



Embodied mathematical pedagogy to liberate racialized and multilingual bodies

Shimeng Liu¹ · Miwa Aoki Takeuchi¹

Accepted: 18 September 2022 / Published online: 13 October 2022
© The Author(s), under exclusive licence to Springer Nature B.V. 2022

Abstract

When language is defined narrowly in mathematics classrooms, racially and linguistically minoritized students in classrooms could be systematically positioned as “learners of deficiency.” Recent scholarship calls for expanding the notion of language to emphasize embodied expression of mathematical ideas. Taking a critical perspective to understand racialized experiences of using languages in disciplinary learning spaces, this article proposes the reconceptualization of embodiment as a language for racialized multilingual learners. This study was conducted in a Grade 1 classroom in a linguistically and racially diverse school in Canada. Through a series of professional development sessions, we worked with an experienced teacher to redesign the normalized and institutionalized pedagogy toward greater mobility of racialized multilingual learners’ bodies, which was intertwined with their intellectual liberation. Focusing on the spatiality of pedagogy, the previously restrictive areas in the school were transformed into a place that augments embodied expression of mathematical ideas and agentive participation of minoritized learners. The analysis focused on the embodied discourse that participating racialized multilingual students used to actively engage in mathematical discussion. Our findings show that the designed pedagogy, characterized by the spatial and temporal expansion of the learning environment, offered more spaces for uncertainty and spontaneity with the decreased control of the teacher as an explicator. Our article furthers anti-colonial approaches to understand the intersection of racialized bodies and language in mathematics education.

Keywords Early mathematics learning · Embodiment · Discourse · Racialized multilingual learners

Mathematics pedagogy can be enacted spatially. From implicit pedagogy actualized as desk arrangements to normative bodily postures in the classroom, spatial configurations are salient parts of pedagogical contexts. Official policy, assessment, and curriculum in mathematics education have been shaped through the underlying white normativity and have largely ignored the voices of racially and linguistically minoritized people (Davis & Jett, 2019). Within this macro context, spatial configurations of classrooms could reinforce

✉ Shimeng Liu
shimeng.liu@ucalgary.ca

¹ Werklund School of Education, University of Calgary, Calgary, Alberta, Canada

racial and linguistic hegemony by normalizing bodily movements and behaviors that are (il)legitimate as expressions of mathematical competence (Gholson & Martin, 2019; Nasir & McKinney de Royston, 2013). Dominant gazes toward behaviors of minoritized students in school spaces could lead to policing, surveillance, removal, and even criminalization of racialized bodies (Love, 2014). For racialized multilingual learners, bodies are part of the language of mathematics, yet can be masked and become illegible under the dominant classroom spaces (Takeuchi & Dadkhahfard, 2019). In this article, we question the hegemonies inscribed in school spaces that influence how bodies of racialized multilinguals are seen, regulated, or liberated in institutionalized school settings. We aim to understand the spatial configuration in which these learners' multilingual identities come to the surface through embodied discourses.

In this article, we use the term *racialized multilingual learners* to emphasize the coupling of race and language. As Kayumova and Tippins (2021) showed, historically marginalized languages in racialized communities are seen as obstacles to be fixed in the school contexts, while the benefits of multilingualism are afforded to white children. Flores and Rosa (2015) urged us to gauge this coupling of race and language by examining language-minoritized peoples' racial positioning through interactions that mark their linguistic practices as being deviant from white, monolingual norms. Naming and categorizing learners can perpetuate ideologies around language and mathematics (Phakeng, 2016). Immigrant and refugee learners have often been categorized as "English language learners (ELLs)" in schools in the USA and Canada for their developing proficiency in the dominant instructional language. This labeling of ELLs has been questioned as it emphasizes the deficits of racialized multilingual learners. Therefore researchers have advocated for an alternative asset-oriented framing that could highlight learners' mathematical and scientific capabilities (Civil, 2014; González-Howard & Suárez, 2021). Efforts toward asset-oriented framing should not stop at the level of replacement of terms (e.g., from "ELLs" to "emergent bilinguals/multilinguals") but rather should aim for anti-colonial movements to challenge the structure of white, monolingual normativity and histories of oppression that created marginalization and deficiency of immigrant and refugee learners in the first place (Takeuchi et al., 2022). Therefore, we examine how the white monolingual gaze is embedded in the taken-for-granted classroom spatial configurations. We seek to understand how the pedagogical reconfiguration of school spaces can generate budding opportunities for racialized multilingual learners to move their bodies more freely and engage in mathematical discourses by mobilizing their bodies.

1 Literature review

The issue of language and mathematics learning has garnered attention internationally in the field of mathematics education (e.g., Barwell et al., 2019; de Araujo et al., 2018; Moschkovich, 2015; Planas & Civil, 2013). A review conducted by Radford and Barwell (2016) pointed out a relative scarcity of studies working to transform knowledge production in the classroom toward "an emancipatory critical pedagogical agenda" (p. 306) as an alternative to the institutionalized colonialization of underrepresented students. Previous studies on language and mathematics decentered learner deficiency by foregrounding political and social contexts that surround mathematical instructions. Planas and Gorgorió (2004) and Kazima (2007) pointed out that focusing exclusively on language fluency does not accurately reveal the challenges faced by racialized multilingual

learners in mathematics classrooms because they also encounter learning obstacles associated with their cultural practices and racial identities that are deemed irrelevant to in-school learning. Norén's (2015) study in an early mathematics classroom showed how the normalized pedagogy and its normalization process ignored or obliterated the agentic participation of multilingual students, but reform-based pedagogy facilitated the articulation of their voices and agency.

Mathematical instruction with racialized multilingual students should, therefore, be reconsidered by accounting for power that is reinforced or challenged. For example, teachers could reproduce the systematic positioning of racialized multilinguals as "learners of deficiency" through simplified mathematical instruction for them (de Araujo, 2017). Categorical and binary frameworks inscribed in taken-for-granted mathematics curricula could serve as a context for the inheritance and reproduction of existing labels that are attached to colonial representations of racialized multilingual learners' bodies (Takeuchi, 2021). Langer-Osuna et al. (2016) called for counter-narratives against the essentialist notions of multilingual learners' identities by renarrating experiences of their mathematical learning from agency-centered frames.

The mathematics performance, manifested through embodied discourses and examined on the site of pedagogical space, uncovers the microscale construction of identity and power (Chronaki, 2011; Darragh, 2015). Gholson and Martin (2019) conducted a phenomenological study of the bodily performance of a Black girl in a mathematics class to understand her lived experiences of resistance to structural, symbolic, and physical oppression. Focusing on embodied discourses conveyed through students' everyday performances of mathematical learning can offer an alternative space to ruminate on meanings of race, class, and gender (Gholson & Martin, 2019). Taken together, these studies suggest a compelling imperative to examine racialized multilingual learners' embodied learning on sites of mathematics pedagogy that are embedded in the power and reproduction of norms (Langer-Osuna et al., 2016; Norén, 2015). In the institutionalized teaching environment, teachers rarely recognize the importance of adapting to the diverse cultures of the student population and hence have low expectations of racialized multilingual learners (Valoyes-Chávez, 2019). It is thus critical to deconstruct the institutionalized discourse and practice in mathematics classrooms to open more possibilities for teaching and learning toward the embodied, emancipatory pedagogy.

Racialized multilingual students' bodies and their embodied discourses tend to be associated with deficiencies (Halai et al., 2016; Valoyes-Chávez & Martin, 2016). Examining the powerful effect of everyday schooling on learners' bodies and subjectivities, Andrade-Molina and Valero (2017) criticized the training process enabled by school geometry, through which students learn to regulate their own bodies and embodied discourses, so that they perceive the space as expected and wait to be shaped as the school and the society desired. Focusing on the minority Gypsy girls in a Greek context of education, Chronaki (2005) noticed the conflicts between the formation of disciplinary identity central to school arithmetic and racialized bodies and their habitual actions. In other words, the oppression of learning to behave perpetuated in the practice of school mathematics requires a significant change in racialized multilingual learners' bodily movements that are intrinsically entangled with their identities (Takeuchi & Dadkhahfard, 2019). Expanding the existing literature by positioning our study at the intersection of language and racialized bodies, we try to understand the bodies of racialized multilingual learners and their movements in the space of mathematics pedagogy, designing and imagining the embodied pedagogy as a site to liberate the bodies of those learners from the power of normalization.

