22 yrs old invests $4,000 while Malik invests $9,000 at age 32 - both retire at 65 yrs old and both accounts accrue 9% interest annually. Who will have more money at age 65 and is it better to invest early with small or later with large - why?" (T11)	5

Table 5 Coding CoM by rationale

Code	Does the CoM...	Example
Formative	rely on students' prior familiarity with the given context for its solution or meaning?	"Determine whether or not these pairs of activities are commutative: Wash your face / brush your teeth." (T8)
Affective	seem to intend to attract students' interest, such as using personalization in terms of students' names, local places, or assumed pursuits?	"Ariel (name of student) bought several bags of caramel candy and taffy. The number of bags of caramels was five more than the number of bags of taffy. Taffy bags weigh 8 oz each and caramel bags weigh 16 oz each. The total weight of all of the bags of candy was 400 ounces. How many bags of candy did she buy?" (T2)
Functional literacy	demand application of the targeted mathematics (rather than drawing on prior knowledge)?	"Store A was offering a 40% discount on a \$249.99 lawnmower. Store B was offering a 15% discount on the same lawnmower which they regularly sell for \$175.99. Which store has the better deal? Why?" (T10)
Critical literacy	identify a particular socio-political issue for exploration, response, or critique?	(students are presented with associated data) "Argue either that Stop and Frisk unfairly targets Black and Hispanic or youth residents and does not affect crime OR that Stop and Frisk reduces crime and gets many illegal guns off the street." (T1)

We analyzed each CoM segment first using analytic questions summarized in Table 3. Each researcher coded the segments independently, and we resolved any discrepancies through discussion. We used these preliminary codes to generate themes and findings through discussion. We have included, as an example, the set of designated identities indicated by the CoM segments in Table 4, its tabulation an important intermediate step between coding and identifying themes in our findings. Finally, we coded each CoM segment according to the set of four rationales (formative, affective, functional literacy, critical literacy), using the questions shown in Table 5. In our process, segments were often coded as corresponding to more than one rationale.

4 Findings

We organize findings according to the four rationales for contextualizing mathematics across the 120 identified segments. Formative and affective rationales were most frequent, functional literacy slightly less frequent, and critical literacy scarce (see Table 6).

Table 6 Distribution of rationales for CoM

Rationales	# Segments (120 total)	# Lessons (58 total)	# Teachers (12 total)
Formative	60	34	12
Affective	47	37	11
Functional literacy	43	23	12
Critical literacy	5	4	2

4.1 CoM for formative considerations

We identified 60 CoM segments (in 34 lessons from 12 teachers) that condition on prior familiarity with the indicated context for interpretation and solution and therefore suggest teachers' formative intentions. These segments reveal what contexts teachers consider to be available to students. For the most part, the assumed knowledge in these CoM segments referred to generic experiences rather than any specific community knowledge. As an example of this genericism, T5 asked students, "Have you ever noticed what happens when you look in a mirror?" in a lesson on transformations. Many times, though, these ostensibly neutral, generic examples were constructed around taken-as-shared but unexamined social narratives. For example, T2 shared a graph relating yearly income to years of education in explaining the meaning of positive correlation, without any space for troubling the narrative that income is a function of education. This particular CoM segment could communicate an individualistic mentality about inequality and socioeconomic advancement, sidestepping considering the many systems in the US that reinforce inequality, related to food, healthcare, banking, and more.

There were exceptions to the tendency toward genericism, whereby teachers primarily drew on students' geographic knowledge about their city. As an example, in a lesson on mathematical "If-Then" statements, for example, T7 proposed a false statement: "If I take the Eastbound train to school, then I get off at the Lincoln stop. Is it true?"[5] Here, T7 relied on students' lived knowledge about the local transportation system to reason the statement's truth-value as false. T7 then built on students' ability to provide a counterexample in that familiar situation to a similarly structured statement involving purely mathematical objects. As a second example, T3 explained horizontal and vertical displacement for the distance formula using the locally vernacular concept of "street blocks." Most of the segments that we coded as teachers engaging CoM for formative considerations referred to a generic human knowledge base. Yet, these and several other exceptions referred to instances, whereby teachers engaged specialized knowledge pertaining to the local city and movement through it.

4.2 CoM for affective considerations

We identified 47 segments (in 37 lessons from 11 teachers) that show evidence of CoM for affective considerations in terms of personalization, seemingly to attract students' interest. These reveal what contexts teachers consider to be interesting or motivating to their students. Most often, teachers personalized CoMs by using names of students, teachers, or celebrities; phrasing the task in 2nd person ["You own a company that makes cardboard boxes" (T11)]; and at times, using names of local businesses. Inserting names of students was likely prevalent because of its ease as a practice and perhaps because it effectively attracts learners' attention. Personalization using local places likely signals to students a commonality through shared familiarity with the same local city. Here too, were appeals to generic interests like music, sports, or food.

