ORIGINAL PAPER

Challenging Mathematical Tasks for Literacy Intervention = Equity

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Abstract: This article tells the story of a problem solving journey of equity. The story is based upon a pilot study at a K-8 independent school, located in a large urban setting in the southern part of the United States. The school's literacy specialist, who was also the camp's teacher, was invited to implement a series of challenging mathematical tasks as part of the rising third-grade students' camp schedule. The tasks originated from the NRICH website, and were based upon topics of addition, subtraction, logic, and problem solving. Throughout the pilot study, students developed their ability to productively struggle through mathematically challenging tasks. These students who were seen as at-risk with literacy, benefitted from the literacy and oracy skills embedded in the tasks, but also from the experience of solving mathematically challenging tasks within a sociocultural context with systematic support. The students within the study emerged as not only more confident mathematicians who could stick with difficult problems, but also as more excited readers. Elementary and middle level teachers, researchers, and mathematics educators should continue implementing a series of challenging math tasks and organic intervention experiences, so this is precisely what happens in our classrooms.

Keywords: mathematically challenging tasks, perseverance, literacy intervention, stamina

Children deserve spaces that emphasize making sense of math and reasoning, which are related to their culture and everyday world. They also deserve ways to access mathematics even if they can't read all the words in a task (NCTM, 2000; 2014). With the overall goal of providing mathematical challenges to students in a summer literacy intervention camp, I conducted a pilot study at a K-8 independent school located in a large urban setting in the southern part of the United States. I invited the school's literacy specialist, who also served as the camp's teacher, to implement a series of challenging mathematical tasks as part of the rising third-grade students' camp schedule. Based on end-of-year academic testing, these eight students were identified by the school as at least one grade level behind in reading and/or writing and, therefore, eligible for the three-week intervention. According to the literacy specialist, the students lacked enthusiasm for school and confidence in their ability to be successful. Like many schools in the United States, this one experienced a shutdown during the COVID-19 pandemic and chose to focus its summer learning efforts on literacy and mathematics. Throughout the pilot study, students developed their problem-solving ability and perseverance through mathematically challenging tasks. These students who were seen as at-risk with literacy benefitted from the mathematically challenging tasks and grew in their enthusiasm, ability, and stamina.

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The stakeholders and design of the study were carefully crafted. Though initially reluctant to include the mathematical tasks in the program, Ms. Johnson (pseudonym) agreed to give it a go to support the students' math learning with challenging tasks. She agreed that students would benefit from a collaborative process and believed that the reading interventions used within the tasks would support literacy intervention as a whole. As former classroom teachers and math coaches, we provided ongoing support and coaching to the teacher throughout the summer camp by meeting with her before and after the tasks were implemented to discuss reading and math strategies, as well as what worked and what didn't.

The group of students comprised eight rising third graders, five females, and three males. Three students in the group were economically disadvantaged, two students identified as African American, and one student identified as Hispanic, according to the school's admission data. I was interested to see how students identified as struggling readers would find success with mathematically challenging tasks instead of low-level tasks, which are often given to students who have reading difficulties and those who are economically disadvantaged or from marginalized groups (Krings, 2024; Moll, 1990; Smith & Stein, 2018). I also wondered how the literacy specialist would engage with the mathematical tasks as part of her overall instruction during the camp. The literacy specialist, serving as the camp's teacher, Ms. Johnson (pseudonym), soon discovered that, like her students, she too would grow in her mathematical ability that summer, and her attitude toward mathematics would change dramatically:

> In the last three weeks, I've rediscovered a joy for teaching math. I kind of shied away from it for a long time because I was just more comfortable with literacy. But I have definitely seen in the last few weeks the benefits of teaching math, problem-solving, and critical thinking, as well as the concept of having more than one solution or having to work on something more than one day.

