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What Counts? Play as a Mechanism for Disrupting Participation Patterns in School Mathematics

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Abstract: This paper explores how making space for mathematical play can disrupt existing participation structures in classrooms and create space for inclusive and robust mathematical engagement. We analyze one episode of children's play that involved counting and unitizing to measure a rocket created with Magna-Tiles, addressing two research questions: 1) How does children's collaboration during a playful activity contribute to mathematical activity? 2) How did one child (Quentin), who is often removed from mathematics, participate in this activity? Our findings reveal how the collective interactions that led to this moment involved Quentin's sustained engagement, which was outside the norm for him. Quentin was a full participant in the counting and unitizing episode and his thinking had status and was valued by others. This episode points to the possibilities of play as a transformative space that affords creates opportunities to engage in mathematics in ways that disrupt patterns of exclusion.

Introduction

The goal of this paper is to explore how making space for mathematical play can disrupt existing participation structures in classrooms and create space for inclusive and robust mathematical engagement. We situate this analysis in a collective moment of mathematical joy and rigor, which involved four playmates engaging in rich mathematical thinking. We examine how this moment emerged, and specifically, how the act of play—of exploring and sharing materials, and of posing one's own question for inquiry—contributed to this moment. To understand both the final moment and the trajectories of play that contributed to its development, we draw on literature about humanizing mathematics, about disrupting structural racism that leads to alienating participation practices, and about the potential of play for transforming engagement.

The focal moment occurred approximately one month into the school year, during a period of free play in a kindergarten classroom. The four students in analysis, Laura, Briona, Max, and Quentin, chose to play with Magna-Tiles, transparent 2-D shapes with magnets along the sides that can be joined. Throughout the episode, the children played both independently and together. However, one creation received the most attention and the most resources a tall "rocketship" built by Laura that required many magna tiles. About 10 minutes into their free play, taking a pause from his own creation, Max turned the group's attention towards Laura's rocket. What initially began as a single student's reaction to the grandeur of Laura's creation eventually evolved into a mathematically rich conversation involving all four students, as seen in the transcript below.

1	Max:	Dude, this is a tall, it's a tall building! *(Looks at rocket and smiles).*
2	Briona:	It's a toy rocket! *(Walks around K, touches top of rocket, and smiles. Returns to seat).*
3	Max:	Wait so it has levels? *(Gestures at rocket).* The building has levels. One, two, three, four, five, six, seven. *(Points to each level of rocket for each counted number, then pauses).* Eight. *(Points to roof).* Eight levels! This thing has eight levels! *(Looks at Quentin and gestures towards rocket while smiling).*
4	Briona:	It's eight levels cause it's a hotel. *(Looks at rocket).*
5	Quentin:	One, two, three, four, five, six, seven. *(Touches each level of rocket, excluding roof, for each counted number).* Seven levels! *(Looks at Max).*
6	Max:	I thought it was eight levels. *(Looks at Quentin).*
7	Briona:	You're counting too much. *(Walks around Laura to rocket).* One, two, three, four, five, six, seven, eight. *(Touches each level of rocket, including roof, for each counted number).*
8	Laura:	No that's the roof. *(Touches roof).* There's no layer to the roof. *(Turns to face other students).*
9	Briona:	The roof don't count. *(Looks down at table).*

This moment was significant for several reasons. First was the *collective engagement*—all four students were involved in this conversation, exchanging ideas and taking turns, as seen in turns 3, 4, 5, 6, and 7. Second was the *mathematical content* of the students' discussion: counting that demonstrated one-to-one correspondence (turns 3, 5, and 7); and debating about minimally defining characteristics of a set (turns 8 and 9). Third was the fact that this occurred *independently and spontaneously*, as no adult was present, and the students were never asked to count (their only task was to play). And finally, was the *absolute joy* that was evident amongst the group. The students were smiling, laughing, and generally celebrating the eye-catching creation of their peer. It was a moment of mathematical joy, mathematical rigor, and legitimate mathematical inquiry.

This episode is also an instance of *disruption* of established participation practices in the classroom. In this class, math instruction typically involves working on prescribed tasks that are highly structured, with little space for spontaneous decision making. Thus, free mathematical play served to disrupt the typical practices around what it means to do math. Equally importantly, these different mathematical practices resulted in very different forms of participation for the students. Max, who is often quiet and hesitant to share what he knows, was talkative, engaged, and initiated the mathematical inquiry in the episode (turn 3). Quentin, who is frequently excused from the mathematical work of the class because his behavior is seen as disruptive, was engaged, collaborative, and offered his own mathematical expertise as a legitimate contribution to the group's discussion. In what follows, we consider how this spontaneous moment developed between the four students, and how it served to disrupt existing structures of what it means to do math, and who gets to participate in the activity.