2 Theoretical framework

2.1 Critical reconceptualization of embodiment

Our reconceptualization of embodiment in this study concerns the colonized discourse inscribed on the bodies of racialized multilingual learners in the context of pedagogical spaces. Embodiment discourses have amassed critical attention in mathematics education in recent years (Abrahamson & Sánchez-García, 2016; Hall & Nemirovsky, 2012; Hwang & Roth, 2011; Radford, 2009). This set of studies has taken constructivists' rejection of mental and physical division and offered insights about the intrinsic quality of sensorimotor activity to learning. Learners' bodies have come to be considered a valuable contributor to creating interactions between subject and environment, and perception and action toward mathematical understanding (Abrahamson & Sánchez-García, 2016; Hwang & Roth, 2011). However, this conceptualization of embodiment still largely ignores the power dynamics that play a significant role in shaping the interaction between body and learning environment (Luke, 1992) and could limit heterogeneous ways of being and mobility in mathematical thinking and learning. Foucault (1980) maintained that power "reaches into the very grain of individuals, touches their bodies and inserts itself into their actions and attitudes, their discourses, learning processes and everyday lives" (p. 39). In pedagogical spaces, power matters in how students' bodies are physically positioned, mobilized, or constrained through the configuration of classrooms and schools. There should be critical eyes toward the institutionalized pedagogy that overcontrols bodies of learners, especially racialized bodies under the guise of maximizing institutional regulation and pedagogical efficiency (Andrade-Molina & Valero, 2017; Chronaki, 2005; Luke, 1992).

In this sense, it is crucial to examine how practices and spatial-temporal configurations of pedagogy (Sheehy, 2004) construct or fabricate the cultural and historical subjects (Andrade-Molina & Valero, 2017) for racialized multilingual learners and how their bodies can be liberated on the site of mathematics learning. The term spatial-temporal configuration in this article refers to the space and time parameters of learning environments that have the potential to influence the affordance of distinct circulations of mathematics discourses and modes of bodily engagement in mathematics learning (Kelton & Ma, 2020), as the embodied cognition is oriented spatially (Lakoff & Johnson, 2008) and situated in time (Wilson, 2002). Emphasizing that knowing and being are inseparable (de Freitas & Sinclair, 2012; Valero et al., 2012), our reconceptualization of embodiment strives to explore the form of knowing and being entangled with spatial and temporal configurations of pedagogy that enable or hinder racialized multilingual learners "to effect by their own means [...] on their own bodies and souls [...] and way of being" (Foucault, 1988, p.18) in mathematics learning spaces.

However, Foucault's conceptualization of power and body was circumscribed within Western colonial perspectives. As Spivak (1988) critiqued, the Western discourse has long been exercising epistemic violence against non-Western bodies. Said's (1978) critique of Orientalism also extended to the Western gaze of othered bodies. Anti-colonial discourse calls for scrutinizing the lived experiences of racialized and colonized bodies in the field. This is where the Eurocentric narrative positions, regulates, and constitutes certain bodies as subjects or the other, as well as governs the rules of embodiment and formation of identities within the spatial and temporal affordance (Simmons & Sefa Dei, 2012). We pay attention to bodies from an anti-colonial perspective by attending to subtle embodied acts as a site of enacting ethics and care (Vossoughi et al., 2020) and also to how the liberation of subjugated bodies could disrupt normative mathematical representations (Takeuchi & Aquino Ishihara, 2021).

2.2 Norms, normalized pedagogy, and agency/liberation

Human agency is the site of “possibilities for (partial) liberation” (Holland et al., 1998, p. 5) from the forces of domination by social power dynamics. Critical theories understand individual agency and personal meaning making as a product of discourses and negotiations arising from power struggles with the environment and others (Foucault, 1977, 1980; Peters & Burbules, 2004). Through displaying power relations in discourses, critical theories resist the metanarrative of “norms” by creating spaces for new agentive participation and meanings. This study focuses on the subtle, yet significant moment-by-moment enactment of agency exercised by learners who have historically been subjected to racism and language-based exclusion and marginalization.

Taken-for-granted norms in pedagogy could potentially limit learners’ exercise of agency. Rancière (1991) problematized excessive explication that overemphasizes transmission of knowledge by a teacher to students. This explicatory instruction has an underlying rationale supportive of the hierarchy between teachers and students, which indefinitely defers the latter’s agentive participation. Rancière (1991) maintained that the teacher’s explicatory instruction could hinder what is conceptualized as intellectual liberation, where learners exercise agency to understand and solve problems that are unknown to them or to a teacher. For both teachers and students, human faculties of will power and intelligence are equally involved in the activity of learning, which was interpreted by Pelletier (2012) as: “there is no relationship between one’s intellect and one’s position in the social order” (p. 112).

The institutionalized and normalized pedagogy, where the teacher conveys knowledge exclusively through explication, could risk subjugating students’ understanding to that of a teacher. In this learning environment, the teacher’s intention also dominates the students’ agency. As a counterpoint to the pedagogy ruled by explicatory instruction, pedagogical practices oriented toward intellectual liberation practiced by the “ignorant teacher” (described by Rancière) could lead to redistribution of power, wherein a teacher–student relationship was relinquished from the institutionalized social order. Under such pedagogical interactions, the distinction between leaders and followers is no longer the result of uncriticized authority but of the “differentiated distribution of expertise” (Pelletier, 2012, p.109) gained through agentive participation over time. Seeing agentive participation of language-minoritized learners should include attention to their embodied expression of mathematical ideas (Norén & Andersson, 2016). Standing in the scholarly scarcity of the critical examination of racialized multilingual bodies in mathematics learning, we seek to understand how embodiment can be reconceptualized and designed as a site to liberate bodies that are typically monitored and controlled under normalized pedagogies and how such liberation is able to support racialized multilingual learners’ agency in engaging in mathematics discourses.

2.3 Research questions

This study focuses on racialized multilingual learners’ embodied and agentive participation in early mathematics learning in the classroom, where the teacher redesigned her use of school spaces for mathematics lessons. Through a series of professional development (PD) sessions that we organized with school leaders, an experienced teacher identified and redesigned the normalized and institutionalized pedagogy (including the taken-for-granted use of classroom spaces). Through our participatory observations, we addressed the following

research questions: (1) How can embodied mathematical pedagogy be redesigned as a site to liberate racialized multilingual students' bodies that are typically carefully monitored and controlled under the normalized pedagogy? and (2) How does the learning environment afforded by the designed pedagogy affect racialized multilingual learners' agency in engaging in mathematics discussion and thinking? We examined the embodied discourse and agency of racialized multilingual students in variations of spatial-temporal configurations from the normalized to the designed pedagogies.

3 Methodology

Framed within a design-based research methodology (Design-Based Research Collective, 2003), this study has the following methodological characteristics. First, the design of embodied mathematics lessons was guided by a critical theoretical orientation to the embodiment of racialized multilingual learners. Second, the new pedagogy was developed through (a) cycles of co-design between the teacher participant and the research team, (b) a classroom enactment, (c) a reflection during the teacher PD sessions, and (d) a refinement again between the teacher and researchers. Third, the purpose of the designed pedagogy was rooted in the participating teacher's hopes to understand the implications of redesigning the spatial configuration of classrooms, especially in racially and linguistically diverse classrooms.