In some cases, these seemingly generic interests invoked racial stereotypes, yet still avoided explicit expressions of racism. Consider, for example, T8's recontextualization of a group of party attendees with low incomes, before and after they are joined by a much higher earner, "Beyoncé Knowles."[6] T8 intended to demonstrate the mean's sensitivity to outliers, a characteristic T8 termed "the Beyoncé effect." This choice could signal the teacher's recognition of

[5] These names have been blinded. The teacher named a specific train line and station close to the school.
[6] Beyoncé Knowles is a highly successful and influential African American pop singer, actor, and artist.

background through an effort to meaningfully personalize CoM. T8's likely sensed that students would be interested in this pop icon; in addition, his pointing to a Black woman and emphasizing her as a high-income earner could be seen as doing foregrounding work by breaking certain stereotypes. At the same time, this recontextualization conceals the nature of income inequality and the actual outlying wealth holders, all of whom are white men, whose wealth vastly exceeds that of Beyonce's (by a factor of at least 250). Furthermore, this recontextualization sidesteps how African American musicians (like athletes) are front-facing in industries where owners and others derive most profits (Braddock et al., 2012). More broadly, the teachers in this study, nearly all of whom were White, rarely personalized CoM in terms of current events or public figures and did so only with African American basketball players or musicians.

A second example of a teacher personalizing CoM ostensibly for affective considerations amplifies the potential consequences of the mismatch between white teachers and their students:

> Mr. Guzman is a business man - he does business - he makes stuff happen. 'Nuff said, don't ask too many questions.... Let's say Mr Guzman received a signing bonus of \$5000 and then will charge \$250 per hour on top of that. Write a function that relates the total *dinero* he will earn to the total *horas* he works. (T12)

T12's designation of the surname Guzman, along with the insertion of some Spanish, seems to have been intended to signal a Latino actor, and "he makes stuff happen. 'Nuff said, don't ask too many questions…." conveys an associated stereotype about criminality. The translations of these two words to Spanish does not seem to have been intended to support students to access the problem's statement. Rather, we interpret this as a misguided attempt to connect with students using intended humor. This example shows how, under the guise of affective considerations, teachers can propagate pejorative stereotypes through CoM.

Outside of the pattern of personalization, there was scant evidence of engaging learners in creative interactions with instruments and materials, what Harouni (2015b, p. 63) calls "artisanal mathematics," an absence that is unsurprising given the current organization of public, US schooling. In one example that could be identified as artisanal mathematics, T6 tasked students with designing a model of a 9 in × 9 in floor-tile using smaller tiles and then scaling for a larger area. The design element added to the lesson's time demands and might be seen as distant from the lesson's mathematical goals. However, this component of the task perhaps invited learners to participate and enabled greater success with the intended learning about ratios. In a second example, T7 organized students to use various measuring equipment to use their own physical heights and angles of sight as a way to create similar triangles towards estimating unknown heights of landmarks outdoors. Both examples were based on garnering students' interest through creative participation with materials and tools.

4.3 CoM for functional literacy considerations

Forty-three segments (in 23 lessons from all 12 teachers) show evidence of CoM for functional literacy considerations, by demanding application of the targeted mathematics, and reveal ways that teachers view the applicability of mathematics for their students. In general, the CoMs offered students a limited set of designated identities, clustered around retail business: consumers in retail exchanges, salespersons (of electronics, cars, clothes), bank customers, or hourly wage employees (see Table 4). The implied decision-making criteria and relevant parameters were financial: to reduce individual costs, to compare salary plans, to project banking outcomes, and to maximize profits. Only two segments described decision-making of business owners (a box manufacturing company, car dealership), rather than consumers or salespeople. The goals remained maximizing profit, without invitation for critical analysis, for instance, of how any given industry impacts a community or the environment. These functional literacy segments propagate assumptions that financial choices should always and only be based on individualistic or capitalistic values. There were no mentions of invitations for other concerns, such as quality of life, community wellness, or environmental impact.