Literature review and framing

Although play is acknowledged to be a crucial aspect of general well-being (Brown, 2009; Gray, 2011), and an important mechanism for learning (Vygotsky, 1967), it is also often dismissed as non-essential and is quickly removed as a consequence for bad behavior or to bolster instructional time (Chang & Coward, 2015; Jarrett et al., 1998; Massey et al., 2021). Consequently, play is becoming increasingly scarce in classrooms, even for the youngest kindergarten students. Although this is a problem for any subject, we argue that play in mathematics classrooms is particularly important to consider, as the discipline is often introduced in prescriptive ways that primarily focus on computation (Wager & Parks, 2014). This creates a challenge when supporting learning, for while prescriptive and streamlined activities are an efficient solution to the task of moving large numbers of students through many topics, it does not support students to develop robust number sense. Further, the practices that such approaches to teaching mathematics require, such as a focus on efficiency, speed, and memorization, are known to undermine students' enjoyment and deep understanding (Boaler, 2002; Boaler & Staples, 2008). In contrast, classrooms that offer time for exploration, that emphasize reasoning and understanding over accuracy and speed, and which place student identity at the center of instructional design, have been found to support a more productive relationship with the domain of mathematics (Grant et al., 2015; Gresalfi, 2009).

The mathematician Francis Su describes his own vision for mathematical engagement as follows: "I hope that…you can see yourself as a *mathematical explorer*, who can think in mathematical ways and who is welcome in mathematical spaces" (2020, p. 12). As Su and others explain, "expert" engagement with mathematics involves exploration, play, aesthetical judgement, and joy (Bergen, 2009)—terms that are not commonly associated with school mathematics. However, when students are invited to engage with mathematics in this way, they have opportunities to reason about the why of mathematics, to engage in the "call-and-response" of mathematics, when "…the mathematics calls out to the explorer and asks, 'What do you notice? What do you wonder?' and the explorer responds with an observation" (Su, p. 54).

Play not only offers the potential to disrupt mathematical practices, but it also can serve to disrupt who gets seen as mathematically capable. Many scholars have argued that mathematics classrooms are sites of white supremacy, offering narrow conceptions of what counts as mathematical excellence (Ladson-Billings, 1998), recognizing only some kinds of thinking and people as mathematically relevant (Joseph et al., 2017), and conflating mathematical aptitude with overall intelligence (Martin, 2019). While these practices interfere with students' likelihood of engaging with rich mathematics in general, they are particularly problematic for students of color, who are more likely to have less-qualified teachers (DeMonte & Hanna, 2014), to be removed from school by suspension (Gregory & Roberts, 2017), and to face stereotyped low expectations for their mathematical success (McGee & Martin, 2011; Nasir & Shah, 2011).

Analytic framework

This paper connects with the concept of play in two ways. In addition to grounding our analysis in studies of the potential efficacy of play, as described above, we also use the concept of play as an analytic framework to explore the potential of play as a productive practice. Specifically, we explore whether and how play offers a potential inroad to the question posed by Martin: "What can and should refusal of dehumanizing and violent mathematics education look like in principle and practice?" (2019, p. 461). This is also responsive to the proposal made by Joseph et al., (2019), who wrote: "A second area for further research is the idea of humanizing Black girls by creating a space for play—a place for them to be happy, gregarious, social, and "goofy" …. Our emerging analysis illuminates that when the Black girls in this study were afforded the opportunity to be both serious and silly, they were more engaged in mathematics learning" (pp. 149). However, before making the fundamental error of romanticizing children's activity, we note that play is not a panacea—it characterizes a form of human interaction that is fraught with the same perils, biases, and oppression that characterizes all interactions (Bryan, 2020). We know that children's play can be racist, mean, gendered, and exclusionary. Although it has the potential to liberate students from the conventions of the discipline, it by no means transcends the everyday structures that dictate our interactions. Therefore, even as we look for sites of potential disruption, we must stay vigilant at noticing the ways it might fail, lest we contribute to the continued reproduction of mathematics reform that ultimately serves to change nothing for students who are already being oppressed by its structures (Martin, 2019)

