Critical envisioning of embodiment in mathematics teaching

Miwa A. Takeuchi, University of Calgary, ✉ miwa.takeuchi@ucalgary.ca
Shima Dadkhahfard, University of Calgary

A body of scholarship on embodied mathematics learning has demonstrated the process of mathematics learning that is inseparable from learner bodies. Thus far, the scholarship on embodied mathematics learning has made limited connections with the critical conceptual-ization of embodiment that allows us to see the history and power behind mathematization of bodies. How can teacher candidates come to see embodiment in mathematics learning through critical lenses? In this study, we consider the possibility of utilizing digital illustrated stories based on ethnographic findings on (im)migrant families' intergenerational embodied mathe-matics learning. We present preliminary findings to illuminate how teacher candidates' discourses became heterogenous when they made meaning of the details in the designed illustrated story.

Toward critical conceptualization of embodiment

In mathematics education, there has been a body of work that highlighted mathematical thinking and body in light of gesture production, bodily coordination and mobility (e.g., Abrahamson & Sánchez-García, 2016; Alibali & Nathan, 2012; Chronaki, 2019; Hall & Nemirovsky, 2012; Hwang & Roth, 2011; Lee, 2015; Ma, 2017; Nemirovsky et al., 1998). Episte-mologies and ontologies supporting this body of embodiment literatures in mathematics education range; for instance, ecological dynamics (as seen in Abrahamson & Sánchez-García, 2016), material phenomenology (as seen in Hwang & Roth, 2011), and distributed cognition (as seen in Ma, 2017). de Freitas and Sinclair (2013) drew from new materialism to emphasize assemblages of diverse materialities and learner bodies. Scholarship on embodied mathematics learning altogether has demonstrated the process of mathematics learning that is inseparable from learner bodies.

In a slightly different vein of scholarship, learner body was considered in relation to the development of culturally specific forms and functions as seem in an Indigenous numerical system observed among Oksapmin children and youth in Papua New Guinea in Saxe's (2012) study. Historical and longitudinal accounts of the Oksapmin people's 27-body-part counting system illuminate how the counting system has been reproduced and altered along with the shift in political, economic, and educational macro systems in Papua New Guinea (Saxe, 2012).

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We seek to further advance this line of research by shedding light on how certain bodies are forced to be *hidden* in the public space of learning, how the mobilities of certain bodies can be restricted or liberated, and how such negotiation of bodies interact with the stories and histories of the learner. In the study focused on (im)migrant families' embodied multiplication algorithm (Takeuchi, 2018), both children and mothers were hiding this algorithm because it differed significantly from the mainstream norm. They were hiding what was passed on intergenerationally, through which they conformed themselves into the mainstream. Thus far, the scholarship on embodied mathematics learning has made limited connections with the critical conceptualization of body or embodiment. However, critical conceptualization of embodiment is crucial in seeing the history, power and politics behind mathematization of bodies (Takeuchi & Dadkhahfard, 2019; Takeuchi & Aquino Ishihara, 2021). In considering norms and hiddenness, we conceptualize body guided by queer theory (Ahmed, 2006; Butler, 1993, 2015) that brings forth the tangled relationships among body, norms and power. *Othered* bodies or *unintelligible* bodies that deviate from the norm can be tacitly excluded from materialization and be treated as *abject* (Butler, 1993) — that is masked and hidden. Power is exercised over non-normative bodies through materialization and abjection of bodies. Such othered and unintelligible bodies can become less extended and less mobile in social space and when such bodies are constrained in their mobility, they turn to "the body that is 'out of place'" (Ahmed, 2006, p. 140). Resistance to this exclusion can be actualized by making visible the hidden bodies as a performative act, as proposed by Butler (2015): "bodies in their plurality lay claim to the public, find and produce the public through seizing and reconfiguring the matter of material environments" (p. 71). In the following section, we discuss the possibility of digital illustrated stories as a potential tool to make the invisible visible and queer the normative mathematics teaching practices.

The possibility of digital illustrated stories to make the invisible visible

The use of an alternative medium of research communication has been discussed in relation to its power for displacing and disrupting colonizing knowledge-making practices (Kayumova et al., 2018). Researchers have employed various forms of artistic renderings to communicate theory with the general public as seen in digital storytelling (Lambert, 2013) and graphic novels and comics (Curnow & Vea, 2020). Our goals of utilizing digital illustrated stories are aligned with such collective efforts to evoke the power of artistic renderings for public communication — in the context of this study, public communication of theory with teacher candidates. Toward this goal, we utilized visual art in the form of research-informed illustrated story. In our project we focused on interrogating dominant narratives and deficit perspectives with teacher candidates by centralizing the unseen story and silenced voices of historically marginalized groups. Our project holds a similar vision discussed in Chronaki's (2019) study where creative choreography was used with teacher candidates to enact and reconstruct their pedagogical moment of teaching (or not teaching) the concept of area to children in the early years. Chronaki (2019) proposes "an affective bodying with concepts" (p. 329) as a reconstructive pedagogy of early mathematics education. In our study, we

explore if the visual medium of graphic design in the form of designed illustrated story could offer unique affordances to facilitate experiences and dialogues on equity and learning with teacher candidates.

