TODOS Mathematics for ALL

Growth Mindset to Support Equity and Excellence in Linguistically Diverse Elementary Classrooms

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Abstract

Research suggests cognitive advantages of speaking more than one language – for example, cognitive flexibility, higher order thinking skills, and better problem solving. We posit that strengths associated with bilingualism suggest potential for a growth mindset and productive struggle that could support mathematical problem solving. This article investigates mathematics teaching and learning practices designed to uncover and support a growth mindset and productive struggle in linguistically diverse elementary classrooms – with an eye toward equity and excellence. We share and discuss lessons learned from educational literature, professional practice, and evidence from a small-scale growth mindset action research project in a linguistically diverse first-grade classroom.

Discussion And Reflection Enhancement (DARE) Pre-Reading Questions

1. What strengths and challenges do you think emerging bilingual students bring to the classroom that can help or hinder their problem solving in mathematics?
2. What do you know about growth mindset?
3. What are your current experiences or perceptions about how growth mindset, productive struggle, and problem solving do (or could) play out in linguistically diverse mathematics classrooms?
4. What are your thoughts about how emerging bilingual students are positioned to engage in productive struggle and problem solving in linguistically diverse classrooms?

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Jessica Guo, Mary Truxaw, and Rebecca Eckert

> "…there is a grain of discovery in the solution of any problem. Your problem may be modest, but if it challenges your curiosity and brings into play your inventive faculties, and if you solve it by your own means, you may experience the tension and enjoy the triumph of discovery." (Pólya, 1945/1985, p. v).

When George Pólya wrote these words over 70 years ago, he advocated for rich mathematical problem-solving experiences that challenged curiosity, rather than simply focusing on routine procedures. Relatedly, the Common Core State Standards for Mathematics (CCSSM) expect *all* students to develop rigorous math content and practices, including problem solving (Council of Chief State School Officers [CCSSO] & National Governors Association Center for Best Practices [NGA Center], 2010). Similarly, the joint position statement on mathematics education and social justice from NCSM and TODOS recommends cultivating and sustaining "a positive mathematics identity and affect in students as doers of mathematics" and providing "access to high cognitive demand tasks" (National Council of Supervisors of Mathematics [NCSM] and TODOS: Mathematics for ALL [TODOS], 2016).

Emerging bilingual (EBs) students, as they negotiate more than one language, demonstrate problem solving. Research suggests cognitive advantages of speaking more than one language – for example, cognitive flexibility, higher order thinking skills, and *better problem solving* (Hakuta, 1986; Howard, Christian & Genesee, 2004). Indeed, language can be a resource (e.g., Moschkovich, 2013) and can provide "sources of meaning" (Barwell, 2018). Thus, the growing population of EBs should be well positioned to engage in problem solving. However, math instruction for EBs often focuses on procedures and vocabulary rather than linguistically and cognitively demanding practices (Driscoll, Heck & Malzahn, 2012; Moschkovich, 2007, 2012, 2013). There are consequences of compromising mathematical rigor and practices. For example, national assessments report significantly lower math performance for EBs than for overall students in the same grade levels (National Center for Education Statistics [NCES], 2015). Such performance results suggest disparities in educational opportunities.

Discrepancies between EBs' strengths and math performance suggest a need to rethink how we teach math to them. When perceived from deficit perspectives, EBs may not be held to the same high expectations for math as other students. In order to promote excellence and equity, EBs need "access to rich, rigorous, and relevant mathematics" (NCSM & TODOS, 2016) that recognize their competencies and challenge their thinking (Moschkovich, 2012, 2013). Growth mindset (GMS) and productive struggle are aligned with these recommendations and, further, are associated with motivation, resilience, persistence towards learning goals, and overall academic achievement (Boaler, 2013, 2016; Dweck, 2006). We conjecture that focus on GMS and productive struggle, accompanied by opportunities for rich mathematical problem solving, could support excellence and equity in linguistically diverse classrooms. With these ideas in mind, we ask the following research question:

> *How can a focus on growth mindset and productive struggle support mathematical problem solving and rigorous mathematics in linguistically diverse elementary classrooms?*

To address this question, this paper provides: an overview that defines and connects GMS, mathematics, and issues of equity; a description of a GMS action-research project in a linguistically diverse first-grade classroom; lessons learned; and concluding thoughts.