Although there is variation among the definitions of play, most involve characterizations of spontaneity, interest, choice, and pleasure (Brown, 2009; Burghardt, 2010). This is not to say that play is divorced from rules or constraints—part of what makes play enjoyable is the opportunity to explore in relation to a set of existing structures (Ginsburg, 2006). In this work, we define play as pleasurable activities where children can explore, engage with interesting materials and make choices. We use this understanding of play to explore how and why young children constructed their own rich mathematical engagement, and how, in doing so, they managed to include all members of their group in reaching a conclusion. We look at students' interest, their agency, their mathematical reasoning, and their emotions, to better understand whether and how situating mathematics in the context of play was ultimately productive for the group. In so doing, we ask the following questions:

1) How does children's collaboration during a playful activity contribute to discussions about the rocket?
2) How did one child, who is often removed from mathematics, participate in this activity?

To address these questions, we analyzed each student's specific contributions, both leading up to and during this episode, and how play afforded their collective mathematical engagement towards Laura's rocket.

Methods

Participants and context

This episode comes from the fourth day of co-designed "play lessons," which focused on the properties of shapes, part of a larger study about how early-grades teachers integrate play into their mathematics teaching. The teacher, Ms. Rosinsky, co-designed lessons that included whole-class introductions and reflections but predominantly centered on guided play centers, in which students engaged with playful mathematical materials. At the end of the lesson children were invited to choose a table and play with mathematical toys—no other instructions were given. Children played at these free play stations for approximately 15 minutes.

The four students in analysis, Laura, Briona, Max, and, Quentin, chose to play with Magna-Tiles. Laura is a white girl who was typically quiet but attentive in mathematics lessons. Brionna is a Black girl who generally worked independently, particularly during center work. Max is a Latino boy who was often reserved but engaged during mathematics activities. Quentin is a Black boy who was often called out for not paying attention or for disrupting his peers. In general, Quentin often spent time during math lessons at the back table, rather than sitting on the rug with the rest of the class engaging with the lessons. For example, in the activity before the free play episode, the children were participating in guided math centers. At his table, in response to other children who were making loud noises, Quentin started to yell, "QUIET! QUIET!" A moment later, the teacher came over to Quentin and guided him to a table on his own.

We collected data in two forms: observation notes and video. Observation notes served as the initial place we used to identify the focal moment, which was then selected for in-depth analysis collectively. Video was taken by a GoProMAX, a small camera which sat in the middle of the table and captured a 360-degree visual field. The video can be replayed either by flattening the image as you might unwind a sphere, or by swiveling the view in 360 degrees, seeing only a subset of the view at a time. We looked at the video first as a flattened view to see the entire group and then looked closely at each child. The episode lasted approximately 16 minutes, beginning with their first negotiations about play rules to the deconstruction of their creations during clean-up.

Analysis

The analysis began with all seven members of the research group and all five cooperating teachers watching the video. We discussed the instance and shared ideas about what was taking place in the video. These initial viewings confirmed that the instance of collective engagement felt important and interesting and was worthy of additional investigation. A smaller group used interaction analysis to analyze the video more closely, first developing an emergent set of inductive codes, and then a second set of inductive codes that we used to document the ways that children were working together, how they were working independently, and when and how their work came into contact, as depicted in Table 1. Our final analysis focused our view on the ways each child contributed to the final moment of "counting the levels," attending to the construction of the rocket, and the times and ways that different children felt that its size was worthy of commentary and documentation. Ultimately, we used this coding to tell a story of each of the four children and the ways their work came together.

Table 1
Final Set Of Codes Used To Examine Each Student's Contribution to Laura's Rocket

Resource Codes	Mathematics Codes	Intention Codes
Sharing	Counting	Articulating Plan
Grabbing	Discussing Unit of Measurement	Articulating Imagined Storyline
Protecting	Fitting	
Co-Building	Making Shapes	
	2-D Building	
	3-D Building	

Resource codes focused on the ways students shared, grabbed, and protected resources, and co-built alongside Laura. We also coded for each student's *mathematical* contributions, which included counting, discussing the unit of measurement, fitting shapes together, making shapes from other shapes, 2-D building, and 3-D building. Finally, we considered the ways students communicated their intentions by coding for moments when students articulated a plan or imagined storyline. From the codes, we crafted narratives of each student's trajectory towards the focal moment with Laura's rocket, which formed the basis of our conjectures about the participation practices and mathematical opportunities that their free play afforded.

