MATHEMATICS TEACHER

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Mission Statement

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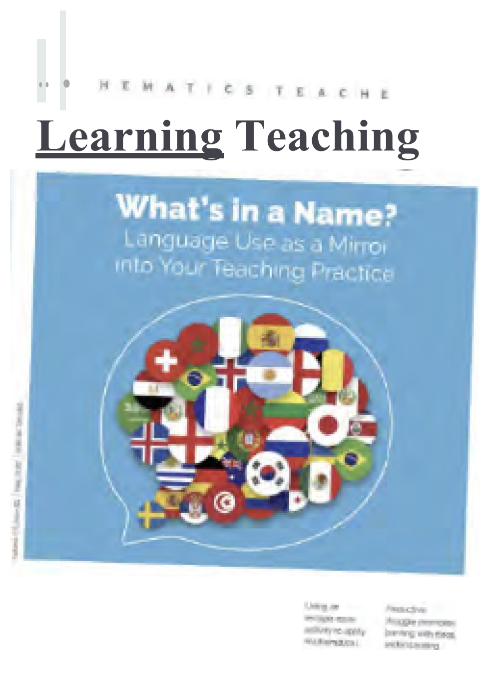

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Inclusive Playground Desiqn

The mathematics of budgeting and space can leadto ajustice-orientedexperience for elementary students as they design a proposal for an Inclusive playground.

Holly Tate, Samantha Anstett, Beth Cooke, Merrie Joy Hrabak, and Jennifer Suh

Webegin this articlewith a quote froma third-grade wheelchair user whosparkeda month-long mathematical investigation into ways toadvocate fora more inclusive playspace for manystudents in our school.

> "The perfect playground would look like a play-groundwhere everyone can play and where everyone can join their friends and play together, and everyone is having fun, not beingleft out. So everyone has a place toplayand a place to have fun."
>
> -Third-Grade Student

Centering studentsand community in mathematics is essential toauthentic and meaningful learning and an ambitious endeavor for teachers as facilitators ofchildren's inquiry. Our workfocused oncreating thespace forelementary children tosee the interconnectedness between mathematics and a communitysocial injustice, lack of inclusive playground access, through community-based mathematical modeling (CBMM). As Bliss and Libertini (2019) describe, mathematical modeling (MM) is a cycle of investigation within relevant contexts that positions students to recognize important quantities, make assumptions and collaborative decisions, and strategize to solve rigorous mathematics. Leveraging the MMcycle, CBMM emphasizes contextual problems designed within the community and issues of injustice and uniquely createsopportunities for elementary school students tolearn deeply aboutlocal inequities to take structural action (Aguirre, Suh,et al., 2022; Anhalt et al., 2018;Suh et al., 2023). Figure 1 shows bow CBMM intentionally places sense making around the community issue and action forjustice within the MMcycle (Suh et al., 2023). We have explicitly connectedthe National Council of Teachersof Mathematics' (2014) effective mathematics teaching practices (MTPs 2, 3, 4, and 7) to the cycle, illuminated through the story that follows.

This article highlights bow third-and fourth-grade teachers, a math coach, and a university professor (also authors of this paper) collaboratively and thoughtfully engaged in the CBMM cycle. We use "we" throughout the article to describe this authorship and collaborative group. The CBMM cycle often starts with "build awareness;' where we began planning. We found that building awareness was not just a necessary partof CBMM for students, but also imperative for educators facilitating this work.

BUILDING TEACHER AWARENESS

Our creation of the inclusive playground task began with brainstorming community issues. We wondered: What are some issues relevant to our students and our school? FUrther, how does mathematics connect to these issues? We realized that a theme emerged from our earliest discussions centered on issues of *access,* including access to an inclusive playground. Ourschool comprises a unique population ofstudents, specifically in neuroand physical diversity, with approximately 20% of children enrolled in special education services in the 2022-23school year. Among our diverse learners, some children need wheelchairs, walkers, or braces; others are non-verbal or have sensory and/or developmental disabilities that require greater access toadaptive playground equipment, sensory equipment, and other amenities. Housingspecial programs for students with disabilities set our school distinctly apart from many others in the district, with a much larger population unable to access the playground. At the time, our playground was not a welcoming play space for children to playside-by-side; creating an inclusive play space became a critical and vital issue for our teaching team to pursue alongside the school community.