Oftentimes, students, regardless of their reading or math ability, believe that math problems should be solved "in a snap" (Schoenfield, 2013, Stage & Kloosterman, 1992). Most students do not develop strategic thinking or problem-solving skills because math instruction focuses more on mastery of facts and procedures than understanding. We told the students that good math problems might take longer to solve and that some mathematicians spend their whole lives solving one problem! Would this phenomenon of wanting to solve problems quickly be more likely with students behind their peers in reading and writing? Would engaging in these tasks take precious time away from the urgent literacy work the students needed before the new school year, or might engaging with these mathematically challenging problems support their literacy goals? Ms. Johnson realized during the study that building grit and stamina through mathematical challenges could also improve students' efforts toward literacy:

> Even in just three weeks with these students, I was able to see improvements in their stamina and willingness to stick with a problem or go back to a problem. When we think about the whole child just in the academic realm, we can't lean on one content area over another. Math is included in that, and not just included. It's imperative.

During camp, Ms. Johnson launched two tasks each week (we share three tasks in this article), providing support and scaffolding through essential questions and other strategies, including reading strategies, to help them grow their understanding. The students grappled with the problems, but the teacher encouraged them to stay with it until they came to a solution or got closer to solving it. This productive struggle was intentional and something all students should experience regularly in mathematics. Productive struggle is necessary to deepen students' conceptual mathematical knowledge and to increase stamina for solving problems over time (Huinker & Bill, 2017; NCTM, 2014; Terada, 2022). As Ms. Johnson shared, "In math and in everything, I don't think you grow without a struggle."

Selection of Tasks

For the tasks, we selected a series of problems from a University of Cambridge website called NRICH (nrich.maths.org). These problems are designed to nurture students' potential and provide the opportunity for engagement with mathematically challenging tasks. The complex tasks require students to utilize prior knowledge, develop and strengthen conceptual mathematical understanding, and embody perseverance through problem-solving (Manuel & Frieman, 2017; Smith & Stein, 2018). The NRICH problems are free and include resources "designed to nurture curious, resourceful, and confident learners of school mathematics" (NRICH, n.d.). The beliefs of the NRICH team mirrored our own and served as a focal point in supporting the teacher and the students in this study:

- All students have the right to shine, and all have the right to struggle.
- Working mathematically requires more than just conceptual understanding and procedural fluency; it also requires the ability to reason, to think strategically, and to have a productive disposition.

Below, I share three of the tasks from the study; one was designed for 5-7-year-olds, and two were for 7-11-year-olds, and all were considered "favorites" on the site. The NRICH website also has tasks for 11-14-year-olds, which can be differentiated according to topic, interest, or any other category in your math classroom (NRICH, n.d.). Also, the tasks had a range of math topics, reading levels, and opportunities for students to collaborate, all of which would support their literacy needs and the opportunity to experience challenging mathematics and productive struggle.

Why Use Mathematically Challenging Tasks

A mathematically challenging task must allow students to engage actively in reasoning, sense-making, and problem-solving to develop a deep understanding of mathematics (NCTM, 2014). Student learning is greatest in classrooms where tasks consistently encourage high-level student thinking and reasoning and least in classrooms where the tasks are routinely procedural in nature (Boaler & Staples, 2008; Hiebert & Wearne, 1993; Stein & Lane, 1996). When students engage in mathematical reasoning, especially in their adolescent years, they activate their abstract thinking and heightened reasoning skills.

Again, this practice is for *all* students, regardless of their literacy needs or abilities. Not all tasks provide the same opportunities for student thinking and learning (Cai, 2003; Stein et al., 2009). Research also suggests that challenging math tasks are the most difficult to implement; these tasks are often transformed into less demanding tasks during instruction (Stein et al., 1996; Stigler & Hiebert, 2004; Smith & Stein, 2018). In the work with Ms. Johnson, I aimed to guide her through facilitating these tasks so the demands were not lowered (Smith & Stein, 2018).

Connecting Literacy Intervention to Mathematically Challenging Tasks

As previously noted, we were interested to see how students who were in need of traditional reading intervention would find success with a series of mathematically challenging math tasks. Social interaction (Cherry, 2023) and access to resources, including a rigorous curriculum, are essential elements for equity and learning among students (Gutierrez. 2009). We ensured the study was designed so students had guidance from the teacher acting as facilitator, social interaction with their peers in partners and groups, and tasks that positioned them in their zone of proximal development (Cherry, 2023).