4.4 CoM for critical literacy considerations

Few CoM segments were organized around critical literacy (5 segments in 4 lessons from 2 teachers). Despite their rarity, they are worthy of analysis here because the contexts are so central to the problem-solving in this kind of CoM. These segments mostly were organized around race-based inequalities, yet, here too, teachers did not engage students' individual experiences with racism. In one example, T4 provided data with which to explore the fairness of the SAT,[7] with respect to race. Learners were assigned particular roles to play (e.g., spokesperson for a test-prep company, school administrator, anti-testing advocate). This feature of T4's recontextualization makes visible ways in which stakeholders—that is, various foregrounds—might make use of data and statistics to argue for competing conclusions. Uniquely expansive in its explicit offering of multiple designated identities, the task did not leverage or connect to students' prior knowledge; that is, so they could formulate, test, and refine hypotheses. We interpret T4's approach to critical literacy in this instance—of emphasizing the validity of multiple viewpoints—as a form of so-called "bothsidesism;" that is, a way to mitigate controversy by highlighting the validity of multiple, contrasting perspectives.

We share a second such example, of a value-neutral framing as part of CoM. T1 prompted students to "Argue either that *Stop and Frisk* unfairly targets Black and Hispanic or youth residents and does not affect crime OR that Stop and Frisk reduces crime and gets many illegal guns off the street" relative to a set of relevant data.[8] T1's intention was for students to use data and statistics either to challenge or affirm this policing practice. Yet Stop and Frisk practices are widely regarded to be unjust, in how they disproportionately impact Black youth, criminalize Black neighborhoods, and increase the danger of violence at the hands of police. T1's recontextualization, however, solely privileges the criteria of whether or not the policing practice reduces crime. Straddling an issue with purported neutrality appears to be a pathway for teachers to navigate what could feel to them like risky terrain (Mamolo & Pinto, 2015), but this maneuver is anything but neutral, a point to which we return below.

5 Discussion

Prior research identifies four primary rationales that support contextualizing mathematics as a pedagogical practice. The formative and affective rationales regard CoM as a way to encourage and support learning mathematics, whereas the functional and critical literacy perspectives

[7] The SAT (Scholastic Aptitude Test) is widely used in the US as a criteria for university admission.

[8] *Stop and Frisk* is a policing practice that consists of stopping and questioning pedestrians, leading often to full-body searches. Black and Latinx youth are most often those stopped (Kalhan, 2014). Himmelstein (2013) presents an example of a secondary mathematics lesson, whose purpose was to "emphasize the important roles of both qualitative and quantitative data, affirming students' experiences and mathematical analysis as two powerful tools to document racial distrcimnation in stop and frisks" (p. 124).

position mathematics as a necessary tool for solving essential everyday problems or for participating in social critique. CoM was very common in the observed lessons, often with formative, affective, and functional literacy underpinnings and critical literacy less frequent. The complexities identified by prior research that qualifies CoM's presumed affordances came to bear, and we organize this discussion relative to those complexities.

5.1 Pseudo-contexts and generic prior knowledge

The literature describes how school mathematics traditionally engages pseudo-contexts that detract from CoM's formative potential. In many cases, teachers selected familiar contexts but intended for learners to set aside prior experiences, rather than engage any lived knowledge. For example, T8 asked students how to choose "the better deal" between buying a box of 25 diapers for $7 or a case of 125 diapers for $35. T8 was drawing on students' abilities to compute unit prices to then formalize that process into a ratio table. Based on his experience as a pedestrian shopper, a student insisted on the box's preferability. Even though the unit prices are equivalent, this student argued, it would be easier to carry the box home. In other words, the student was considering practical considerations: carrying a box is easier than carrying a case for pedestrian shoppers. Because T8 had not anticipated this perspective, it momentarily derailed the lesson's goal and perhaps signalled to students that actual experiences are meant to be disregarded. The goal was finding equivalent unit rates, so broadening to include transportability might not have been feasible or desirable. This example is emblematic of how many CoM segments were personalized in terms of names and locations, but otherwise did not represent situations about which students could bring expertise. As cautioned in the literature, pseudo-contexts communicate a mismatch between mathematics and real-world problem-solving as well as between learners' lives and mathematics education.

CoM can function as an identity resource through the extent to which it reflects students' backgrounds. Our findings reveal a tendency towards drawing on backgrounds as generic human beings, rather than any particular backgrounds, confirming patterns in the literature. An interesting exception was CoM about movement through the local city, in terms of the transit system or street geography. At other times, as cautioned by Larnell et al. (2016), teachers demonstrated blind spots to race and racism through CoM by invoking racial stereotypes. In the few CoMs around social justice, teachers emphasized neutrality amidst contrasting interpretations, rather than eliciting and validating students' lived experiences or explicitly addressing the political implications of one stance over another. Inviting and welcoming opposing perspectives but only in relation to explicit issues of race and racism could communicate that anti-racism is a matter of personal opinion and that racist perspectives or policies are legitimate or condoned. Furthermore, if contrasting perspectives are highlighted only in relation to race and racism, this could support the illusion that otherwise, mathematics and the teaching of mathematics are apolitical.