3.1 Context

This study was conducted in an urban elementary school in Canada in an economically under-resourced neighborhood. In the year we collaborated for teacher PD sessions, the principal and the assistant principal started to develop a makerspace to foster "design thinking" in the school that included robotics and coding robots (including Ozobot). At the time of the study, reform of the provincial mathematics curriculum was discussed to include new outcomes such as "computational thinking." One of the designed activities was formulated with the teacher in this context of supporting students' design and computational thinking. Through the PD sessions, the research team and the school's assistant principal discussed various ways to maximize this makerspace in early mathematics learning. Our analysis focuses on data from the Grade 1 mathematics class of Ms. Johnson that was collected in the school year of 2018–19. Through our collaboration during the PD seminars, some lessons were co-designed with Ms. Johnson to mobilize students' bodies to facilitate their understanding of key mathematical concepts (such as the decimal system, number lines, and coding). Before the implementation of the designed pedagogy, we observed the instruction that was routinely practiced by Ms. Johnson to understand what was treated as normative in her mathematics class. For example, Ms. Johnson took 20–25 min daily, in a fixed corner area within the classroom, to teach arithmetic, with the lesson scripts similar in style and content from one day to another.

In conversations with us, Ms. Johnson developed lessons to mobilize students' bodies to interact with mathematics in spaces that were not usually viewed or allowed as sites of instruction (e.g., the school hallway). Similar to classrooms, the space of the school hallway was typically the site where regulation and control of student bodies happened constantly. The following are examples of the designed pedagogy that we highlight in the findings because of substantial differences demonstrated by these two lessons as compared to

Ms. Johnson's routinized mathematics instruction. In "counting floor tiles to 100," Grade 1 students created a number line up to 100 using a floor tile in the school hallway as a unit of counting. In "becoming Ozobots," Ms. Johnson used number lines and mapping. The students, who modeled robots, walked on a track taped on the classroom floor with color codes. On this taped route, students not only had to figure out the direction and distance of walking, but they also needed to understand the meaning of color codes and change their speed or direction according to the code. For both lessons, new learning spaces such as the school hallway and an unused area within the classroom were employed for young learners and their embodied discourses.

3.2 Participants

In the two designed lessons, there were seven racialized multilingual learners (Brody, Ethan, Rahul, Samir, Sharik, Sophia, and Trisha — all pseudonyms) identified by the school as "ELLs" according to their registration information. By focusing on these seven students, we tried to understand ways in which their racial and linguistic experiences would enrich their mathematical understanding. During in-class observations, we used interviews to understand their linguistic backgrounds and everyday mathematical experiences by asking questions such as: "what language do you speak at home?" "can you write in languages you use?" "how far is it from Canada to your home country?" "how long/how many hours is your flight from Canada to your home country?" and "do you know that there is a time difference and money difference between Canada and your home country?" These seven students represented both similarities and differences in their racialized and language experiences identified through our interviews.

Ms. Johnson played a significant role in this design-based study as a teacher partner. She is a veteran teacher with decades of experience in teaching elementary school students. She participated in this study because she believed that co-designing with us would allow her to reflect and challenge herself as a teacher. During our interview, she mentioned that her regular teaching practice was occasionally constrained by the school architecture — a building of no-wall classrooms centered around the library. It was originally built in the early 1970s and caused immense barriers (e.g., noise levels and constant disturbance) to teaching and learning until the walls between classrooms were partially restored.

3.3 Data collection and analysis

We conducted 14 visits to Ms. Johnson's class and collected approximately 19 h of video data. Video ethnography (Derry et al., 2010) was used to document in-class interactions and embodied discourses present in the normalized and designed pedagogies. We transcribed the video data using the format adapted from Ochs (1979) and uploaded the transcripts into the qualitative data analysis software *NVivo* for further analysis. Focusing on the embodied discourse surrounding the seven focal students, we winnowed the transcripts (Guest et al., 2012) and selected the two lessons ("counting floor tiles to 100" and "becoming Ozobots") for coding. In the process of coding, we used the combination of predetermined and emerging codes to stay focused on the research topics of interest and to capture the emerging information from participants (Creswell & Creswell, 2018). We read through the transcripts thoroughly and assigned codes ("learning environment afforded by the normalized pedagogy" and "learning environment afforded by redesign of spatial-temporal configuration"). At this stage, we

coded the data individually, and after the coding was completed, we discussed the differences until a consensus was reached. We then shifted our analytical attention from summarizing segments of data to generating emerging codes (“restrained bodily movement,” “liberated embodiment,” “student agency within spatial and temporal limits,” and “student agency within spatial and temporal expansion”), which are explanatory and inferential codes that can identify different characteristics in these two learning environments.

Our analysis was guided by our interest in examining the embodied discourse that the new learning environment afforded and in understanding the moments when our focal racialized multilingual students enacted their agency to have active participation in mathematics discourses. Their agentic participation suggests to us the *micro-politics* (Andersson & Wagner, 2018, p.194) to be liberated from the colonized submissive embodiment forced in histories of racism and the power of institutionalized school mathematics regime.

4 Findings

4.1 Characteristics of learning environment under the normalized pedagogy

The normalized pedagogy routinely used in this Grade 1 classroom was characterized by Ms. Johnson’s excessive monitoring of students’ body movements (e.g., to determine the proper body postures). Ms. Johnson was positioned at the center of the learning environment space (see Fig. 1), which seemed to reflect the social order in this classroom. Mobility within and out of this space was not allowed without approval. In this place, mathematical knowledge was accessible by reason and logic but cut off from bodies and senses (Andrade-Molina & Valero, 2017). The temporal pattern of what mathematical learning activities were included and how they unfolded was prescribed and recurrent. This normalized pedagogy started when Ms. Johnson had taken the central sphere of instruction (see Fig. 1), along with a student chosen to be the assistant standing beside her. Routinized activities, such as counting the distance between two numbers, identifying the date, singing calendar songs about days and months, and composing the number of days in school by hundreds, tens, and ones, were repeated daily.

4.1.1 Restrained bodily movement

The normalized pedagogy, with its spatial and temporal configurations, was characterized by teacherly control of bodily movements for young students, particularly the racialized multilingual learners who tended to be a target of subjugation. For example, Fig. 1 depicts



Fig. 1 Spatial representation of bodily engagement in the normalized pedagogy

what we observed typically in this normalized pedagogy. Ms. Johnson occupied a central position where she could monitor and regulate learners' bodies. In this interaction, a racialized student (in a striped shirt in the third picture from left to right) stood up from his designated place, walked out of the pedagogical space, and intended to take out a chair to change his seat. His movements were stopped immediately by Ms. Johnson who occupied the territorial authority of this space.

Within the closely monitored space, racialized bodies frequently became the subject of correction of movements, discipline, and "behavioral control." The ensuing dialogue in Excerpt 1 showed that the racialized multilingual students, Ethan and Rahul, were immediately called on to answer the question because they moved their bodies (Ethan's playful hands and Rahul's swaying torso in utterance 5 of Excerpt 1) in a way that was not allowed by the teacher. Ms. Johnson only asked for raising up fingers from students. In other words, the question asked by the teacher (the bolded sentences in utterance 5 of Excerpt 1) was to alert Ethan and Rahul to their unauthorized bodily movements.

Excerpt 1

1	Ms. Johnson	Ok. (<i>Zendaya, the student standing beside the teacher, held up a number card.</i>)	00:00:43
2	Students	Nine. (<i>They read the number card.</i>)	00:00:44
3	Ms. Johnson	And what number do we want? (<i>She indicated today's date.</i>)	00:00:47
4	Students	Thirteen. (<i>They checked out the number on the calendar.</i>)	00:00:48
5	Ms. Johnson	Thirteen. So, how far is it from nine to thirteen? Raise your fingers, show us how many fingers (<i>Some students raised their hands, showing their fingers. But Ethan extended his hand to a neighboring bookcase, playing with pencil and paper.</i>) Ethan, how far is it from nine to thirteen? (<i>Ethan stared at the calendar and raised his four fingers halfway to the height of his face, and cast his look at Zendaya.</i>) A lot of people are saying... (<i>turning to Rahul, who turned his head backward and sideward and stretched his upper body to catch a glimpse of the calendar.</i>) What do you think?	00:00:49
6	Rahul	Three.	00:01:07
7	Ms. Johnson	Three?	00:01:08

By and large, in the routine sessions characterized by the institutionalized and normalized pedagogy, students' body movements were constantly monitored by the teacher and also limited.