Mindsets, Mathematics, and Equity

A **mindset** is a core belief about oneself and how one learns. Someone with a **fixed mindset** believes intelligence and abilities are unchangeable – that is, one is either good at something or not. Someone with a **growth mindset** (GMS) believes it is possible to grow intelligence and ability through effort; innate qualities are starting points, not endpoints (Dweck, 2006). Importantly, a supportive learning environment can enhance GMS (Boaler, 2013, 2016). Recent research recognizes neuroplasticity – that is, a capacity for brains to grow and change (Boaler, 2016). There is evidence that when people encounter challenges and make mistakes there is increased brain activity; further, brain activity is enhanced by GMS (Boaler, 2016). GMS and productive struggle are aligned with the CCSSM Mathematical Practices – in particular, MP1 – "Make sense of problems and persevere in solving them" (CCSSO & NGA Center, 2010, p. 6). GMS can powerfully impact math teaching and learning, including motivation, reaction to challenge, and responsibility for one's own learning (Boaler, 2013, 2016).

There are persistent negative narratives that mathematics skills and competencies are innate. In contrast, GMS perspectives assert that everyone is capable of learning mathematics with effort and meaningful learning opportunities (Boaler, 2016). However, some critics worry that focusing on GMS (and similar ideas, such as *grit,* Duckworth, 2016) do not consider structural inequities and discrimination that may hide and/or fail to nurture strengths that students possess (Love, 2018; Wormeli, 2018). EB students, as they negotiate more than one language, demonstrate characteristics of GMS; yet, these characteristics may not be recognized or nurtured. We posit that linguistically diverse classrooms can (and should) provide opportunities to help EB students uncover and develop GMS potential not only for language, but also for mathematics.

Growth Mindset Action Research

To provide a sense of what is possible, we describe a small-scale GMS action research project. The context, lesson design, and data sources are described in this section.

Context. The action research project place took place in a first-grade classroom in Eastbrook School (all names are pseudonyms), a K-5, Title I school (i.e., school receiving supplemental federal funds to assist educational goals of students from low-income homes) in the Eastern United States. The state database identified the school population as follows: 79% Hispanic, 85% eligible for free/reduced meals, and 33% English learners (ELs) (EL is a designation for services based on language proficiency assessments; additional students may be bilingual or emerging bilingual). Eleven of the 21 students in the first-grade class came from homes where Spanish was the primary language; seven students were identified as EL students.

Ms. G. (an author of this article) was a Master's intern in an integrated Bachelor's/Master's teacher preparation program. She co-taught the first-grade class three days per week during the 2016-17 academic year. Her co-teacher, Ms. S., was a full-time teacher at the school. They participated in a professional development and research project aimed at enhancing co-teaching and mathematical discourse in linguistically diverse classrooms. Each co-teaching team included an experienced teacher and an intern who had completed student teaching the prior year.

In university coursework, Ms. G. had been learning about growth mindset and mathematics, as well as strategies for teaching in linguistically diverse classrooms. She decided to develop and implement action research aimed at better understanding and improving her teaching practice and her students' educational experiences (Rossman & Rallis, 2003) – specifically, she focused on GMS to improve student perseverance, academic achievement, and enjoyment of learning challenging mathematics. Key components included: teaching students about GMS; providing a classroom environment that reinforced benefits of GMS; and providing opportunities to experience rich mathematical problem solving within a context where productive struggle was recognized and valued. Ms. G. took the lead in planning and teaching seven GMS-focused lessons and three weeks of math challenge station work. Ms. S., her co-teacher, served in various co-teaching roles during the lessons and activities – for example, she assisted during GMS lessons and worked with other students while Ms. G. facilitated the math challenge station.