Further, studies on reading intervention suggest that using manipulatives and multiple representations embedded within mathematics instruction helps students make connections to the real world and form relationships between math and language (Bawa & Imam, 2020; Krings, 2024; Lesh et al., 2003; Stein & Bovalino, 2021). To fulfill the study's goals and the goals of the literacy intervention camp more broadly, we intentionally selected the tasks based on the need to connect language to the mathematically challenging tasks.

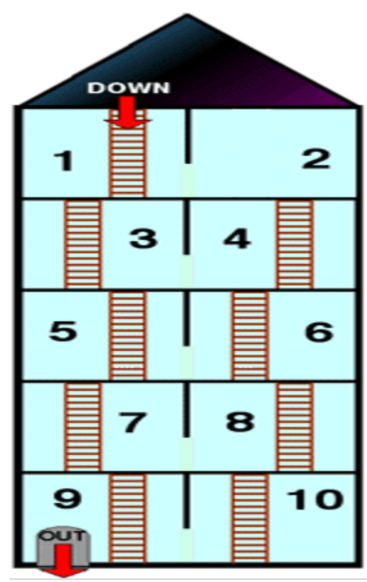
Exploring The Tasks

Tall Tower

On the first day of camp, Ms. Johnson presented the *Tall Tower* (NRICH, n.d.-c) problem, which focused on addition and subtraction skills for 7-11-year-olds. The visual representation of real-life ladders and rooms and the need to escape (see Figure 1) immediately captured the students' interest and positioned them in an imaginative story. These were the instructions:

> You have been imprisoned at the top of the Tall Tower by the Wicked Magician. You can get out by climbing down the ladders. As you come down, you collect useful spells. You can go down the ladders and through the doorways into an adjoining room, but you cannot go into the same room twice or climb up the ladders. The room numbers show how many spells there are in each one. Which route would allow you to collect the most spells? The least number of spells? Exactly 35 spells? (NRICH, n.d.-c, problem tab)

Figure 1 *Tall Tower Task*



Ms. Johnson read the problem aloud twice while showing the *Tall Tower* (Figure 1) picture on the screen. To ensure the problem was accessible to all readers, we created a separate sheet (see Figure 2), which provided systematic scaffolding by breaking the paragraph of text into smaller chunks. We also added pictures to support the students, especially the multilingual learners, and their ability to visualize the problem and connect the text with the image (Kurz et al., 2017); see Figure 2. Each student had their own copy of the *Tall Tower* problem, the adapted problem, and a separate copy of three towers (See Figure 3).

Figure 2 *Tall Tower Task Simplified*


The Tall Tower

Name: ______________________________ Date: ____________

You have been captured by the Wizard and taken to the top of the Tall Tower. Your goal is to escape the tower!

You CAN go down the ladders.

You CAN go through the doors.

You CANNOT go into the same room twice.

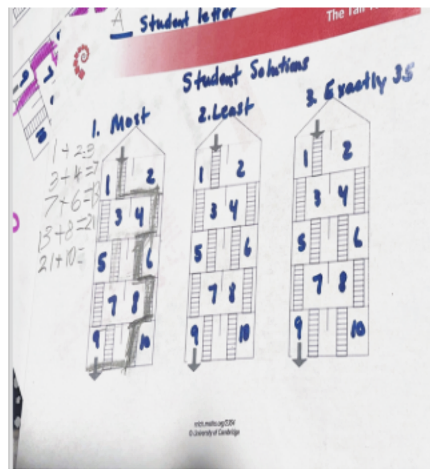
You CANNOT climb UP the ladders.

The numbers in the rooms show how many spells there are in each room.

After Ms. Johnson launched the task with the students, she provided feedback and explicit guidance. Providing scaffolding and miscue correction for the students was pivotal to reinforcing appropriate word reading strategies and supported the students' comprehension and connections to the word problem (Endo, 2024).