4.1.2 Student agency within spatial and temporal limits

In the fast-paced temporal flow set up in the normalized pedagogy, as reflected in the subsequent excerpts, the interaction between the teacher and the focal participants was completed rapidly — within a few seconds. Excerpt 2 showed that Ms. Johnson's question, Sophia's response, and Ms. Johnson's feedback were compressed within only seven seconds. Thomas's idea, as an extension of Sophia's answer, was not given time to clarify, develop, or even respond to, despite the evident error (the bolded sentence in utterance 6 of Excerpt 2). Under the teacher's lead, the students swiftly moved to interaction over another

topic. With the instructional focus on one right answer only, learners were limited from developing their reasoning.

Excerpt 2

1	Ms. Johnson	What is the equation? Grade one.	00:01:49
2	Students	<i>(Three students raised their hands, including Sophia.)</i>	00:01:49
3	Ms. Johnson	Sophia	00:01:50
4	Sophia	Nine plus four equals thirteen.	00:01:51
5	Ms. Johnson	Yes <i>(She thumbed up for Sophia.)</i> Good job.	00:01:56
6	Thomas	And four plus four equals eight and three plus three equals nine.	00:01:58
7	Ms. Johnson	Ok, ready? <i>(She moved to the next topic.)</i>	00:02:02

Besides being streamlined and tightened in the tempo, classroom discourses between the teacher and racialized multilingual learners also indicated that mathematical thinking was compressed to unidirectional acquirement at the expense of suppressing students' agency in participation. For example, in Excerpt 2, Thomas' utterance (# 6), which contained a mathematical error, was not taken up or discussed. However, when the student's utterance was correct, it was reinforced by the teacher. By looking at the following segment in Excerpt 3, we could see that, after Samir gave his answer to the question, Ms. Johnson asked the whole class to repeat Samir's response.

Excerpt 3

1	Students	How many days have we been in school? <i>(The student representative, Zendaya, pointed to the question posted on the wall and students read it.)</i>	00:03:35
2	Ms. Johnson	So, choose someone. <i>(Several students raised their hands quickly, and Ms. Johnson talked to Zendaya.)</i>	00:03:43
3	Zendaya	Samir.	00:03:44
4	Samir	A hundred and twenty.	00:03:46
5	Ms. Johnson	A hundred and twenty? Why do you say one hundred and twenty?	00:03:47
6	Samir	Yesterday was a hundred and nineteen, so today is a hundred and twenty.	00:03:55
7	Ms. Johnson	Ok. Did you hear what he said?	00:04:03
8	Students	Yes. One hundred and twenty.	00:04:04
9	Ms. Johnson	What did he say?	00:04:06
10	Ms. Johnson and Students	Yesterday was one hundred and nineteen, so today is one hundred and twenty. <i>(Students spoke after Ms. Johnson.)</i>	00:04:06

In this learning environment, the lesson scripts were mostly curated by the teacher and characterized by what Rancière (1991) termed as "explication." The teacher placed her prescribed pedagogy and intentions over learners' agency and exercised intellectual power structured in the hierarchized relationships.

4.2 Learning environment afforded by redesign of spatial–temporal configuration

With the redesign, mathematics lessons "counting floor tiles to 100" and "becoming Ozobots" were given more flexibility in spatial and temporal configurations. These configurations were new for both the students and the teacher. Therefore there was uncertainty and

spontaneity inherent in these contexts due to unfamiliar pedagogical intentions. For example, the “becoming Ozobots” session came to be centered around an emergent problem of a “traffic jam” observed during the lesson. There was also a process of deterritorialization whereby the local control held by the teacher was challenged and forfeited (Duncan, 1996). As shown in the following sections, the reconfigured instructional space occasioned more agency to racialized multilingual learners’ embodied discourses in mathematics learning.

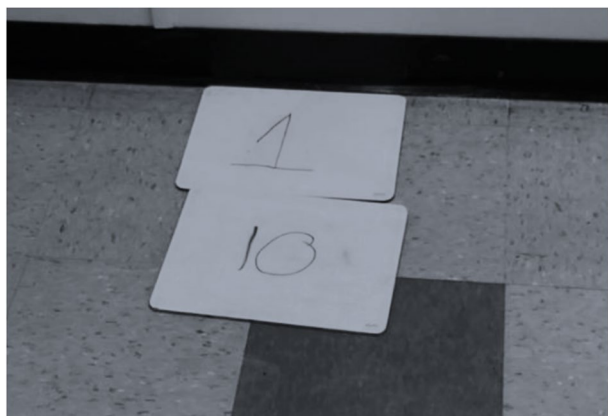
4.2.1 Liberated embodiment

The designed session called “counting floor tiles to 100” reconfigured the classroom space by extending it to the hallway, which is not usually viewed as an appropriate instructional site. In the warm-up activities, students were in groups reviewing various ways of counting to 100 introduced in previous classes. The students counted the number of floor tiles, wrote down corresponding numbers on the whiteboards, and put those on the hallway floors. Ms. Johnson refrained from giving her evaluation and feedback during the whole process of students counting in the hallway. In the group of Sharik and Emily, a conflict emerged regarding the sequential spacing of numbers. They brought their whiteboards and went to their start point in the hallway, deciding to resolve the problem by skip counting the tiles by tens. Emily put the number one on the first tile and placed the number ten right after number one as the second count (Fig. 2).

Our focal participant, Sharik, did not agree with Emily’s way of skip counting, so she explained her method to Emily using embodied discourse on the floor that considered the space between numbers rather than just the number itself.

As Fig. 3 shows, Sharik demonstrated her way of counting tiles to 100 with her whole body. It showed a chronological progression from left to right: she first took the number ten away from the number one and told Emily that the number ten should go to a different tile. Then she crawled on the floor, counting the distance between the numbers one and ten. After counting ten tiles on the floor, she looked back and confirmed the space between the tile number one and the tile number ten. The middle image shows the new placement of the number one and the number ten on the floor given by Sharik. By counting tiles by ones, she also determined the place for the numbers twenty (the fourth image) and thirty (the fifth image) and placed the numbers 20 and 30 by herself. By using embodied reasoning of skip

Fig. 2 The sequential spacing of numbers by Emily



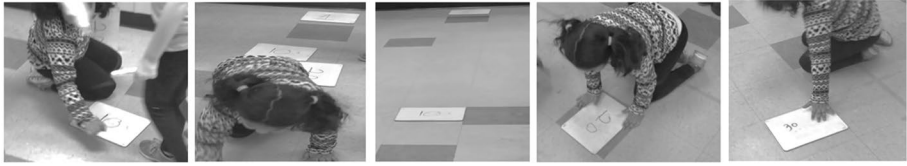


Fig. 3 Sharik's embodied discourse in the hallway



Fig. 4 Spatial representation of bodily engagement in “becoming Ozobots” session

counting by 10s and by utilizing the previously restricted space of the hallway, Sharik was able to demonstrate her emergent understanding of the decimal system.

The designed session called “becoming Ozobots” reconfigured the routine classroom space arrangement by relocating some of the desks and chairs and creating spaces for students to move around (see Fig. 4). The classroom floor was also used by adding tape with color codes, creating a space where students could learn by mobilizing as robots.

In this reconfigured classroom, Ms. Johnson stepped away from the central position of the instructional space, while students moved closer to the center of the classroom as a collective. Figure 4 illustrates that, while students were reading and walking on the coded tape like robots, Ms. Johnson stayed outside of their space, being a facilitator and observer rather than an explicator.