Methodology

Our study was carried out in the three interrelated phases. We designed the illustrated story in Phase II, based on the findings of Phase I. We then used the designed illustrated story in Phase III in the context of teacher education.

Phase I: Ethnographic study on embodied mathematics in an (im)migrant community

A year-long ethnographic study was conducted on in-school and out-of-school mathematics learning for Filipino (im)migrant community in an urban city of Japan that is increasingly becoming linguistically and ethnically diverse. In preparation for Phase II, we identified key themes from the analysis of the following data: 1) semi-structured interviews with 12 Filipina women who were living and raising children in Japan, 2) semi-structured interviews with nine elementary school-aged children. Filipina women in this study came to work in Japan and the majority (10 of 12 participants) stayed in Japan after marrying Japanese men. At the time of study, Filipino was one of the major and the fastest growing ethnic groups in Japan. Since the late 1970s, Filipina women have been coming to Japan to fill the bride shortage in farm village areas, to work as entertainers in urban cities, and, more recently, to work as nurses, caregivers and English language teachers and tutors. All of the Filipina mothers interviewed said that they were from a big family of lower socioeconomic status and that financially supporting their family was their main motivation for coming to Japan. Parental involvement in children's school learning was reported as limited, partially because Filipina women in this study felt they did not know the curriculum and pedagogy in Japanese schools. The immigration policy of Japan grants citizenship by parentage: children who are born into a family of a Japanese father or a Japanese mother are granted citizenship. Some of the child participants did not meet these criteria for citizenship and therefore were unsure whether they would continue to be granted for their residency. Because of this context, we use the term, "(im)migrant" community to refer to our research participants in Phase I.

Phase II: Designing a digital illustrated story.

The goal of this phase was to design an illustrated story based on the analyses of ethnographic observation data and interview data carried out in Phase I. Both authors repeatedly discussed the storylines and images based on our analyses and we decided to visualize a story of two migrant children (May and Ryan, pseudonyms) whose parents taught non-dominant method of mathematics (i.e., finger multiplication method depicted in Takeuchi, 2018). The theme of the story reflects key findings from Phase I about how May and Ryan experienced learning of multiplication differently at home and in school. The illustrated story showcases how these migrant students had to hide what was taught at school in fear of the teacher's gaze and their mothers' instruction not to share the finger multiplication method at school.

We decided to create an open-ended illustrated story to invite participants' storytelling and collectively created the stories that continue after the last frame illustrated. We also decided to create an illustrated story with no text in order to communicate with young learners from diverse linguistic backgrounds in our future projects. Author 2 (Shima Dadkhahfard) who has a background in both graphic design and picture book illustration used her skills to digitally illustrate the story. The design of the digital illustrated story was carried out in iterative cycles by attending to the feedback shared by the participants.

Phase III: Using the designed illustrated story

We used the illustrated story designed in Phase II in a teacher education course and facilitated the conversation about mathematics teaching, equity, and power. The Phase III of the study was conducted in a teacher education program located in a city in Canada. All the teacher candidates were recruited from a Year 1 teacher education course and they were specialized in early childhood education and in elementary school education. All the teacher candidates were English language speakers and were born and raised in Canada. A total of 22 teacher candidates participated in the study and five of them were racialized teacher candidates. Written responses were collected during in-class activity and follow-up interviews were conducted with five teacher candidates. Each interview lasted approximately 90 minutes. Interviews elicited how teacher candidates interpreted the illustrated story and whether and how they connected or did not connect with the story (as a teacher candidate or as a student). They were also asked to discuss mathematics pedagogy depicted in the illustrated story in relation to their future teaching. During the interview, teacher candidates sketched and drew images of how they would continue the story. All the interviews were audio- and video-recorded and to ensure anonymity of teacher candidates, video did not capture faces their participants (video was mostly used to capture gestures and drawings). Soon after each interview, we have written detailed field notes and interview data was fully transcribed.