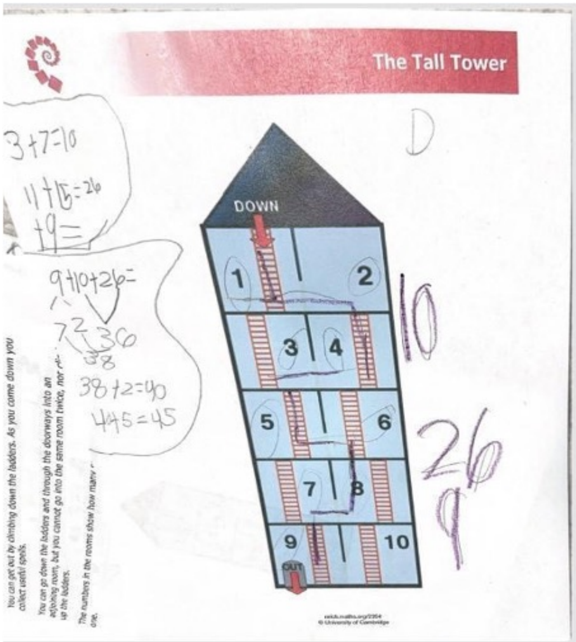
She told the class they had two minutes to work independently but could then work with a partner. Throughout the task exploration, Ms. Johnson selected various students to show and explain their thinking; she encouraged them to share why they approached a strategy a certain way. One of the students (Student A) began by trying to solve the problem of getting the "most" spells. She focused on the larger numbers on the right side of the tower by adding the numbers together in separate sums: 1+2 =3; 3+4 =7; 7+6 = 13; 13+8=21; 21+10 =__, as shown in Figure 3, and then drawing the route on the tower.

Figure 3 *Student A's Tall Tower Work*



Ms. Johnson strategically selected a student who was using visualization as a strategy to solve the problem (Kurz et al., 2017; Gallagher et al., 2021). Student D saw each tower level as a floor and simply added the numbers across and wrote the sum to the right of the tower (see Figure 4). He then showed smaller sums to arrive at a total (he was working to find the most spells) but appeared to have added the numbers (on each "floor") mentally without notating them: 3+7 = 10; 11+ 15=26; +9 +10 = 45. Though the most spells that can be collected for this problem is 53, this was the highest sum the group found on the first day.

Figure 4 *Student D's Tall Tower Work*



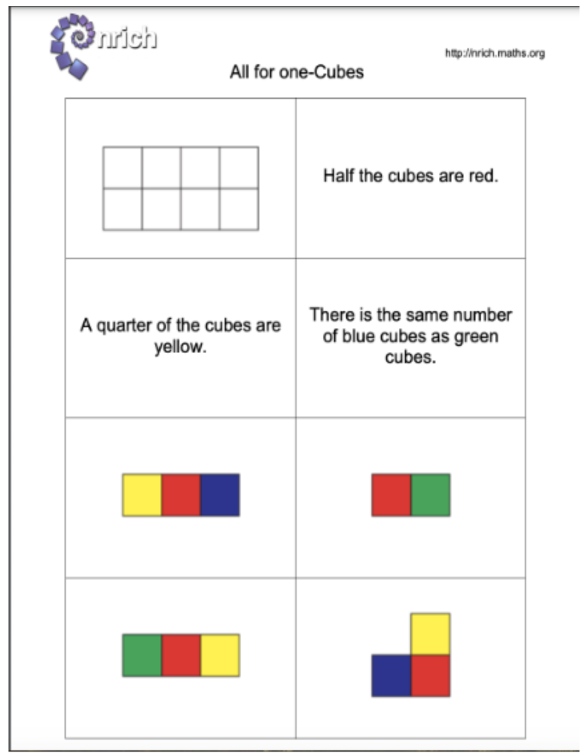
Ms. Johnson provided counters (a suggestion from the task) in case students wanted to keep track of the spells that way. Some of the questions she asked were, "Which might be the best number to leave out?" and "Might it help to record your routes so you don't repeat yourself?" She also shared the student strategies provided in the teacher resources, which included, "I thought that if I want to get the highest number of spells, I need to visit as many rooms as possible." The students continued working on this problem throughout the week, and several asked if they could take the *Tall Tower s*heets home to continue working on them after camp! Students expressed excitement about collecting spells and using addition strategies to solve the problem.