4.2.2 Student agency within spatial and temporal expansion

As mentioned in the above section, in the designed session called “counting floor tiles to 100,” the conflict between Emily and Sharik's ways of skip counting by tens occurred spontaneously. The interaction documented in Excerpt 4 showed that Ms. Johnson saw their disagreement but she did not explicate to teach as she would have done in the normalized pedagogy. Instead, she asked for clarification (the bolded line in utterance 4) and restrained from giving evaluation and feedback.

Excerpt 4

1	Sharik	No. (<i>She showed her disagreement with Emily on where to place numbers one and ten.</i>)	00:19:46
2	Emily	No, we are going this way. (<i>She pointed her hand to the left.</i>)	00:19:47

Excerpt 4

3	Sharik	(<i>She began to count the tiles by ones using her whole body.</i>) ...seven, eight, nine, ten. It goes here. (<i>Talking to Emily</i>)	00:20:09
4	Ms. Johnson	Is this what you mean? (<i>She handed the board of number ten to Sharik.</i>)	00:20:25
5	Sharik	(<i>She put the number board down where she sat on the floor.</i>)	00:20:25

Even though no clear instructions were given by the teacher, Sharik still demonstrated her reasoning with embodied discourse (utterance 5) in the space where students' bodily movements were not strictly monitored and regulated. Sharik's agency of reasoning a mathematical problem using her own way was not curbed — as in the moments with Ethan and Rahul in the normalized pedagogy.

More instances of racialized multilingual learners' agentic participation in mathematical thinking and discussion were observed in the session "becoming Ozobots." During the first attempt of becoming Ozobots, students faced the problem of getting stuck due to a lack of direction and dense bodily distribution. Ms. Johnson named the problem a "traffic jam" (Excerpt 6, utterance 1). To solve the problem, Ms. Johnson called on students to discuss it and its possible solution. She threw out the question, "What can we do to solve the problem?" Focusing on how the class approached the "traffic jam" problem and through the analysis of Excerpts 5, 6, 7, and 8, we have demonstrated how racialized multilingual learners (Sophia, Brody, and Sharik in the following excerpts) actively contributed to the discussion. In the end, Ms. Johnson affirmed students' suggestions (Excerpt 8, utterance 7) but did not evaluate their responses.

Excerpt 5

1	Ms. Johnson	What can we do to solve the problem? What should we try? Ok, what do you think, Sophia?	00:35:18
2	Sophia	Make more tape. We can do it right here (<i>pointing to the spot</i>) because... over here (<i>jumping to the spot</i>), we actually do a U-turn again.	00:35:25
3	Ms. Johnson	We got a problem here cause people are not listening. (<i>There were shouts from other students here and there trying to respond to Ms. Johnson's question and Sophia's reply. So, Ms. Johnson decided to call all the students together to have a discussion.</i>)	00:35:34

In Excerpt 5, Sophia implied that two U-turn codes produced a high concentration of "robots" (in this case, students) at some point and suggested increasing the volume of their path. But she did not name the problem verbally in English; instead, she moved to the site and represented her idea using gestures (utterance 2). Even Ms. Johnson did not know exactly what the problem and solution were before Sophia's utterance 2 (which could justify the lack of evaluation and response seen in this excerpt).

Ms. Johnson identified the problem as a traffic jam when she finished the first exchange with Sophia. Subsequently, in Excerpt 6, the teacher put the question to Brody, who responded with hand gestures. Spontaneity was reinforced when Brody ignored Ms. Johnson's urge not to use hand gestures and insisted on using embodied discourse and murmurs to express his thinking (all the "robots" needed to head forward and start off toward the same direction). Here, in Excerpt 6 (utterances 5, 7, 11, and 13), the teacher's uncertainty and absence of pre-set answers could be observed again. Ms. Johnson replaced the normally used clear-cut explications with a set of questions as the response to Brody's answer. It is noteworthy that the teacher's requirement ("No, do not do hand gestures" in utterance

3 of Excerpt 6) ran counter to the intention of designed lessons to allow more embodied discourses, despite her patience in deciphering Brody's "talking" through body (utterance 5, 7). This interaction shows that temporal reconfiguration of classroom spaces alone would not challenge taken-for-granted discourse on language nor normative gazes toward racialized multilingual learners.

Excerpt 6

1	Ms. Johnson	<i>(They returned to the carpet area and sat on it.)</i> So how can we solve the problem of traffic jam that was taking place here? It seems like it was really getting bunched up. <i>(Several students raised their hands)</i> Brody, what do you think?	00:36:38
2	Brody	<i>(He made a sound and "talked" using a hand gesture to point in a forward direction.)</i>	00:36:50
3	Ms. Johnson	No, do not do hand gestures. Use your words and use your voice that everyone can hear.	00:36:52
4	Brody	<i>(Being silent and moving his body back and forth.)</i>	00:36:57
5	Ms. Johnson	Turn the other way? How?	00:37:01
6	Brody	<i>(Keep being silent and point his figure again forward swiftly.)</i>	00:37:07
7	Ms. Johnson	How do we get everybody turned that way? What are you thinking about, Brody? Stand up and come here and describe what you think quickly, please	00:37:11
8	Brody	<i>(He moved slowly to the front and murmured to Ms. Johnson.)</i>	00:37:24
9	Ms. Johnson	Pardon?	00:37:31
10	Brody	<i>(He continued murmuring with the help of hand gestures.)</i>	00:37:32
11	Ms. Johnson	Oh, just, just go that way?	00:37:34
12	Brody	<i>(Nod his head in the agreement.)</i>	00:37:35
13	Ms. Johnson	And, then what? When we come to a code, then what? <i>(no response)</i> Not sure?	00:37:37

As we will see in Excerpt 7, Sharik caught and developed Brody's response from Excerpt 6 (i.e., everyone facing toward the same direction) further. She gave her answers both in words (Excerpt 7, utterance 2) and with her gestures. Different from interactions under the normalized explication pedagogy, the chain of thoughts was stretched across racialized multilingual learners (Brody's hand gesturing in the forward direction and Sharik's idea of organizing people in a line heading the same direction), rather than just between Ms. Johnson and one student (Ms. Johnson did not explicate the "right" answer).

Excerpt 7

1	Ms. Johnson	Sharik, what are you thinking? Come on up.	00:39:05
2	Sharik	We should make a line of the people. <i>(Stand up and come to the front.)</i>	00:39:11
3	Ms. Johnson	Make a line of the people, and not everybody starts from their own spot? But everybody follows one another?	00:39:14
4	Sharik	<i>(She explained her idea by walking on the tape, pointing her feet to the spots where people should stand in a line.)</i>	00:39:23

The extended chain of thoughts in this interactions, afforded by the temporal lengthening, allowed racialized multilingual learners to express and extend their ideas. After Sophia was given another chance to restate her initial idea, as represented in Excerpt 5, she demonstrated the capability to deepen it with more details on her own without the teacher's

explication (as seen in Excerpt 8). Building an alternative route to distribute the load of traffic started to generate a collective solution for the traffic jam problem. This series of discussions allowed the Grade 1 students to create a map that could avoid traffic jams (by adding routes in important places or changing the codes on the road).

Excerpt 8

1	Ms. Johnson	What are you thinking, Sophia?	00:40:11
2	Sophia	We could put tape right here (<i>walking to the spot she meant</i>), right here.	00:40:13
3	Ms. Johnson	And where would it go? Where would you put the tape? Oh, straight through this side?	00:40:22
4	Sophia	Yea. (<i>She walked from one side of the tape to another side.</i>)	00:40:29
5	Ms. Johnson	So, there is an alternative route? So how would the robot know to turn there?	00:40:31
6	Sophia	<i>(She shrugged her shoulder and did not answer.)</i>	00:40:36
7	Ms. Johnson	How would the robot know whether to turn or whether to go straight through? (<i>No response</i>) Not sure, think about it some more because you guys got some great ideas. We just need to know how to put them into place. (<i>To test out their solution to the traffic jam problem, Ms. Johnson asked the students to walk on the route again in a way that everyone started off toward the same direction in a line as suggested by Brody and Sharik. It worked out!</i>)	00:40:38

Within these four excerpts (Excerpts 5–8), these racialized multilingual learners actively contributed to collective problem solving through embodied discourses. Sophia’s preliminary understanding of their problem became the foundation for the teacher’s identification of the exact issue (i.e., a traffic jam). Brody picked up Sophia’s answer later but could not put his thinking into words. Sharik gave her answers both in words and bodily representations. Sophia eventually refined her earlier responses by coming up with a more clarified response.