The inclusive playground task becan1e vertical, with collaboration between the third and fourth grades. As an educator team, we feltvery passionate about this community issue.Staff and srudents noticed how, during recess, some studentswith disabilities lacked access to the playground equipment. This caused some children to sit on the sidelinesor orbit around the playground, watching peers play and have fun instead of joining in. We noticed that the uneven

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Beth Cookehas been aneducator for32 yearsin Fairfax County PubUc Schools.She wasnot a fanof mathin her own schooLing,but once she foundher math identity as a graduate student she beganprioritizing supporting li<>rstudents in finding their mathidentity andproviding safe spacesfor pmductive mathstruggleand risk-taking.

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sidewalk and the mulch were challenging for students in wheelchairs, walkers, or bracesto navigate.Students left out of opporttmities to play missed opportunities to socialize, learn, and grow together. Fortunately, our school playground was in the queue for redesign in the upcoming schoolyears, and we seized this moment to take action in designing an inc.lusive playground wilh playspaces for students of all abilities to enjoy.

In the followlngsections, wedetail tl1e parts of the CBMM cycle that led to srudenls col.laborating toward an in-0epth understanding of thecommunity issueof access to playand thecrucial mathematics thatcomes into play when considering the design of a new playground.

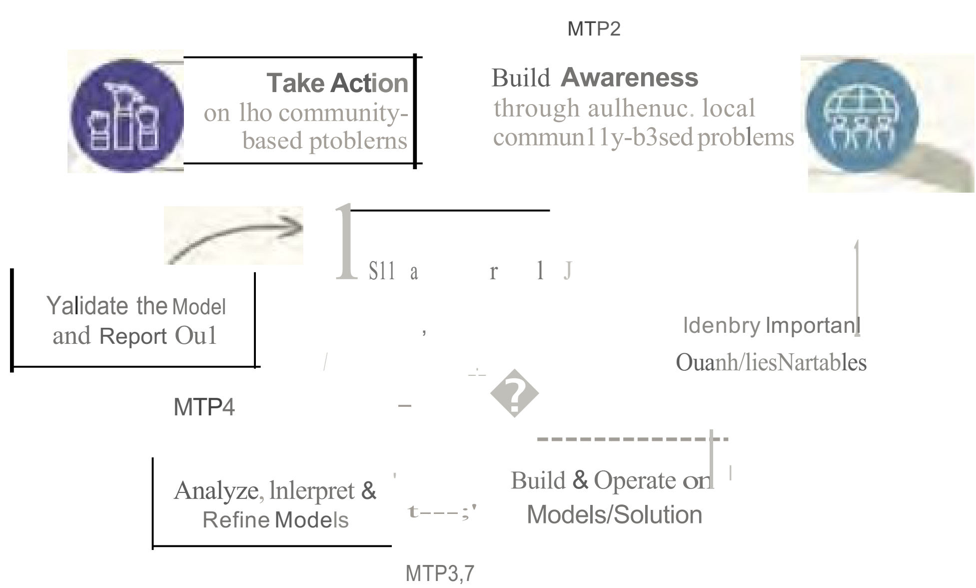
BUILDING STUDENT AWARENESS

To make sense of the problem of playground accessibility, we situated thissignificant community issue locally and unpacked it with our srudents. First, we engaged third-and fourth-grade students ina series of Mathematizing the World routines (Aguirre, Tt1me_r, et al.,2022) (CBMM cycle step: malting sense of the situation or problem) in Morning Meeting and as a part of the numeracy routine for the math block. Students considered images of their cu1Tent playground and other inclusive playgrounds and noticed, wondered., and asked mathematical questions about them. Figure 2 shows some eirnmple images we used and anchor charts that made student thinking visible during these routines as they considered whocould and could not enjoy the playgrounds. More teacher moves and student ideas are seen in Video I as a teacher asks several students to share their noticings, wonderings, and mathematics questions with the class.

Next, we planned a playdate for third and fourth graders to visita local two-acre inclusive playground constructed for children of all abiLities as another way to make sense of tl1e problem. As cl1ildren played together in this unique space, we noticed it bad ramps, high-back swings, non-slip and porous surfaces, flat pathways, and wider equipment. For the first time, many of them could play alongside a peer who was a wheelchair user, as seen in Figure 3, opening theireyes to the joy of such an authentic experience.