5.2 Narrow foregrounds

A second significance of CoM is the way it contributes to the shaping of students' available foregrounds. Our findings reveal an emphasis on shopping, sales, banking, and employment situations, in agreement with critiques in the literature that mathematics education remains focused on consumerism (Bright, 2016; Harouni, 2015b). Many of the marketplace or leisure contexts that appeared in this study's collection of CoM, such as buying a car, reflected adult rather than youth contexts. At the same time, these adult-based contexts did not index activities of low-income adults in particular. Teachers perhaps included those contexts out of personal familiarity. An alternate explanation is that CoMs like these present objects and processes of middle class or affluent lifestyles and are thus being signalled as aspirational, as described by Bright (2016). While the CoMs emphasized consumerism that could be seen as aspirational for low-income youth, around buying lawnmowers, jet skis, and snowboards, the CoMs did not contribute complementary designated identities indexing professions with salaries that correspond to those purchases or lifestyles.

Goals fixated on maximizing profit or minimizing cost: there were no metrics of other values, such as community wellness, care for elders, public goods, environmental impact, or public health. It is reasonable that teachers seek to prepare their students for participation in current systems and realities. Mathematics education that emphasizes financial education or data literacy, absent critique of underlying systems, positions schooling as a mechanism by which students can secure their own footing in woefully unequal systems but without reimagining those systems. Presenting financial systems and resource distributions as inevitable and unmalleable, while overlooking the vast inequalities they create and reinscribe, obscures that mathematics education potentially holds liberatory purposes.

We are as interested in the silences in the CoM, in terms of what was *not* included. As Skovsmose (2005b) explains:

> A language (a discourse) operates like a fishing net. It determines what can and cannot be caught. It determines talk and silence. To understand the nature of a certain language it is important to understand the extent of the *silences in that language*. (Skovsmose, 2005b, p 99, italics in the original)

Absent in this collection of CoMs were designated identities such as scientists, mathematicians, social activists, entrepreneurs, doctors, clergy, chefs, government leaders, and more. Relational designated identities for people as friends, spouses, children, or parents were scarce. The limited number of situations beyond home or the marketplace is perhaps attributable to tensions for teachers around offering designated identities that might seem inaccessible to low-income youth. However, we concur with Skovsmose (2005a), who characterized a limiting of students' foregrounds as itself a "sociopolitical act," a "brutal form of a learning obstacle" (p. 7). Here, the narrow set of designated identities, as well as the tendency for CoM to focus on the generic, translate to limited resources for identity negotiation. One of the purposes of education is to expand students' lives: what they see; what they value; how they care for one another and our planet; how they live and work together; how they act upon feelings; changes that they will yearn for or demand; and even about what they dream. For the most part, our findings do not show CoM in support of such a vision for education.

5.3 Limitations of study

We risk that we may be perceived as criticizing teachers while not including their voices. Our intention here is to describe patterns in the kinds of identity resources provided through CoM and not attribute aspects of its practice to specific teachers. We acknowledge the US boundedness of this study and the likelihood of blind spots in our analysis as insiders in this regard. Finally, readers might note that the courses we observed are limited to introductory-level courses. We are interested in studying CoM in advanced secondary courses, but this study did not allow for that, since in most cases, these schools did not offer *any* courses beyond the introductory level. These introductory courses play a high-stakes role for students as a graduation requirement and increasingly for schools and teachers because of accountability metrics used to measure their effectiveness. This pressure likely plays a role for teachers in terms of a tendency towards the generic and taken-as-shared narratives sans examination, because after all, this is how standardized tests engage test-takers. The findings of this study illustrate additional constraining features of this school context.

6 Conclusions

Our findings confirm that teachers often contextualize mathematics with contexts that they create or select and then adapt. We need a deeper understanding of this practice. In addition, we need research that explores how CoM is taken up and negotiated by students as an identity resource. A potential response from some readers could be to avoid the many pitfalls we have pointed to here by abstaining from CoM altogether, but that route would circumvent its many potential benefits. Instead, we suggest exploring in teacher education how to better account for this practice, to support teacher reflection about: recontextualization practices (guided by the questions in Table 3), how to better leverage students' backgrounds using strategies from CRP, and how to be intentional about expanding possibilities for students' foregrounds. Viewing CoM as a classroom-based identity resource, future textbook designs might provide teachers with various kinds of flexibility to support adaptation of its CoM. In conclusion, our study sharpens the field's understanding of a common, but at times uninterrogated, practice. Findings clarify an additional dimension of the gatekeeping that happens in mathematics classrooms, through CoM that limits whose backgrounds are reflected and constricts vision towards possible foregrounds.

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