A short discussion between the teacher and students at the end of the “becoming Ozobots” lesson showed a moment of intellectual liberation afforded by the designed pedagogy. The discussion was an exchange of views about the differences between robots and humans. Ms. Johnson asked the question, “What is the difference between Ozobot and you?” Sophia put forward the idea that the Ozobot had to behave under the control of codes. Trisha believed that the robot possessed more eyes than a person, and her response sparked the curiosity and interest of her peers. However, Ms. Johnson did not voice any comments to evaluate Sophia’s and Trisha’s contributions. Instead, she quietly nodded. Following this exchange, other students, Sharik and Samir, also voiced their observations on the differences between humans and robots (e.g., “We have a head, and they do not.”). The interaction ended with a comment made by Trisha, another racialized multilingual student, who stated that “we have a brain, and they do not.” After carefully listening to the students’ discussion, Ms. Johnson asked a new question: “how do they (Ozobots) know what to do (if they do not have a brain)?” Trisha responded, “they have memory cards,” while another student said, “they know by reading the meaning of codes.” Without further explication, Ms. Johnson concluded the discussion with an appreciation (“Good job, thank you.”) of students’ agentive participation.

As seen in these instances, the designed pedagogy offered opportunities in which the teacher’s *explication* had to step out, and students’ *agency* was brought forth (Rancière, 1991). Temporal extension in the designed sessions was observed in the intervals between the teacher’s utterance and student utterances as well as in the teacher’s holding back of feedback to students. Mathematical thinking and discussion involving racialized

multilingual learners evolved into an iterative adaptation within the learning community that shared a common problem for which neither the teacher nor students had a preset solution. In contrast to the normalized pedagogy, it flowed into a decentralized collective (Towers et al., 2013) because of the reduced control of the teacher as an explicator.

5 Discussion and conclusion

In contrast to the institutionalized and normalized pedagogy, the redesign of spatial–temporal configurations of the classroom mobilized the bodies of racialized multilingual learners more and encouraged their use of embodied discourses that fostered agentive participation in mathematical discussion. We demonstrated how this redesign afforded the decentralized position of the teacher. Spatial and temporal expansions allowed freer bodily movements and agency in mathematics learning for our focal participants. In the “becoming Ozobots” lesson, these students led the in-class discussion with their initiatives, including suggestions for how to distribute the traffic load and how to regulate the traffic users by reprogramming codes. In this process, racialized multilingual learners’ contributions were recognized by the teacher. In contrast to the normalized and institutionalized pedagogy, in the designed sessions, strictly regulated spatial–temporal configurations of classes and restricted movements of minoritized bodies came closer to liberation. The findings presented in this article suggest the pedagogical possibilities of liberating learner bodies that could lead to embracing relevant questions posed by learners and the chain of thoughts among learners (e.g., the differences between robots and humans, as presented in our findings). In the school and curricular settings, such liberation could open up more spaces for making sense of mathematics and modeling, rooted in students’ heterogeneous lived experiences (Roseberry et al., 2010; Sengupta et al., 2021).

Our findings also show that the racialized multilingual learners’ agency in the mathematics classroom was fluid and constantly shaped and reshaped through the affordance of the learning environment, which is connected to the power dynamics between the teacher and students on sites of social interactions. In a normative pedagogy that treats mathematical knowledge as antecedent reality (Dewey, 1984), symbols conveyed in the dominant instructional language and their use in mathematical thinking become the important criteria of the teacher’s evaluation. Under such normative pedagogical contexts, the perception of deficiency in racialized multilingual learners can be reinforced because of their seemingly limited agentive participation in learning and discussion. Redesigning spatial–temporal configurations of the classroom could enhance mathematics learning experiences for racialized multilingual learners due to its openness to involving embodied discourse as a mathematical language. In this way, mathematics learning could become more meaningful and authentic to racialized multilingual learners who could contribute to nurturing their confidence, interest, and identity in mathematics (Lambert et al., 2022; Leonard et al., 2010; Young et al., 2021).

This study adds to the ongoing discussion on equity in mathematics education focusing on racialized bodies (e.g., Gutiérrez & Dixon-Román, 2010; Nasir & Hand, 2008; Philip et al., 2016) and to the discussion on racialized multilingual learners’ participation in mathematics learning (e.g., de Araujo et al., 2018; Domínguez, 2011; Fernandes et al., 2017; Langer-Osuna et al., 2016; Ng, 2016; Norén, 2015; Takeuchi, 2021; Warren & Miller, 2013). Building on anticolonial lenses toward othered

bodies (Said, 1978; Spivak, 1988), this study advances a critical reconceptualization of embodiment, in which pedagogy could be a site for learners' bodies to be liberated from the monitored and controlled white monolingual gazes and physical regulations imposed in mathematical learning spaces.

Our study aims to deepen this critical reconceptualization of embodiment by showing how redesigned spatial–temporal configurations in school spaces could lead to intellectual and bodily liberation of racialized multilingual students and expand their agency for mathematics learning manifested in the chain of interactions. The taken-for-granted and normalized pedagogy for the sake of pedagogical efficacy could perpetuate flawed perception and institutional control over bodies for racialized multilingual learners. We acknowledge the limitations in this study, including the limited time (1 year) in our collaborations with the school due to the COVID-19 pandemic. We also acknowledge that our study was with one teacher and two Grade 1 classes that she taught and did not fully describe the school-wide changes in spatial–temporal configurations of pedagogy. Despite the limitations, we hope that our work could invite further studies and discussions on spatial–temporal aspects of pedagogy from an anti-colonial lens of embodiment toward equity for racialized multilingual learners in early mathematics education.

Acknowledgements We are grateful to the teacher and all the student participants for collaborating on this study. We give thanks for the contributions made by our team members — Venise Bryan, Shima Dadkhahfard, and Jenny Yuen — in assisting with the data collection and professional development sessions. We also appreciate the expertise, detailed constructive critiques, and equity-oriented commitment to the field shared by Dr. David Wagner and anonymous reviewers in the production process of our manuscript.

Funding This study was supported by the Social Sciences and Humanities Research Council of Canada under grant # 435–2020-0134 and the University of Calgary URG Seed Grant. Any opinions, findings, and conclusions expressed herein are our own and do not necessarily reflect the views of the funding agency. Both authors contributed to data collection, analysis, and writing collaboratively and equitably.

Declarations

Consent for publication This work has not been published previously. It is not under consideration for publication elsewhere, and its publication is approved by the responsible authorities where the work was carried out. If accepted, it will not be published elsewhere in the same form, in any language, including electronically, without the written consent of the copyright holder.

Competing interests The authors declare no competing interests.