It was important for the children to become fom• iliar with our school data, primarily to hear the voices of their peers with disabilities who might not have been in U1e third- or fourth-grade classrooms. Thus, we conducted a school-wide survey for K-S students to give their opinions on how accessible

Figure 1 The Community-Based Mathematical Modeling Cycle



NotJ, Source:SUh+i al.. 2023,

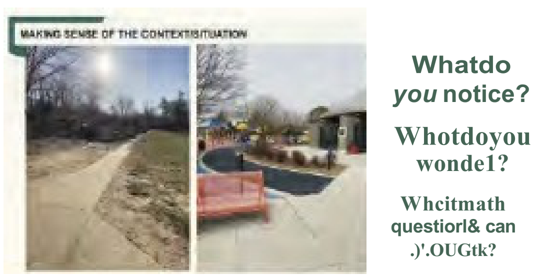
the current playground equipment was and their wants and needs in a fun playground space. Children also worked in collaborative teams toinventory our current playground for accessibility using a Playground Planning Checklist (see Figure 4), adapted from an organization of child development and inclusMty experts (PlayPower, Inc., 2019). These data sets informed the mathematics across our vertical classrooms to evaluate our current playground and determine our school's needs.

Using our inclusive playground inventory data (see examples in Table 1), we generated graphs that would inform students' decisions in their playground planning process.

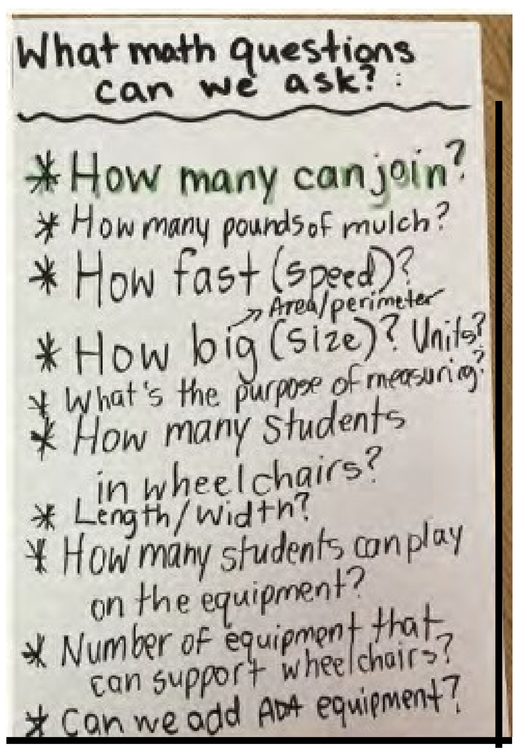
Asseen in Figure 5, students worked in small groups to consider and interpret the data. As we considered the voices of students across the school, it was apparent that more than1 in 10students acknowledged that they, in fact, could not play on the playground by themselves as it was. Additionally, students noticed

Figure 2 Images and Anchor Chart From Mathematizing the World Routine

Sample Images



Sample Anchor Char1ShowingStudent Thinking
(CBMMcycle step: identifying important variables and quantities)



that our playground area was not easily accessible by wheelchairs. They further discovered that not aU activities and areas appealed to students' senses, including manipulative and sensory play, varied levels of challenge, desire forshade or comfort, and opportunity to access all equipment. Classes had rich discussions about whatequipment would best meet the wants and needs of the students based on the data from the whole school. Individual preferencescould not determine design choices. Instead, everything went backto what the school's data showed. For example, the K-3 grade-level survey and the grades 4-6 survey results showed that the mostcrucial part of a playground is having things to climbon(34.8% and 29.9%, respectively). Another consistent noticing was that all grades prioritized swings (23% and 29.9%, respectively).With this data analysis, children were more informed and intentional when looking through catalogs of accessible equipment, selecting pieces that met most students' wants to climb or swing while allowing those with limited mobility to access the same equipment.

Video1 Students Notice, Wonder. and Ask Mathematics Questions

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Figure 3 Students Play Together at a LocalInclusive Playground

Students joined as a class to further explore and discuss the mathematics questions they identified as potential problems. We, as teachers, helped to home in on the problem posing that related to two content areas: decimal computation and measurement. For example, children asked about the playground's length and width, which helped us recogni2e the need to visualize space in playground construction. Students also wondered about the possibility of adding American Disabilities Act (ADA}-compliant equipment, leading to further questions about cost and budgetary constraints. These questions in problem posinghelped us,as facilitators, frame the tasks that the third and fourth graders would later tackle and helped the children make sense of the complex connections between reimagining our accessible playground and mathematics.