Findings
We begin with a brief story of each of the four children, before turning our lens to their collective work.

Laura
When Laura sat down at the table, she immediately asked "Can we build together?" However, even as she was speaking, she slid a stack of squares over and placed them directly in front of herself and started to build. It appeared that Laura already had an idea in mind of what she wanted to do, as there was no observable exploration of shapes. Instead, she took several squares off the pile and arranged them into a net of five squares, which she then folded into an open-topped cube. Although she did not hesitate when laying down the 2D net, she did pause when folding up the sides (because Magna-tiles are magnetic, you must place the tiles adjacent to each other in order for them to stay up). For her first cube, Laura placed a square on top, then removed it. She then created a second cube using the same 2D net to 3D cube strategy, this first by counting off five squares from her pile of squares, and then time adding it on top of the first cube. She continued to build a tower using this method for every single level, stopping only to defend her resources or to secure the resources that she needed for the roof of the building. Laura's building required many Magna-Tiles, something that her group mates noted and challenged her about. Overall, despite Laura's expressed interest in working with her peers, much of her free play was characterized by single-minded determination. She rarely participated in conversation with the other members of her group, and stayed focused on her design until it was completed. After its completion, she was happy to engage with her peers and began to build with Brionna, before the group's attention turned to the height of her rocket.

Briona
From the onset of her free play experience, Briona consistently weaved in and out of her own Magna-Tile creation and Laura's rocket, which predominantly showed up in the form of sharing resources and protecting resources. Briona very quickly articulated her imagined storyline of constructing a three-dimensional garden house. This initially consisted of fitting large squares together to form a cube; however, as she approached the roof of her garden house, she realized the limited resources at her disposal and thus turned to the group to articulate her plan and elicit help. She stated, "I need four!" to her fellow playmates, but did not specify which shape. Therefore, Laura shared small squares and Quentin shared small triangles, but neither shared the large squares that Briona

had been using up until that point. Briona explored with these shared resources by forming large squares from the small squares to construct the remaining side and roof of her garden house. This period of exploration was notable, as it led to a shift in Briona's original plan. In creating shapes, rather than already having large squares, she experimented with forming shapes from other shapes, eventually realizing that she no longer needed the small triangles that Quentin had shared with her. Consequently, Briona shared these triangles with Laura, who later sought this resource to complete the end of her rocket.

Briona was also instrumental in protecting Laura's resources. For example, as Briona worked on the roof of her garden house, she realized that she needed another small square, which Quentin then removed from Laura's rocket and placed on Briona's roof. Briona, however, quickly removed this piece and returned it to Laura's rocket. In other instances, Briona went so far as to create a physical barrier between Laura's rocket and the other students by putting her arms around the rocket to protect it from Quentin or Max. Although she was invested in her own garden house, she appeared equally invested in contributing to and protecting what Laura had created.

Max

Like Briona, Max's fluidity between independent and collaborative play also contributed to the focal moment of analysis. Of the four students, Max took on a more explorative approach, rather than executing an articulated plan. Although he did eventually decide to construct his own rocket, which differed considerably from Laura's, his initial play began as collecting various shapes that other students were not using. After evaluating the resources that he had available, he started fitting small triangles together to create a two-dimensional pattern, similar to how tiling might occur. As Laura's rocket became taller and taller, Quentin started commenting on its height, which then caught Max's attention. Noticing that Laura's rocket was almost complete, he gathered four isosceles triangles and handed them to Laura, stating, "Here Laura! For your end. Here for your end. That's for your end." Laura took these triangles and although she did not end up using them for the tip of the rocket, she did include them as embellishments on the sides. By sharing these resources, Max demonstrated an early investment in Laura's rocket. Like Briona, he frequently negotiated the materials that he was willing to share (or not share) based on a consideration of his own construction in relation to Laura's.