Ms. Johnson wanted to know if she could leave the *Tall Tower* problem in a center for students to return to during the week. We agreed that this was the right way to continue the students' engagement and work on the solution.

Arranging Cubes

The *Arranging Cubes* (NRICH, n.d.-a) task (recommended for 7 to 11-year-olds) required students to arrange eight cubes of four different colors based on eight different clue cards, as shown in Figure 5.

Figure 5 *Arranging Cubes Task*

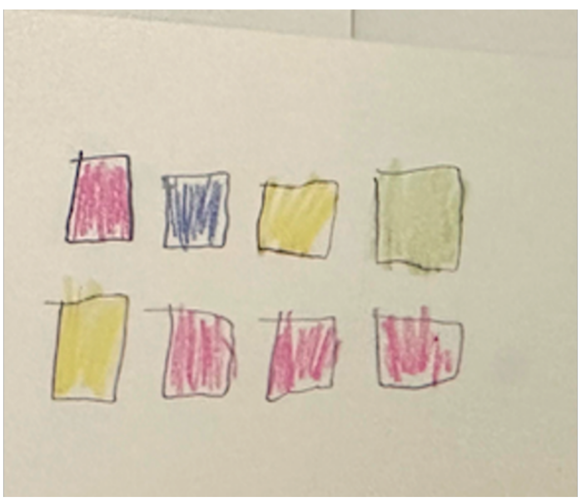


We selected this task because it was less text-reliant, had a geometry focus, and used manipulatives. Manipulating objects like blocks, chips, or cards creates a hands-on path for understanding math, science, language arts, or other content concepts. Manipulating selected objects can make complex concepts more concrete, which is one effective way to scaffold comprehension of grade-level concepts. Furthermore, this task required students to partner read the text. According to Endo (2024), when students read a section of text with a partner, this allows for sufficient cognitive breaks needed for perseverance and increases their reading stamina (Endo, 2024).

The teacher placed students in small groups, read the task directions, and asked, “Does anyone have an idea of how they will get started with this task?” Without responding, the students quickly pulled the clue cards from an envelope and eagerly began to work together to solve the puzzle, and the partner read the clues.

> Student E: “Look, guys, we should move both blues here and read this card: there are the same number of blue cubes as green cubes. This card is the key to figuring this out!”
> Student F: "Oh, that means they have to have two or three each because we have to have red and yellow too.”
> Student E: “Let’s look at your picture again and figure this out!”

Figure 6 *Students E and F Cubes Work*



Ms. Johnson approached the students, eager to see why they were so excited. “What are you all discussing? The students said, “It’s so tricky when you read the clues, but we are each reading one card at a time and trying to figure it out.” When students engage in reasoning, argue their opinions, and discuss their mathematical thinking with other students, they actively use their mathematical language and funds of knowledge to enter the floor of the task (González et al., 2005; Gutierrez et al., 2012). The students continued using the unifix cubes to draw the design. See Figure 6 for the arrangement Students E & F created (which is almost, but not quite, correct). The students declared they knew there had to be four reds because the clue card said half the cubes are red. They also determined there were two yellows because a clue said a quarter of the cubes were yellow. They told Ms. Johnson, “We used our reasoning to figure out there were two empty cubes left, and they had to be green and blue.”

Domino Square

In the final week of camp, the students explored this task (designed for 7-11-year-olds), *Domino Square* (NRICH, n.d.-b) depicted in Figure 7, which challenged them to take a set of ten dominoes and use them to build a square where each side has a sum of eight dots. (We provided cardstock dominoes, which were included in the task materials, but you can use real ones.) As she launched the task by reading it aloud, Ms. Johnson wanted to be sure students thought carefully about decomposing the number eight and considered the sum combinations. She was purposeful in making real-life connections between the task and the game of dominoes. To solve the task, students had to use three dominoes on each side of the square and arrange the dominoes as shown in Figure 8.