BUILDING AND OPERATING ON MATHEMATICAL MODELS

After establishing accessibility to inclusive playground structures as an issue, we moved on to the work of doing mathematics. Ioboth third andfourthgrade, students considered what they knewand needed to know to develop solutions and identified assumptions/decisions to make in groups (CBMM cycle step: identifying important quantities and variables). These whole-group routines inspired children to draw on the ways they had made sense of the problem in previous lessons:

Torenzo: We need something everyone can use.

Grace: Yeah. We know that people with wheelchairs can, reallyget in the playground because of the mulch; the terrain is really bumpy.

Andre: I think we need to decide on if we need more things that spin.I've been hearing that a biggroup of people are bored at recess.

Ms. *T:* Is that a decision we can make? What equipment?

Andre: Yes.

Grace: But, todo that we need to know how much space is in the playground; if wegota huge thing we would nothave enough space.

Torenzo: We also knowwhat people like...like what's thevote of what people like? What equipment is the favorite?

Figure 6 shows the ideas students bad when considering these prompts and tl1eirconnections toCommon CoreStateStandards (National Govemors Association Center forBest Practices & Council of ChiefStateSchool Officers, 2010). Both third and fourth graders brought upthe monetary and space constraints they hadto work within and thesurvey data from theschoolsurveys. Asa class, engaging in U1is routine helped usclarify points of assumptions, such as thesize ofour playground space staying thesame. Additionally, we wereable toexplore some more excitingand flexible points of mathematics. For example, in fourth grade, children asked about the budget. *As* teacher facilitators, we providedstudents data with the range of a possible budget provided byour school district (S75,000-Sl50,000), while acknowledging that groups maygobeyond that price point.

Budgeting for our new inclusive playgroundelicited notable mathematics sense making as fourth graders planned how to spend money on equipmenl. Third-grade students, on the other hand, considered the playground areaand were tasked tobudget forthe spaceand size of the equipment theychose while using theschool-wide data to justify their choices. Reasoning included twoessential considerations of space: the area of the land the playground would sit on, and the area of the pieces ofequipment they wanted to use (called the "usable space"). Students made representations of theequipment using grid paperand based their final decisions on thedimensions that best fit and whether allsn1dents could enjoy it.

To helpstudents consider the mati1ematics, we encouraged children tooutline the usable s1, ce for eacll piece of equipment basedon its length and width on grid paper. Dimensions for each Hem induded measurements in feet, resulting in rectangular space. Using the gridpaper, a common strategy that we observed, especially forsmaller equipment, was counting the number of square mlits, as described by the third grader in Figure 7.

Most students connected finding the area toother math strategies and began tosee how theycould use multiplicative reasoning toconsider larger spaces. It no longer made sense tocountevery square because