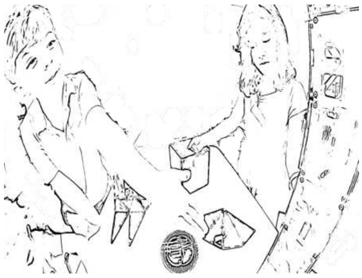
Quentin

Quentin was fully engaged with the Magna-Tiles, working independently most of the time. He said he was creating a car which then morphed into a bus as the play progressed. There were only a few instances where his attention was directed toward anything other than his own building. The first occurred when Quentin was out of Magna-Tiles and started looking for more. It was during this instance that he noticed Laura had many pieces, resulting in the interaction reviewed above. After this initial interaction, Quentin kept the Magna-Tiles that he took from Laura and continued building his structure for roughly one minute. He then looked up at Laura's rocket and exclaimed, "What!" and pointed at the rocked and started to count as he pointed to the different pieces and noticed that she had "seven stacked." In one instance, Quentin made a square out of 2 triangles and offered it to Laura, although this was his only contribution of physical objects to her rocket. Beyond this one instance, Quentin only attended to her rocket when he was looking for more pieces for himself or others and when he was counting the layers. As the playing progressed, Quentin directed Max and Briona to take some pieces from Laura as she had the most. Quentin even took one square piece from Katharine's rocket and gave it to Briona, who immediately gave it back to Laura. After Quentin had finished building his structure, he played with it pretending it was a car. He moved it around, making noises that sounded like a car accelerating or turning quickly. He then stepped away from the table just as Max counted eight levels of the rocket. This drew Quentin back to the table as he ran over and counted seven levels. Quentin's engagement and participation in the counting episode were collaborative and not disruptive toward the other children or the teacher.

The focal moment—Mathematical play as disruptive

As indicated earlier, these interconnecting trajectories of play resulted in collective inquiry into the question of the height of Laura's rocket. The moment began with Max's observation—and seeming delight—at the height of Laura's creation (turn 1). Briona echoes this endorsement, gesturing to the very top of the rocket (which is above her head). Although this was Laura's creation, insofar as she is the person who created and stacked each cube, each member of the group has contributed by protecting or offering resources for its creation. Perhaps as a consequence of these contributions, all children at the table seemed equally delighted by the rocket, and perhaps even a bit proud of its scale. However, what turned this into a mathematical moment was Max's decision to *count* its levels as a means of documenting its height (turn 3).

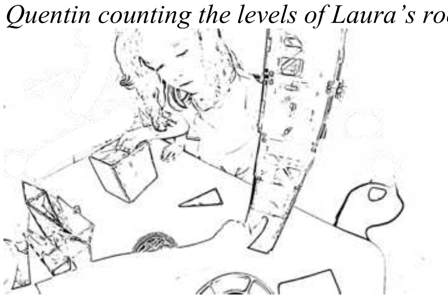
Figure 1
Laura's rocket



(1) Max: Dude, this is a tall, it's a tall building! *(Looks at rocket and smiles).*
(2) Briona: It's a toy rocket! *(Walks around K, touches top of rocket, and smiles. Returns to seat).*
(3) Max: Wait so it has levels? *(Gestures at rocket).* The building has levels. One, two, three, four, five, six, seven. *(Points to each level of rocket for each counted number, then pauses).* Eight. *(Points to roof).* Eight levels! This thing has eight levels! *(Looks at Quentin and gestures towards rocket while smiling).*
(4) Briona: It's eight levels cause it's a hotel. *(Looks at rocket).*

At this point, at least two members of the group were invested in connecting Max's count with evidence of the scale of the creation. Mathematically, this was an important moment, particularly for new kindergarten students. Max's counting is sophisticated in that it demonstrates *one-to-one correspondence*—counting each item separately, only once. His counting also demonstrates *cardinality*—knowing that the last number counted refers to the total number in the set. This act of counting—of documenting the height of the rocket—appears to continue to give Max delight, and he shares his excitement by turning towards Quentin as he speaks, smiling (figure 2).

Figure 2
Quentin counting the levels of Laura's rocket



(5) Quentin: One, two, three, four, five, six, seven. *(Touches each level of rocket, excluding roof, for each counted number.* Seven levels! *(Looks at Max).*
(6) Max: I thought it was eight levels! *(Looks at Quentin, smiles).*