Figure 7 *Domino Square Task*

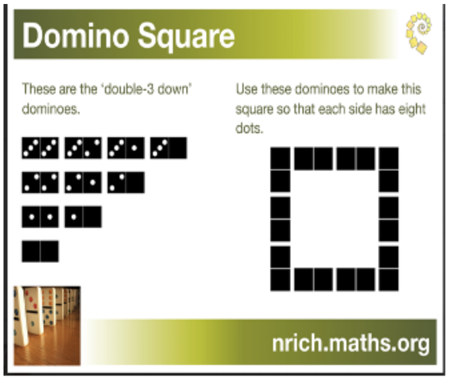
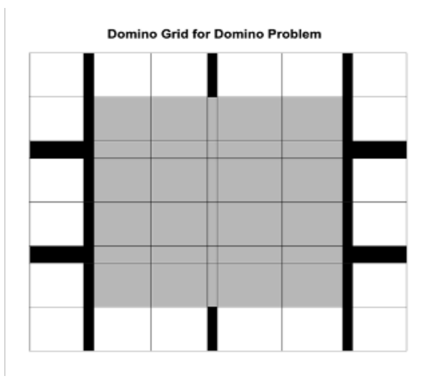


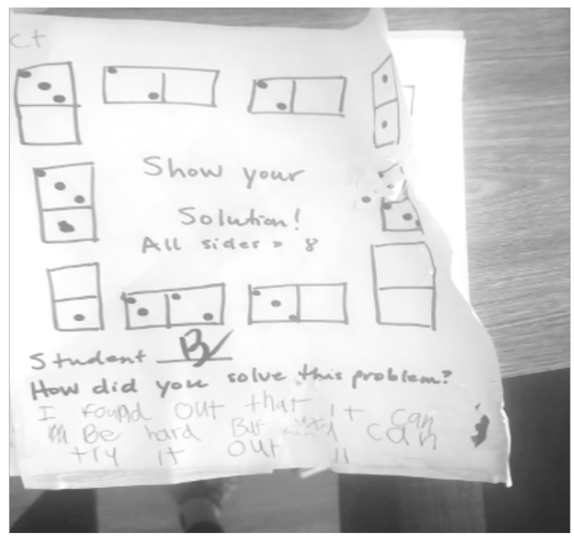
Figure 8 *Domino Square Grid*



Ms. Johnson told the students, "While working, I want you to think about strategies. You're going to get a whole set of ten dominoes. You'll have to figure out how you will arrange them." To facilitate the task, we created a grid template that used blank spaces for the dominoes to match the size of the cardstock ones (see Figure 8). Student A grabbed some domino cards with ones and twos. While watching Student A, Student B was frustrated and unsure of what to do next. After two attempts at the task, he declared (and wrote!), "It can be hard, but you can still try." The students engaged in discussions throughout the task, sharing their mathematical thinking while rearranging the dominoes. We also provided a "Show Your Solution" sheet for students to record their domino dots and where they could share how they solved the task. (See Figure 9). Some students preferred to use this format instead of rearranging the domino cards.

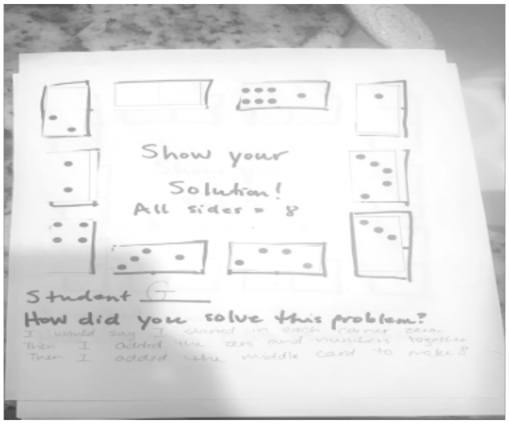
As shown in Figure 9, Student B began recording the "dots" for each domino, working side-by-side with Student A. Using mental math, Student B asked, "That's more than eight; what should we do?" The students decided that if a domino was too large, they had to have a domino with a zero or a one to make the task work. So, together, the pair moved the double three domino to the side for a few minutes while continuing to draw, erase, and redraw their dots.