Figure4 The Adapted Playground Planning Checklist

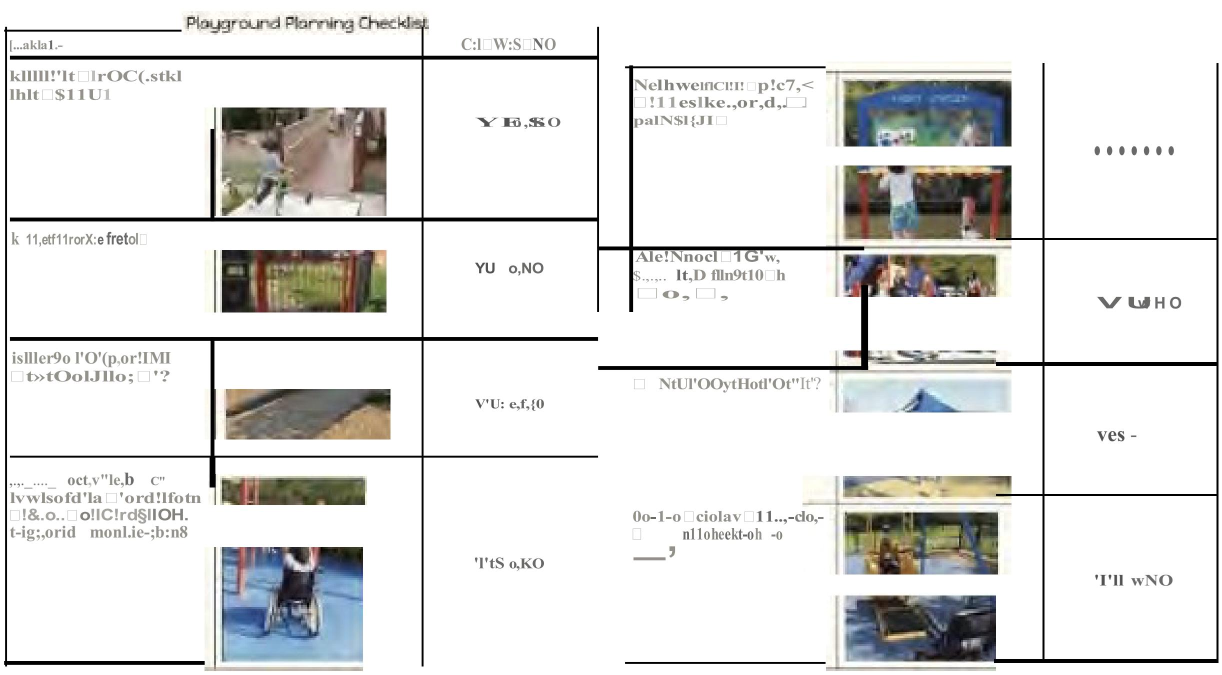


Table 1 Students Used School-Wide Data to Make Mathematical Decisions

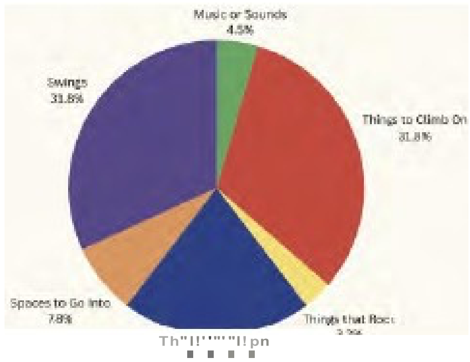
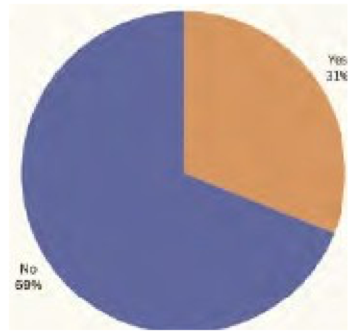
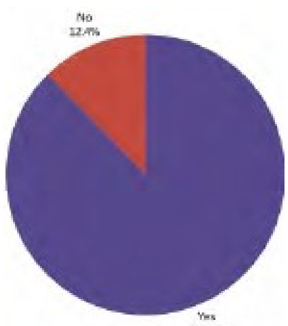
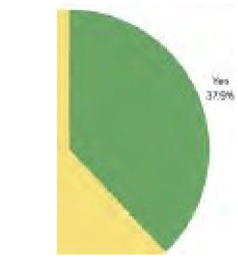
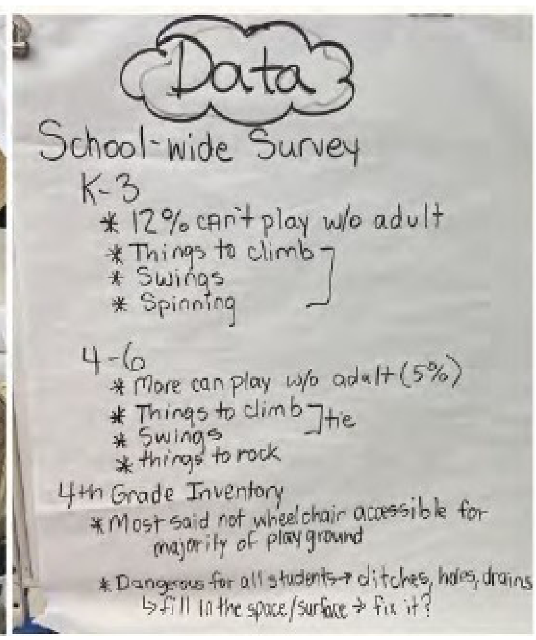
School-Wide Interest and Access Survey Data Example	Current Playground Inventory Data Example
Which of these is the most important part of the playground to you?	**Do we have play structures for people in wheelchairs to enjoy?**
	
Right now, I can play on the playground by myself WITHOUT any **help from an adult.**	**Is there a ramp or level access to all play spaces?**
	