References

- Abrahamson, D., & Sánchez-García, R. (2016). Learning is moving in new ways: The ecological dynamics of mathematics education. *Journal of the Learning Sciences, 25*(2), 203–239. <https://doi.org/10.1080/1058406.2016.1143370>
- Andersson, A., & Wagner, D. (2018). The micro-politics of counting. In T. G. Bartell (Ed.), *Toward equity and social justice in mathematics education* (pp. 191–209). Springer. https://doi.org/10.1007/978-3-319-92907-1_12
- Andrade-Molina, M., & Valero, P. (2017). The effects of school geometry in the shaping of a desired child. In H. Straehler-Pohl, N. Bohlmann, & A. Pais (Eds.), *The disorder of mathematics education* (pp. 251–270). Springer. https://doi.org/10.1007/978-3-319-34006-7_15
- Barwell, R., Wessel, L., & Parra, A. (2019). Language diversity and mathematics education: New developments. *Research in Mathematics Education, 21*(2), 113–118. <https://doi.org/10.1080/14794802.2019.1638824>

- Chronaki, A. (2005). Learning about 'learning identities' in the school arithmetic practice: The experience of two young minority Gypsy girls in the Greek context of education. *European Journal of Psychology of Education*, 20(1), 61–74. <https://doi.org/10.1007/BF03173211>
- Chronaki, A. (2011). "Troubling" essentialist identities: Performative mathematics and the politics of possibility. In M. Kontopodis, D. Wulf, & B. Fichtner (Eds.), *Children, development and education* (pp. 207–226). Springer. https://doi.org/10.1007/978-94-007-0243-1_13
- Civil, M. (2014). Musings around participation in the mathematics classroom. *The Mathematics Educator*, 23(2), 3–22. <https://openjournals.libs.uga.edu/tme/article/view/1737>
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.
- Darragh, L. (2015). Recognising 'good at mathematics': Using a performative lens for identity. *Mathematics Education Research Journal*, 27(1), 83–102. <https://doi.org/10.1007/s13394-014-0120-0>
- Davis, J., & Jett, C. C. (Eds.). (2019). *Critical race theory in mathematics education*. Routledge. <https://doi.org/10.4324/9781315121192>
- de Araujo, Z. (2017). Connections between secondary mathematics teachers' beliefs and their selection of tasks for English language learners. *Curriculum Inquiry*, 47(4), 363–389. <https://doi.org/10.1080/03626784.2017.1368351>
- de Araujo, Z., Roberts, S. A., Willey, C., & Zahner, W. (2018). English learners in K–12 mathematics education: A review of the literature. *Review of Educational Research*, 88(6), 879–919. <https://doi.org/10.3102/0034654318798093>
- de Freitas, E., & Sinclair, N. (2012). Diagram, gesture, agency: Theorizing embodiment in the mathematics classroom. *Educational Studies in Mathematics*, 80(1), 133–152. <https://doi.org/10.1007/s10649-011-9364-8>
- Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Hall, R., Koschmann, T., Lemke, J. L., Sherin, M. G., & Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences*, 19(1), 3–53. <https://doi.org/10.1080/1058400903452884>
- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5–8. <https://doi.org/10.3102/0013189X032001005>
- Dewey, J. (1984). *The later works of John Dewey 1929: The quest for certainty*. Southern Illinois University Press.
- Domínguez, H. (2011). Using what matters to students in bilingual mathematics problems. *Educational Studies in Mathematics*, 76(3), 305–328. <https://doi.org/10.1007/s10649-010-9284-z>
- Duncan, N. (1996). Renegotiating gender and sexuality in public and private spaces. In N. Duncan (Ed.), *BodySpace* (pp. 135–152). Routledge. <https://doi.org/10.4324/9780203974070-17>
- Fernandes, A., Kahn, L. H., & Civil, M. (2017). A closer look at bilingual students' use of multimodality in the context of an area comparison problem from a large-scale assessment. *Educational Studies in Mathematics*, 95(3), 263–282. <https://doi.org/10.1007/s10649-017-9748-5>
- Flores, N., & Rosa, J. (2015). Undoing appropriateness: Raciolinguistic ideologies and language diversity in education. *Harvard Educational Review*, 85(2), 149–171. <https://doi.org/10.17763/0017-8055.85.2.149>
- Foucault, M. (1977). *Discipline and punish: The birth of the person* (A. Sheridan, Trans.). Penguin. (Original work published 1975).
- Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings 1972–1977* (C. Gordon et al., Trans.). Pantheon.
- Foucault, M. (1988). Technologies of the self. In L. H. Martin, H. Gutman, & P. H. Hutton (Eds.), *Technologies of the self* (pp. 16–49). University of Massachusetts Press.
- Gholson, M. L., & Martin, D. B. (2019). Blackgirl face: Racialized and gendered performativity in mathematical contexts. *ZDM-Mathematics Education*, 51(3), 391–404. <https://doi.org/10.1007/s11858-019-01051-x>
- González-Howard, M., & Suárez, E. (2021). Retiring the term English language learners: Moving toward linguistic justice through asset-oriented framing. *Journal of Research in Science Teaching*, 58(5), 749–752. <https://doi.org/10.1002/tea.21684>
- Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied thematic analysis*. Sage. <https://doi.org/10.4135/9781483384436>
- Gutiérrez, R., & Dixon-Román, E. (2010). Beyond gap gazing: How can thinking about education comprehensively help us (re)envision mathematics education? In B. Atweh, M. Graven, W. Secada, & P. Valero (Eds.), *Mapping equity and quality in mathematics education* (pp. 21–34). Springer. https://doi.org/10.1007/978-90-481-9803-0_2

- Halai, A., Muzaffar, I., & Valero, P. (2016). Research rationalities and the construction of the deficient multilingual mathematics learner. In R. Barwell, P. Clarkson, A. Halai, M. Kazima, J. Moschkovich, N. Planas, M. Setati-Phakeng, P. Valero, M. Villavicencio, & Ubillús (Eds.), *Mathematics education and language diversity: The 21st ICMI study* (pp. 279–295). Springer. https://doi.org/10.1007/978-3-319-14511-2_15
- Hall, R., & Nemirovsky, R. (2012). Introduction to the special issue: Modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences*, 21(2), 207–215. <https://doi.org/10.1080/10508406.2011.611447>
- Holland, D., Lachicotte, W., Jr., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Harvard University Press.
- Hwang, S., & Roth, W. M. (2011). *Scientific and mathematical bodies: The interface of culture and mind*. Sense. <https://doi.org/10.1007/978-94-6091-567-3>
- Kayumova, S., & Tippins, D. J. (2021). The quest for sustainable futures: Designing transformative learning spaces with multilingual Black, Brown, and Latinx young people through critical response-ability. *Cultural Studies of Science Education*, 16(3), 821–839. <https://doi.org/10.1007/s11422-021-10030-2>
- Kazima, M. (2007). Malawian students' meanings for probability vocabulary. *Educational Studies in Mathematics*, 64(2), 169–189. <https://doi.org/10.1007/s10649-006-9032-6>
- Kelton, M. L., & Ma, J. Y. (2020). Assembling a torus: Family mobilities in an immersive mathematics exhibition. *Cognition and Instruction*, 38(3), 318–347. <https://doi.org/10.1080/07370008.2020.1725013>
- Lakoff, G., & Johnson, M. (2008). *Metaphors we live by*. University of Chicago press.
- Lambert, R., Hernández-Saca, D., Mireles-Ríos, R., & Monroy Castro, M. (2022). “It is like a feeling”: Theorizing emotion in mathematics through complex embodiment. *Mathematics*, 10(6), 937. <https://doi.org/10.3390/math10060937>
- Langer-Osuna, J. M., Moschkovich, J., Norén, E., Powell, A. B., & Vazquez, S. (2016). Student agency and counter-narratives in diverse multilingual mathematics classrooms: Challenging deficit perspectives. In R. Barwell, P. Clarkson, A. Halai, M. Kazima, J. Moschkovich, N. Planas, M. Setati-Phakeng, P. Valero, M. Villavicencio, & Ubillús (Eds.), *Mathematics education and language diversity: The 21st ICMI study* (pp. 163–173). Springer. https://doi.org/10.1007/978-3-319-14511-2_9
- Leonard, J., Brooks, W., Barnes-Johnson, J., & Berry, R. Q., III. (2010). The nuances and complexities of teaching mathematics for cultural relevance and social justice. *Journal of Teacher Education*, 61(3), 261–270. <https://doi.org/10.1177/0022487109359927>
- Love, B. L. (2014). “I see Trayvon Martin”: What teachers can learn from the tragic death of a young Black male. *The Urban Review*, 46(2), 292–306. <https://doi.org/10.1007/s11256-013-0260-7>
- Luke, A. (1992). The body literate: Discourse and inscription in early literacy training. *Linguistics and Education*, 4(1), 107–129. [https://doi.org/10.1016/0898-5898\(92\)90021-N](https://doi.org/10.1016/0898-5898(92)90021-N)
- Moschkovich, J. N. (2015). Academic literacy in mathematics for English learners. *The Journal of Mathematical Behavior*, 40, 43–62. <https://doi.org/10.1016/j.jmathb.2015.01.005>
- Nasir, N. S., & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *The Journal of the Learning Sciences*, 17(2), 143–179. <https://doi.org/10.1080/10508400801986108>
- Nasir, N. S., & McKinney de Royston, M. (2013). Power, identity, and mathematical practices outside and inside school. *Journal for Research in Mathematics Education*, 44(1), 264–287. <https://doi.org/10.5951/jresmetheduc.44.1.0264>
- Ng, O. L. (2016). The interplay between language, gestures, dragging and diagrams in bilingual learners' mathematical communications. *Educational Studies in Mathematics*, 91(3), 307–326. <https://doi.org/10.1007/s10649-015-9652-9>
- Norén, E. (2015). Agency and positioning in a multilingual mathematics classroom. *Educational Studies in Mathematics*, 89(2), 167–184. <https://doi.org/10.1007/s10649-015-9603-5>
- Norén, E., & Andersson, A. (2016). Multilingual students' agency in mathematics classrooms. In A. Halai & P. Clarkson (Eds.), *Teaching and learning mathematics in multilingual classrooms* (pp. 109–124). Sense. https://doi.org/10.1007/978-94-6300-229-5_8
- Ochs, E. (1979). Transcription as theory. *Developmental Pragmatics*, 10(1), 43–72.
- Pelletier, C. (2012). No time or place for universal teaching: *The ignorant schoolmaster* and contemporary work on pedagogy. In J. P. Deranty & A. Ross (Eds.), *Jacques Rancière and the contemporary scene* (pp. 99–116). Continuum.
- Peters, M., & Burbules, N. C. (2004). *Poststructuralism and educational research*. Rowman & Littlefield.