Figure 9 *Student B's Domino Square Work*



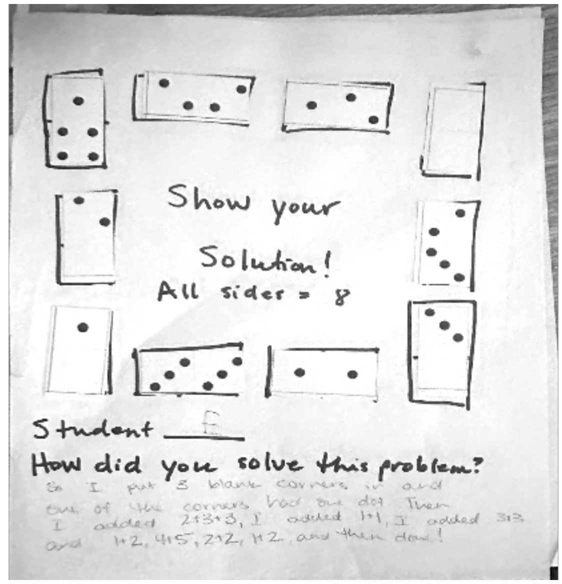
As Ms. Johnson engaged with the students, she noticed the student pairs collaborated differently to solve the task. For example, Student G decided it would be best to put a domino with a zero in each corner of the design (See Figure 10). Then, Student G placed the dominoes without zeros in between the dominoes with at least one zero. To check his thinking, he added the dots on each side of the square to double-check his sums. He worked diligently with the dominoes, turning them in different directions until he got a sum of eight on each side. He concluded that the sides with double zeroes needed the dominoes with higher numbers.

Figure 10 *Student G's Domino Square Work*



Finally, Student E (see Figure 11) used a strategy similar to Student G. She realized she needed to place the dominoes with a zero in each square corner. Then, she decided she needed dominoes with higher numbers to complete the square. She reasoned abstractly by using equations and checking the sum of other non-zero dominoes. She said, "I know 2 + 3 is 5. I know 3+ 3 is 6. So, I think I need a domino with a 1, 2, or 3. I can pair 5, 2, and 1 or 4, 2, and 2. I'm going to study the double ones and keep arranging my dominoes. Then, I will be able to solve the task."

Figure 11 *Student E's Domino Square Work*



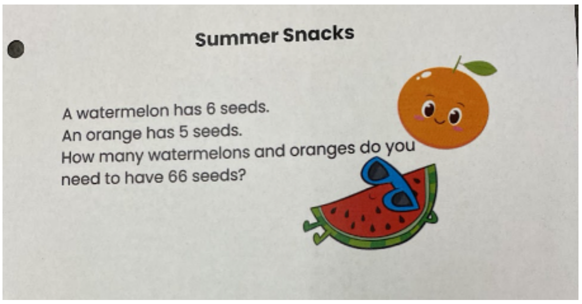
Addressing Equity and Access

To sustain a culture of equity and access in the teaching and learning of mathematics, it is critical that "all students routinely have opportunities to experience high-quality mathematics instruction, learn challenging mathematics content, and receive the support necessary to be successful" (NCTM, 2014, p. 60.). In our research, I noticed that although the students had been identified for literacy intervention, they also grew in their enthusiasm and ability to solve difficult problems through the NRICH (n.d-a, n.d.-b, n.d.-c) tasks, as evidenced in the focus group statements:

> Student A: "The Tall Tower task reminded me of a maze. It was fun, and it helped me understand how to solve it because I like mazes."
> Student B: "I like using number lines, and counting groups helped me solve math problems with adding and subtracting."
> Student G: "I learned not to give up. The problems were challenging and fun. I went home and asked my mom to buy stuff to play with me."

> Student F: "I felt excited about math. I created some of my own problems." (see Figure 12)

Figure 12 *Student F created math task*



Their teacher, Ms. Johnson, engaged the students in mathematical reasoning, which built upon their conceptual mathematical knowledge and their funds of knowledge to help them enter the "floor of the mathematical tasks" (Celedón-Patichis et al., 2017; Moll, 1990). Providing students access to rich tasks with multiple entry points is key to creating an equitable mathematics experience for all students (NCTM, 2000, 2014).