Figure 5 Groups Worked to Interpret Data, Then Class Listed Their Findings



students were getting lost in the large number of boxes or just wanted to find a more efficient way. For example, ooe group recognized that the dimensions of 20 ft. by 17 ft. could be found by skip-counting by 2017 times until they reached 340. Another group calculated 15 x 4 by adding 15+15=30 twice and then adding 30+30=60. As the dimensions goteven more extensive, several students organically began using the distributive property, breaking apart the area into smaller sections, finding the area of those, and putting all the pieces backtogether. Using grid paper, we tried the partial-product multiplication strategy with two-digit by two-digit multiplication to see bow the abstracted area model connected to the individual square units in their models. Figure 8 depicts bowa student created a drawing of area abstracte<i from the original model on grid paper.The student writes the total for each partial product (400,140, 140, 49), then shows the total of140 and 49 as "189"in the area model.

We overheard group members recounting squares 011 the grid paper to confirm their mathematical thinking, makingestimates, and deciding if an answer was within reason (CBMM cyclestep: analyzing, interpreting, and refining models). For example, one student tried to breakapart 27x 27 by multiplying 20 x 20 to get 400 and 7 x 7 to get 49, then adding the

Fig11rc 6 Know/Need to Know/Decide Routine

USTQUANTITIES AND A88UMPTION8

How would you design a new playground tor RVES?

Know	Need to Know	Decide/assume
• Need tochange the playground togive more **access to people in wheelchairs** • Moreitems for ALL **people, with and without wheelchairs** • Mulchllerrain is bumpy • **We have more swings tha1 are not inclusive 1h;::1n acC"..es.sible swlngs** • Length around each **side** of the playground fence	• Area and perimeter of the playground • **How much space is in the** playground • What equipment is the most **favorite** • **What equipment domost** people want? • Can we addbuckles to swings **and swingsandequipments**	• Whal equipment to pick • Whal equipment is mostused andby whom? • **Who can use what equJpmenl** • Can we add more safety **features to help more people** • **Variety of options** Assume the fence and size will stay the same as **it** is now. We only have this space for equipment.

Grade 3 CCSS	Grade4 CCSS
Studenlsrecognize area as anattribute of **two-dimensional regions. They measure the area of a haf)A by finding the total numbAr nf ;:,me 12e unl1$ nf** arearequired tocover the shape withoutgaps or overlaps, a square withsides of unit length being the standard unit for measuring area. Studentsunderstand that rectangular arrays can bedecomposed into identical rows or into identical columns. By decomposing rectangles into rectangular arrays of squares, students connect area tomultiplicallon,and **justify using multiplication to determine the area of a** rectangle.	Use the lour operaUons to solve word problems **involving distances, Intervals or time, liquid volumes. m;tsses nf obJecti:.. and money, inclvding problems** involving simple fractions ordecimals, and problems **that require expressing measurements given in a larger** unit in termsof asmaller unit. Represent measurement quantities using diagrams such as number line diagrams thal feature a measurement scale.

sums to total 449square unHs. Agroup member said it could not be thatsmall because anod1er section that was 30 x 30 hadan area of900,and another section's areameasuring 20 x 20 was 400square units. *He* noted to hisgroup that 27 wascloser to30 than 20,so their productshould becloser to900 than 4()0. This resulted in one member breaking up the array in dlfferent ways, anotber countingsquares, andanother student informally learningabout the cUstributive property witha classmate as theydiscovered unaccounted-for pa11s ofdie area. The area model in Figure 9 helps to highUght thedistributive property and how, in breaking apart thefactors, d1ere were four sections of area to consider instead of justtwosections (20 x 20 and 7 x 7).

Because this wasstudents' first year wilh area included instalestandards, itstruck usas mamematically important thatthird gradersweremakingsenseof tl1econnection between dimensions and thespace matsomeming would take up. Some groups began to understand that as the dimensions of thespaceavailable for usedecreased, so did thedimensions of the IotaI playgrounddie pieceofequipment would need on the total play space. Onegroup, whose finished product is shown in Figure10, talkedthrough tl1eirdecision to"save space" as they *were* planning:

Pria: We need to avoid thisspace. Westill have a really big play space we need to figu.re out.