In turn 5, Quentin undertakes his own count of the rocket, again demonstrating one-to-one correspondence and cardinality, but this time arriving at a different number—seven—due to excluding the roof in his count. Max does not dispute Quentin's count, but instead seems to simply remark on their different numbers, finding this amusing, as demonstrated by his smile and laugh (turn 6). In this moment, Quentin's experience in the mathematical conversation is different from what we typically observed in the class. First, and most noticeably, Quentin was a part of the mathematical work, not removed from it. Second, his participation was invited by his friends, and his contributions were valued and ultimately endorsed. Quentin's contributions to the rocket were often related to resources, as his interactions with the other children were mainly about Laura having the most and Quentin trying to gather or share her resources. Notably, Quentin was engaged in this Magna-Tiles free-play activity in ways we (the first and third authors) had not observed previously. He sat and quietly played while he independently built his structure. He shared a piece he built with Katharine. He attended to Laura's rocket and was even drawn back to the table after he walked away to participate in a conversation about the number of levels in the rocket. Quentin's engagement was productive and collaborative, which deviated from his frequent patterns of disrupting others.

(7) Briona: You're counting too much. *(Walks around Laura to rocket).* One, two, three, four, five, six, seven, eight. *(Touches each level of rocket, including roof, for each counted number).*
(8) Laura: No that's the roof. *(Touches roof).* There's no layer to the roof. *(Turns to face other students).*
(9) Briona: The roof don't count. *(Looks down at table).*

Briona and Laura also enter the conversational space, introducing a new idea—what ought to be counted in the determination of the number of levels contained in the rocket. Briona's count—which also demonstrates one-to-one correspondence and cardinality—includes the roof, echoing Max's approach. However, Laura—the rocket's creator and therefore apparently the definitive voice on its components, sides with Quentin, asserting that "there's no layer to the roof," a perspective immediately affirmed by Briona. In this interaction the children's conversation about what counted as a level (turns 3-9) reflects an important mathematical concept related to measurement – *unitizing*. As the children discussed what counted, they were discussing the unit of measure to determine the height of the rocket. In their conversation, it was determined that the unit was the levels, rather than the individual pieces of Magna Tiles.

Conclusion and implications

This study explored an episode of free play that resulted in children's spontaneous and joyful engagement in a conversation about measurement and counting. This moment served to disrupt typical math practices in the classroom which involved students working on questions and problems that were posed by the teacher and was instead a moment when the children themselves articulated a mathematical question and went about answering it themselves, collectively. This moment also served as disruption for one child, Quentin, who was a full participant in counting and unitizing, and whose thinking had status and was valued by others.

In contrast to the idea that play might take time away from mathematics instruction, this episode suggests that play can create new opportunities for mathematical engagement, which has the potential to transform and disrupt what it means to do math and who is seen as mathematically competent. The play activity and the participation norms that were established for this free play activity allowed children to talk, laugh, play, and move around the classroom at will. Children were also encouraged to think about mathematical concepts like shape attributes and counting, but the goals were less narrowly defined as compared to the playful mathematics lessons and math centers that occurred before the episode. As a consequence, this episode created space for young children to engage in problem posing, asking a question (how tall is it?) that was interesting and important to all students in the group. It was not a requirement but rather a choice to count and discuss what gets counted. In addition, the activity created space for Quentin to engage productively—he participated for a sustained time, returned to the conversation after leaving, and was not disruptive to the children around him. His contributions were considered by other students, and valued—it was clear they regarded him as a legitimate and important member of the group. Thus, we argue that play acted as a mechanism for disrupting and transforming patterns of exclusion. We conjecture that other activities that offer these kinds of freedom and engagement to children have the potential to disrupt patterns of exclusion in similar ways. However, to this promising note, we also offer the observation that play did not disrupt all ingrained participation structures, as the activity of the group centered the demands and wishes of a single child: a while girl who effectively dominated resources through a combination of whining and demanding. The instance needs to be considered from that lens as well, as we must take seriously whether and how we might truly challenge and disrupt a broad range of existing inequities and hegemonic practices (Bryan, 2020).

This study adds to the literature on learning through play in early grades as it highlights another way that play can create opportunities to learn. The literature on learning through play, particularly after pre-school, is very small, and such rich examples add to our burgeoning understanding of what playful mathematics learning looks like. The findings also offer an example of possible strategies to disrupt ingrained classroom practices, such as patterns of exclusion, authority, and positioning of children. Future work may explore how offering play rather than taking it away can impact the participation of children in classrooms beyond this single case study. In fact, a limitation of this study is that it is focused on a single instance, which inspires but does not persuade that free play is necessarily always mathematical. While we do not make such a claim, we note that continued research is necessary to identify the conditions under which free play can become mathematical, work that we will continue as the project continues and we collect more data about student learning through play.

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