Analysis

We first analysed how the participants interpreted the illustrated story and the amount of detail they paid attention to in the illustrations. In particular, we examined whether the participants attended to the illustrated differences and marginalization in classroom mathematics learning for the students and families depicted in the story (e.g., a parent is instructing the child not to share the finger multiplication strategy at school). We used this analysis to gauge how the participants attached value to the use of body parts in mathematics classrooms. We draw from Bakhtin's (1981) notion of "authoritative discourse and an internally persuasive discourse" (p. 342). Bakhtin depicts authoritative discourse as "the word of the fathers" (p. 342) that is *a prior* discourse demanding to bind and obey. It is a form of discourse that does not merge with others and remains "sharply demarcated, compact and inert" (p. 343). In contrast, internally persuasive discourse is "half-ours and half-someone else's" (p. 345). It is not finite and open to "ever newer ways to mean" (p. 346), and to be

unfolded through its contact with other voices. Authoritative discourse and internally persuasive discourse are not dichotomous; dialectical struggles between them characterize the process of our ideological becoming. In our analysis, we examined whether and how the voices of a teacher, as a student, and as a character depicted in the story, came to be in contact with each other. In doing so, we gauge the interactions between authoritative discourse and internally persuasive discourse that is more heterogeneous (Rosebery et al., 2010) and open with the possibilities for new meanings.

This paper's central focus is on how the teacher candidate participants made sense of the illustrated story that was designed based on a study on (im)migrant families' use of finger multiplication algorithm at home and at school. In this paper, we examine discourses around embodiment in mathematics classrooms in relation to the participants' interpretations of the illustrated story and their described relationships with mathematics.

Results

Authoritative discourse on embodiment in mathematics teaching

Authoritative discourse — a prior discourse that remains demarcated and solid —treated any method that involves body parts as something to be discouraged or replaced in mathematics classrooms. Such discourse was not questioned or challenged by some participants even when they engaged in meaning-making around details in the illustrated story. For example, the authoritative discourse manifested in the following quote from Alissa's interview that was constructed mostly from the standpoint of a teacher. It positions what parents taught at home with fingers (that was depicted in the illustrated story) as something to be "deconstructed" or replaced with an online resource widely used in the local school board for in-school mathematics learning. In this discourse, the finger multiplication method was predetermined to be devalued as a wrong method. The topics of emphasized parts of the following quotes are about finger multiplication method taught at home.

> I think it's very clear, like, in students when they're getting that support at home, um, in compared to when they're not. […] if you're able to supply them with the right resources (…) So for example, with math, right, um, if the parent... *for this child who's, like, being taught the wrong answer, but like, on your fingers, then giving them something like Mathletics Program,* right? That'll teach them correct methods, it'll give them lots of practice. So, I think *giving them the right resources to kind of deconstruct their teaching methods, their parent's teaching methods.*

Similar discourse was observed in Betty's interview, although it is expressed in a more nuanced manner. Instead of prohibiting the use of finger or replacing it without understanding it (as expressed by Alissa), Betty emphasized the importance of understanding why students were using their fingers. But as a teacher, Betty would teach her students that "there is more than just the fingers" by introducing other approaches. The following quote from the interview shows another instance of authoritative discourse expressed from the standpoint of teacher.

> *I think I would ask them why they think the fingers are right first.* 'Cause kind of seeing, like, where they are at, like, in terms of their understanding is really important, 'cause kind of determines how you can help them moving forward and then demonstrating, like, through other activities how they could approach the solution. So, giving them, like, a more hands-on approach and showing them, like, okay, like, let's take these blocks and group them in nine groups of seven and then we can keep telling them, like (...) kind of count and see, like, what the answer is *so that they know, like, there's more than just the fingers.*

The teacher candidates' interpretation of the illustrated story was mainly from the perspective of the future teacher and did not interact with perspectives as a student or as migrant student characters depicted in the illustrated story. Authoritative discourse was reproduced around the norms on the use of body parts for classroom mathematics learning.

Differences in participants' meaning making of the details in the illustration

For the cases where we observed authoritative discourse, we realized the lack of details in the illustrated story that the participants interpreted. In contrast, heterogenous discourse was observed when the participants engaged in making-meanings around details in the illustrated story. The details the participants paid attention to (or did not pay attention to) are summarized as follows: 1) the spatial set-up of the classroom (e.g., individual worksheet, the teacher standing in front of students, memorization of multiplication facts), 2) differences among students (e.g., colour, lines separating main characters from the rest), 3) inter-generational teaching of the finger multiplication method, and 4) the gesture of shushing by a parent and the gesture of hiding by the child.

For example, some participants made meanings of diversity and differences by paying attention to different colours allocated to main characters and their homes (that made contrast with other characters). The following quotes represents how colour schemes helped Carol to make meaning of the diversity and differences.

> I understand that the color makes them different (...) It seems that their lives are way more colorful, like, they (...) I guess now that I understand, like, the cultural aspect, like, *they're coming from different countries, they're bringing so much more, because their homes are colorful, like, their mothers have so much color. Like, they're bringing much more than just themselves.*

Figure 1: A frame from the designed illustrated story (illustration by Dadkhahfard).