Figure7 A Student Describes Finding Area by Counting Each Square

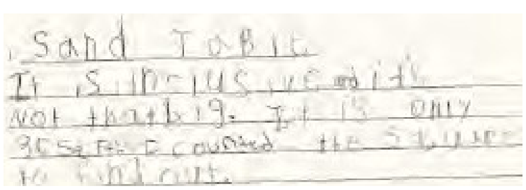
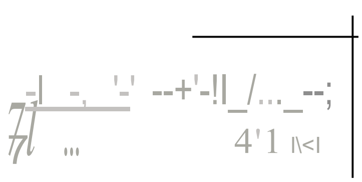


Figure8 Student Drawing of Area



Ms. T: Pria said *we* areavoiding (11.isspace because it's where the main playgrom1d will go but wehaven't picked that yet. Is thegroup going to pict that? Would that be the next thing

PriJJ: Well, what we aJ'e trying todo is get all oftbe little stuff outof the way so we can see how much room for the big thing we have left.

Ms. T: Oh, I see. So, by puttingin the smallerstuff first, you will beable to see how big your larger equipment can be?

Pria: Yep!

REPORTING OUT AND TAKING ACTION

Crucial tothe CBMM cycle, U1ird andfourthgraders leveraged their decisions and math representations to takeaction on the issue of playground access. "Taking action" can come in various forms through UieCBMM process, including reporting findings and advocating co the larger communityor decisionmakers. Our action-seeking process started with a collaboration with third and fourth grade.rs, v.11ere peersshared their decisions aboutspace and budgets with oneanother to reacha consensus on a coUective playground design (CBMM cycle step: ana.ly.zing. interpreting, and refining models). .Because each verticalgroup bada different goal when J)icking equipment (e.g., fitting within the area or staying within a budget), they hingedtheir final decisions on what tlle dataiocUcated most students preferred and whJchequipment could be used by the greatest variety of abilities. Students were veryinvested in theirchoices, so ii wascompelling toobserve them en ,age in collaborative processes toupliftevery child's voice.

One fourth-grade groupargued d1at the least expensive, yet biggest piece of equipment was imperative to the playground design until their third-grade partners explained that the equipment tookup too much space and did not leave enough open space, which data showed students liked. The fourth graders explained thatsome of thesmaller pieces were not economical because theydidnot allow morestudents to enjoy thespace, and they narrowed down which piecescould benefit botbsides. The vertical team of students asked oneanother why they felt thechosen equipment best represented the school's needs and fit the playground's given area. When they came together to communicate their mathematical ideas, they had to evaluate andconnect ideas and compromise on what equipment best represented all requirements.

The srudents' work culminated in a poster presentation to a panel of local and community stakeholders in the playground-building process. The panel included the senior landscape architect in the county, a local blogger on playgrounds, a special education teacher, and a local university professor. It was essential to involve various stakeholders with unique perspectives on playground design and accessibility so thatchildren could gain valuable feedback on their playground design from experts in the field, as well as elevate the issue and advocate for change. As panel members visitedeach group to ask questions about their process and planning, students clearly articulated the mathematics behind their projects and their investment in improving the school playground. We provided the panel with a feedback form so that theycould write to student groups and couldshare their final thoughts at the end of the presentation. Forexample, the playground blogger wrote, "When I asked you 'whyquestions; like *why* did you do this, whydid you include this, you had reasons for why a friend could play with you...... You were really thinking about physical inclusivity and also emotional inclusivity, and I thought that was reallycool:'While we leveraged thisspace as a forum for feedback and protest, we acknowledge that thissmall group of stakeholders does not speak for all the community, most notably those with disabilities. As we continue toseek justice in playground inclusivity, we must focus on gaining the perspectives of community members more closely connected to the lived experiences of our students with disabilities.

It was vital for us, as educators and alongside our students, to recognize that structural change and a project as large as redesigning a playground takes time and is an ongoing process. Action in the form of community awareness and sendingthe message of needing change is critical in the transformation process. In temporary closure to this CBMM cycle, we shared the entiretyof the projects and panel presentations with administrators, who took the call to action very seriously. Since this project, administrators have acted in their positions of power to center the students' voices in making the playground a more inclusive space as they plan for our playground rebuild with district officials. Additionally, because of the protest of a wheelchair user and his family, our school moved up the building of a new playground in its list of future projects.