Growth Mindset Lesson Design. Ms. G. taught seven developmentally appropriate lessons related to the brain, neuroplasticity, and growth mindset. In the first few lessons, Ms. G. taught about neuroscience and plasticity of the brain. Next, students learned about the difference between a fixed mindset and a growth mindset, and how they could adopt a growth mindset. Then, students learned the importance of hard work, making mistakes, and perseverance. Appendix A describes a lesson that involved simulation of neural pathways where students physically represented the neurons and made connections as they shared learning experiences. Table 1 includes examples of topics, objectives, and resources/ methods from the GMS lessons.

Table 1
Examples from GMS Lessons

Example Topics	**Example Objectives:** **Students will be able to …**	**Example Resources & Methods** For all lessons – Supporting visuals and classroom discourse (e.g., whole class, small group and/or partner talk)
The Brain & Grain Growth	• discuss what they already know about the brain • discuss how they can grow their brains	• KWL Chart ("What I **K**now," "What I **W**ant to Know," and "What I **L**earned.") • Read aloud: *Fantastic Elastic Brain: Stretch It, Shape It* (Deak & Ackerley, 2017). • Building modeling clay brain (see Appendix A)
Neural Pathways	• explain how neurons relate to the brain • give examples of things that are challenging for them	• Video: *Ned the neuron: Challenges grow your brain* (see Appendix B) • Neural pathways simulation (see Appendix A)
Mindsets	• categorize phrases that support a growth mindset or a fixed mindset • use hand signals (open/closed) to identify mindset phrases	• Hand signals to represent growth and fixed mindsets (e.g., open, wiggling fingers: open mindset where the brain has room to grow; closed fist: closed mindset where the brain is stuck and can't move.)
Mistakes and brain growth	• explain how making mistakes can make their brains grow. • identify times that they made mistakes	• Read aloud or video: *The Girl Who Never Made Mistakes* (Pett & Rubinstein, 2011)
Power of *Yet*	• discuss things they cannot do *yet*.	• Read aloud: *Giraffes Can't Dance* (Andreae & Parker-Rees, 2016) • Video: Sesame Street *Power of Yet* (see Appendix B)

Supporting Linguistic Diversity. Aligned with recommendations for teaching EBs (and all students), Ms. G. designed activities to be interactive, to make connections to students' lives and learning, to employ multiple modalities (e.g., reading, writing, speaking, drawing, manipulatives, gestures, movement), and to accept written and spoken responses in students' primary language (e.g., García & Wei, 2014; Celedón-Pattichis & Ramirez, 2012; Teemant, Sherman, & Wilson, 2018).

Data Sources. Ms. G. collected and analyzed qualitative data including: GMS lesson plans, video recordings of GMS lessons and challenge station work, student work samples, observational field notes, interviews of selected students (mix of ethnicity, gender, etc.), and her own reflections. To triangulate qualitative data, she administered surveys to students prior to and after the focused GMS experiences. The survey was designed to gauge students' attitudes about intelligence, mistakes, hard work, and challenges. See Appendix C for survey details.

What We Learned

Building on assumptions that EBs demonstrate traits of GMS in their daily lives, we share and discuss what we learned in one linguistically diverse classroom that supported students in uncovering and developing GMS and productive struggle related to mathematics. Our hope is to inspire others to help their students to recognize, develop, and use their potential more fully.

Challenge Station. To focus specifically on math, Ms. G. set up and facilitated a math challenge station for her students to experience rich mathematical tasks that were designed to create opportunities for curiosity, challenge, collaboration, connection making, and creativity. The challenge station was part of a rotation of math stations (Ms. S., the co-teacher, facilitated other math stations). All students participated in the challenge station every couple of days over the course of three weeks. Ms. G. began each small group session with reminders about GMS (e.g., working hard, making mistakes, and tackling challenges grow our brains). She posed the problem, read it, and discussed it with the students. While students explored the problem, Ms. G. observed, listened to, and interacted with the students and encouraged them to interact with each other (e.g., partner talk). She conferenced with students (e.g., asking questions about their thinking and feelings); adapted problem contexts (as needed) to make them more meaningful and accessible; offered feedback; facilitated modeling with visuals, manipulatives, and acting out problems; celebrated productive struggle (e.g., offering high fives and cheers when mistakes were recognized); and provided time for students to struggle, to think, and to practice problem solving. Table 2 shows examples of challenge station tasks and their sources.