Inequitable structures hold students back from achieving their full potential. The deficit mindset that an at-risk student may not be capable of mathematics has emanated from society and is not research-based (Adams, 2018; Moll, 1990). Children who struggle in reading and need strong support are often labeled and tracked into programs focusing on low-demanding procedure-driven mathematics without being given opportunities to connect to high-level tasks (Huinker & Bill, 2017). Teachers may sometimes limit opportunities and access to challenging math tasks for students below grade level in reading because they feel the text is too complex (Smith & Stein, 2018). Or, they resort to a banking concept where students simply memorize and receive information (Freire, 1970, 2000). Creating an equitable, culturally responsive environment requires teachers to shift their thinking and adopt changes in pedagogical practices (Gay, 2002, 2018).

In this study, the floor was lowered so the students could access the tasks through play, fostering a sense of community and prior knowledge (Celedón-Patichis et al., 2017), and their literacy needs were addressed through appropriate adaptations and scaffolding (Gallagher et al., 2012; Kurz et al., 2017). Learning mathematics should include building upon children's prior knowledge and their funds of knowledge to deepen their learning (Huinker & Bill, 2017). A high-quality mathematics program has a "coherent sequencing of core mathematical ideas."

We adapted and redesigned the tasks as needed to create a more equitable classroom environment. The *Tall Tower* task required more reading than the other problems, so we scaffolded the reading and added pictures so students could make connections. Ms. Johnson lowered the floor by accessing students' prior cultural experiences with playing chutes and ladders and solving mystery clues. I also provided multiple copies and sizes of the *Tall Tower* problem (Figures 1 and 3), made the problem less text-heavy with a modified problem sheet with pictures (Figure 2), and encouraged students to collaborate.

I chose the *Arranging Cubes Task* to build upon students' interests and funds of knowledge, play, and collaboration (Celedón-Patichis et al., 2017). Some students were immediately engaged in the task since it was based on using blocks or cubes to build and play. Working in small groups also helped build community and supported reading intervention, as the students had to work together to read the clue cards. Some clue cards were images only so all students could enter the task. This task gave students many options for using manipulatives and drawing representations to make sense of reading the clues.

In the *Domino Square* task, students solved a task based on play and simple sum combinations. Anticipating the solutions and sum combinations and creating a grid to help students set up the dominoes was the just right scaffolding for this task. Ms. Johnson paused several times during this task to encourage students to stick with it—to make sense and persevere in understanding what the problem was asking (CCSSM; CCSSI 2010). Since this task was mostly visual, she asked students more open questions and encouraged them to write equations and ideas down to help them understand the task without giving away the solution (Delpit, 2003; Smith & Stein, 2018).

Conclusion

All students deserve access to challenging mathematics in spaces where sense-making and reasoning are the norm. They deserve to be taught by high-quality teachers who see them as capable mathematicians and who recognize their cultures and languages as strengths and opportunities, even if they are not yet able to read all the words in a task (NCTM, 2000, 2014). Throughout this study, students developed their problem-solving ability and perseverance through mathematically challenging tasks. Students who were identified for literacy intervention benefitted from the experience of solving mathematically challenging tasks within a sociocultural context with systematic support. The students began to see themselves as successful and capable because they could stick with difficult problems. Ms. Johnson shared these thoughts in her final interview about how this work impacted her students:

> Getting kids and teachers pushed outside their math comfort zone a little bit is healthy. Having this open-ended, really challenging work to do taught these kids a lot about themselves and a lot about grit, stamina, and problem-solving. I think the built-in literacy support helped them, too. But it was built through teaching math and doing math in a different way.

I hope this different way of teaching and learning mathematics will become regular and routine for this teacher and her students, and for students everywhere, because all students have the right to shine, and all have the right to struggle. It is up to each of us, as teachers, researchers, and mathematics educators, to ensure this is precisely what happens in our classrooms.

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