IMPACT ON STUDENTS AND WHAT IT MEANS TO DO MATHEMATICS

This CBMM task leveraged mathematics as a vehicle for social justice and inclusion. We recognizeda new lens for children in viewing mathematics connected with a relevant and authentic issue in their lives, an issue

Figure 9 How Dimensions on Grid Paper Fit the Total Playground Space

theywere incredibly passionate about and invested in. Eight- and nine-year-olds noticed and named injustices.They wondered about, mathematically solved, and communicated the changes they wanted fora more inclusive playground design.Students had the opportunity to improve their community by collaborating,problem solving,and makingdecisions for playspaces thatmeet various needs and interests so that*all* students couldgrow side byside.

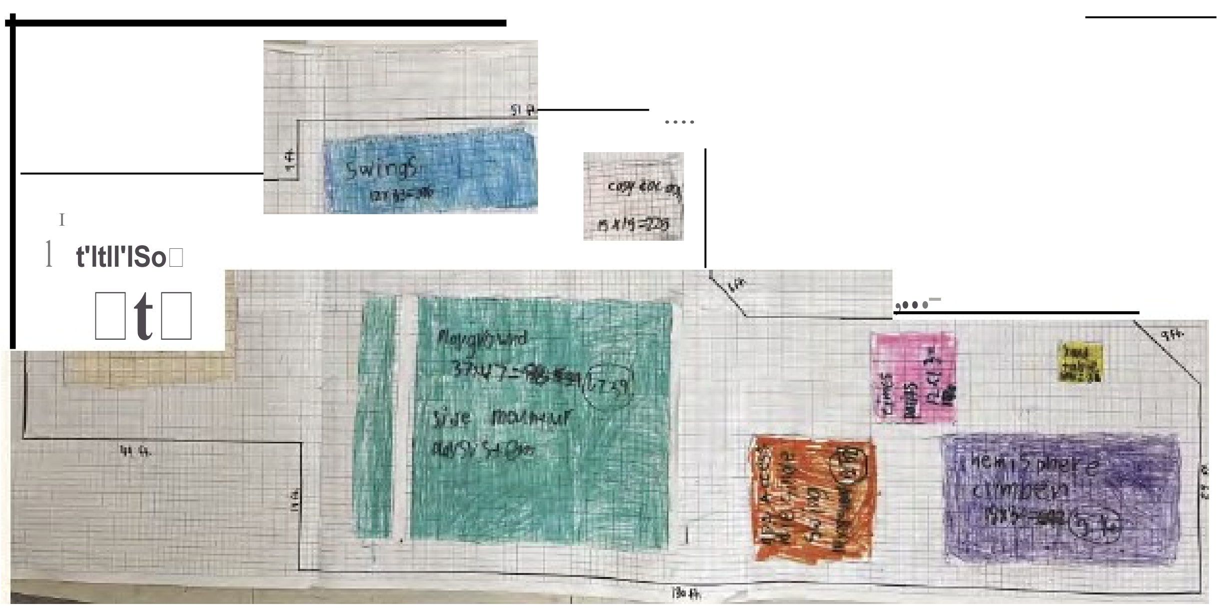
Students found through thisexperience thatthey have the power to take action andworktowardfixing problems they notice in their school.They builton their understanding of the area andexplored different computation anddata analysis strategies through various strategies that maintained high rigorand support.They collaborated to try new ideas and were eager to learn more advanced concepts because the task was necessary and important

Children engaged in the inclusive playground task saw theirability to make a change for their community andexplored mathematical reasoning in their own way. Hearingstudentssay things like, "Everyone should be treated the way they want to be treated:' "We can't use words like normal or regular when we name equipment just like we don't have normal or regular people because everyone *is* unique; or "lt just doesn't feel right if everyone can't use thesame stuff so let's makesomething with noobstacles so no one is left out"shows that mathematics can actasa vessel for building empathy. We end with a quote from the same student we began with, reflecting on what this project meant tohim. He describes the impact on not only him as a wheelchair user but also onothers in the years tocome:

> I think[the playground rebuild is] great because later in the other years, people aregoing to be able to use the playground that we aregoingto design soeveryone can use it Everybody will play with their friends, everyone will ha\·e fun, everyone will enjoy recess, everyone will like recess, and everyone will enjoy their break.

Weinvite teachers to use their positions aschange agents to facilitate experiences that helpstudents see that theycan take onchallenges and build a more just society. Children can challenge the injusticesthey notice in the world to make a better future when they realize that they areadvocates for themselves and others.

Figure 10 A Second Student Group Imagines the Playground Differently



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