- Phakeng, M. S. (2016). Mathematics education and language diversity. In A. Halai & P. Clarkson (Eds.), *Teaching and learning mathematics in multilingual classrooms* (pp. 11–23). Brill Sense. https://doi.org/10.1007/978-94-6300-229-5_2
- Philip, T. M., Olivares-Pasillas, M. C., & Rocha, J. (2016). Becoming racially literate about data and data-literate about race: Data visualizations in the classroom as a site of racial-ideological micro-contestations. *Cognition and Instruction, 34*(4), 361–388. <https://doi.org/10.1080/07370008.2016.1210418>
- Planas, N., & Civil, M. (2013). Language-as-resource and language-as-political: Tensions in the bilingual mathematics classroom. *Mathematics Education Research Journal, 25*(3), 361–378. <https://doi.org/10.1007/s13394-013-0075-6>
- Planas, N., & Gorgorió, N. (2004). Are different students expected to learn norms differently in the mathematics classroom? *Mathematics Education Research Journal, 16*(1), 19–40. <https://doi.org/10.1007/BF03217389>
- Radford, L. (2009). Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics, 70*(2), 111–126. <https://doi.org/10.1007/s10649-008-9127-3>
- Radford, L., & Barwell, R. (2016). Language in mathematics education research. In Á. Gutiérrez, G. C. Leder, & P. Boero (Eds.), *The second handbook of research on the psychology of mathematics education* (pp. 275–313). Sense. https://doi.org/10.1007/978-94-6300-561-6_8
- Rancière, J. (1991). *The ignorant schoolmaster*. Stanford University Press.
- Rosebery, A. S., Ogonowski, M., DiSchino, M., & Warren, B. (2010). “The coat traps all your body heat”: Heterogeneity as fundamental to learning. *The Journal of the Learning Sciences, 19*(3), 322–357. <https://doi.org/10.1080/10508406.2010.491752>
- Said, E. W. (1978). *Orientalism*. Pantheon Books.
- Sengupta, P., Dickes, A., & Farris, A. V. (2021). *Voicing code in STEM: A dialogical imagination*. MIT Press. <https://doi.org/10.7551/mitpress/11668.001.0001>
- Sheehy, M. (2004). Between a thick and a thin place: Changing literacy practices. In K. M. Leander & M. Sheehy (Eds.), *Spatializing literacy research and practice* (pp. 91–114). Peter Lang.
- Simmons, M., & Sefa Dei, G. J. (2012). Reframing anti-colonial theory for the diasporic context. *Post-colonial Directions in Education, 1*(1), 67–99.
- Spivak, G. C. (1988). Can the subaltern speak? In C. Nelson & L. Grossberg (Eds.), *Marxism and the interpretation of culture* (pp. 271–313). Macmillan. https://doi.org/10.1007/978-1-349-19059-1_20
- Takeuchi, M. A. (2021). Geopolitical configuration of identities and learning: Othering through the institutionalized categorization of “English language learners.” *Cognition and Instruction, 39*(1), 85–112. <https://doi.org/10.1080/07370008.2020.1825438>
- Takeuchi, M. A., & Aquino Ishihara, V. (2021). Learning to assemble the hidden bodies: Embodied and emplaced mathematical literacy in transnational migrant activism. *Journal of the Learning Sciences, 30*(1), 103–124. <https://doi.org/10.1080/10508406.2020.1820341>
- Takeuchi, M. A., & Dadkhahfard, S. (2019). Rethinking bodies of learners through STEM education. In P. Sengupta, M. Shanahan, & B. Kim (Eds.), *Critical, transdisciplinary and embodied approaches in STEM education* (pp. 199–216). Springer. https://doi.org/10.1007/978-3-030-29489-2_11
- Takeuchi, M. A., Kayumova, S., de Araujo, Z., & Madkins, T. C. (2022). Going beyond #RetireELL: A call for anti-colonial approaches to languages in STEM education. *Journal of Research in Science Teaching, 59*(5), 876–879. <https://doi.org/10.1002/tea.21764>
- Towers, J., Martin, L. C., & Heater, B. (2013). Teaching and learning mathematics in the collective. *The Journal of Mathematical Behavior, 32*(3), 424–433. <https://doi.org/10.1016/j.jmathb.2013.04.005>
- Valero, P., García, G., Camelo, F., Mancera, G., & Romero, J. (2012). Mathematics education and the dignity of being. *Pythagoras, 33*(2), 1–9. <https://doi.org/10.4102/pythagoras.v33i2.171>
- Valoyes-Chávez, L. (2019). On the making of a new mathematics teacher: Professional development, subjectivation, and resistance to change. *Educational Studies in Mathematics, 100*(2), 177–191. <https://doi.org/10.1007/s10649-018-9869-5>
- Valoyes-Chávez, L., & Martin, D. B. (2016). Exploring racism inside and outside the mathematics classroom in two different contexts: Colombia and USA. *Intercultural Education, 27*(4), 363–376. <https://doi.org/10.1080/14675986.2015.1106135>
- Vossoughi, S., Jackson, A., Chen, S., Roldan, W., & Escudé, M. (2020). Embodied pathways and ethical trails: Studying learning in and through relational histories. *Journal of the Learning Sciences, 29*(2), 183–223. <https://doi.org/10.1080/10508406.2019.1693380>
- Warren, E., & Miller, J. (2013). Young Australian Indigenous students’ effective engagement in mathematics: The role of language, patterns, and structure. *Mathematics Education Research Journal, 25*(1), 151–171. <https://doi.org/10.1007/s13394-013-0068-5>

- Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4), 625–636. <https://doi.org/10.3758/BF03196322>
- Young, J., Cunningham, J., Ortiz, N., Frank, T., Hamilton, C., & Mitchell, T. (2021). Mathematics dispositions and the mathematics learning outcomes of black students: How are they related? *Investigations in Mathematics Learning*, 13(2), 77–90. <https://doi.org/10.1080/19477503.2020.1845537>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.