Another detail in the illustrated story that was interpreted in Dana's interview was the bubble that represents the tradition of the finger method of multiplication. As she pointed out the bubble showing the tradition of the finger method in the illustrated story, Dana said, "this is a reference to the girl when she was younger. So, it must mean her mom taught it to her like that as well, so it's kind of like the traditional aspect of it." There was another layer of detail in the illustrated story that engaged Emma in a heterogenous conversation around the gesture of shushing. The following quote from Emma's interview shows how she interpreted the gesture of shushing by a parent of the main character as counting on the fingers is not acceptable at school.

> It's kind of interesting to me about the *mom shushing her here*. So, it's obviously *a pretty known thing that they don't like to count on their fingers*. Yeah, trying to tell the kid not to show them, I guess. Yeah, the *school doesn't like it.*

In the following section, we examine how interpreting and making meanings of these details in the illustrated story engaged participants in heterogenous discourse.

Heterogenous discourse to challenge the norm

Heterogenous discourse was identified when the participants engaged in interpreting and making meaning of the illustrated story not only from the standpoint of a teacher but also speaking as a student, as a girl, as the character that merged with speaking as a teacher. Carol started her conversation by stating that, "first and foremost I feel like my experience as a woman and like specially math, is like girls are not great at math and so I always had that idea that I was not good at math." She then shared her own story when she was a student at high school. She explained how she was discouraged by her high school teacher in the mathematics classroom:

> I had that experience, I would even count on my fingers doing, like, math in high school, and some high school teachers would be, like, "What are you doing? Like, that's so, like, childish. Like, you should have passed that." But sometimes it's nice to, like, physically, like, understand what you're doing.

The following quote in Carol's interview is heterogeneous in the sense that the standpoint is not merely of a teacher but also of a student. Such discourse helped challenge and disrupt normative practices in mathematics classrooms for some of the teacher candidates. Reflecting on how the negative experiences *as a student* who was ashamed of the use of fingers, Carol said:

> I think, when you've been discouraged yourself, you kind of want to, like, combat those, like (...) Yeah. And don't let some student to feel discouraged because they got the right answer, but they did it in the wrong way, because I don't feel like there's a wrong way. So, yeah, I guess just, like, building confidence in students is super important, and so, that's what I want to do. (laughs)

This quote was spoken from her standpoint as a teacher but also spoken from the standpoint as a student who used to be discouraged in using body parts in mathematics classrooms.

Such heterogenous discourse was similarly observed in Dana's interview. From *the perspective of the characters* in the illustrated story, Dana explained the important role of teacher in understanding the background and history of students and their parents in the following quote:

> I feel like if she [the teacher in the illustrated story] was able to understand where she [the student in the illustrated story] is coming from, or where her parents are coming from, she [the teacher in the illustrated story] could validate their learning by saying, 'yes, this is how you do it. As long as you have a skill and you can apply it, should be fine.

Dana's use of deixis (Hanks, 2009) indicates how she was using the illustrated story and thinking with the characters. Similar to Carol, Dana questioned normative mathematics classroom practices that could lead to students' shame of using body parts. She suggested an alternative, "it's important to allow students to represent their understanding in more than one way" as she envisioned her future teaching.

Discussion

In our study, the illustrated story was developed as a medium to evoke conversations with teachers, teacher candidates and K-12 students around the norms in mathematics classrooms and the power of such norms that could constrain equitable access to mathematics learning. In this paper, we discussed both the possibilities and limitations in facilitating the teacher candidate participants' ways of interrogating the normative practices in mathematics classrooms, through the designed illustrated story. In the teacher candidates' discourse, what Bakhtin (1981) termed as authoritative discourse was manifested, a voice of an authoritative teacher who perpetuates the norm around body and mathematics learning. At the same time, when the participants made meaning of details in the illustration, the discourses came to be heteroglossia that "represents the co-existence of socio-ideological contradictions" (p. 291) and helped the participants to question normative practices in mathematics classrooms.

Our preliminary findings call for advancing critical conceptualization of embodiment in mathematics education, that could bring forth the intertwined relationships among body, norms and power (Ahmed, 2006; Butler, 1993). The participants in this study, even when they questioned the norm, did not explicitly address the issue of race, body and power in mathematics learning. This limitation could be partially due to the fact that our illustration did not make visible race and racism. We are currently in the process of redesigning the illustrated story to evoke conversations on the relationships among race, body, norms and power in mathematics education, with a wide range of audiences including teachers, teacher candidates and parents and children.

Overall, in the context of teacher education, this paper adds to the body of scholarship in embodiment and mathematics learning by illuminating the possibilities of using the research-informed illustrated story for interrogating the norms around body in mathematics classrooms, in the context of teacher education.

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