Aligned with Boaler's (2016) recommendations for rich math tasks, challenge station tasks included opportunities for *low floor, high ceiling*; *openness*; *inquiry*; *visuals*; and *convincing and reasoning*. For example, the Block Towers task was *low floor* in that students could easily make at least one 3-block tower; was *high ceiling* in that students could stretch to make multiple 3 block towers and/or towers with a greater number of blocks or different color combinations; was *open* by allowing for multiple methods, pathways, and representations; provided opportunities for *inquiry* to explore combinations and identify patterns; included *visual* (and hands-on) components; and asked students to *convince and reason* as they explained their thinking verbally and in writing/drawing. Other challenge station tasks had similar rich math task characteristics.

Observations. Ms. G. observed that over time many students began to share their mistakes as opportunities to learn and also persevered with challenging math problems. To illustrate, we share some of Ms. G.'s observations about María, a Latinx student from a Spanish-speaking family (not identified by the school as an EL). Early on in mid-February, María was somewhat tentative in demeanor and lacking in engagement. Ms. G. observed: "After introducing the

Table 2
Example Challenge Station Tasks and Sources

Example Tasks	Sources
Block Towers: Students are asked how many different block towers can be made with 3 different colored blocks (and then 4 colored blocks).	Adapted from 3 Blocks Towers Task at https://nrich.maths.org/137 and https://www.youcubed.org/tasks/3-block-towers/
Number Combinations: Students are asked to find different ways to make particular sums (decomposing numbers).	This task builds from the Block Towers task, but uses numbers added together to find particular sums (e.g., sums of 6, 10, and 12)
Digging Dinosaurs: Students are asked to find possible number of 2 or 4 legged dinosaurs based on a picture of 8 legs shown underwater.	Adapted from *Inside Mathematics* Problem of the Month: Digging Dinosaurs, https://bit.ly/3tC2h7t

challenge center … she seemed very quiet and shy… Body language was slumped." However, with experience and encouragement, María demonstrated awareness of a problem's challenges, her own mistakes, and her willingness to "try again," as shown in Ms. G.'s notes from early March:

> When I asked her what was challenging about this station, she said, "It was harder towards the end because I kept on building towers that I already had." She carefully compared each new combination she had to blocks she had already built. When she realized that she had a duplicate, she was not upset, she just kept trying. She would work off of what she already had, instead of starting over. I heard her say, "*Ooo! I made a mistake, this one is the same – let me try again*."

María demonstrated productive struggle and a capacity for problem solving – suggesting that she was on her way to being an active "doer of mathematics" (NCSM & TODOS, 2016).

Interviews. Overall, interviews suggested shifts toward recognition and value of GMS. We highlight excerpts from two interviews with Fernando, a Latinx student with Spanish home language (identified as EL), who had moved from Puerto Rico the previous year. First, we share excerpts from Fernando's pre-GMS activities interview with Ms. G.:

Ms. G.:	What do you do when something is really hard? How does that make you feel?
Fernando:	A little frustrated.
Ms. G.:	Why?
Fernando:	Because you have to try and try and that is really, you know… frustrating.
Ms. G.:	Trying really hard is really frustrating? Can you tell me a little more about that?
Fernando:	When I am in a test, it's really hard when I don't know what to do.
Ms. G.:	Would you rather work on something that is easy for you or hard for you?
Fernando:	Easy.

Next, we share excerpts from Fernando's post-GMS activities interview with Ms. G.:

Ms. G.:	Can you tell me a little more about how you feel when something is hard? How does that make you feel?
Fernando:	That makes me feel great because it makes my brain grow.
Ms. G.:	Why does it make your brain grow?
Fernando:	Because my brain is kind of short but it is going to grow, when I do something hard.
Ms. G.:	Since you said that, would you rather do something that is easy for you? Or hard?
Fernando:	Hard because it makes my brain grow stronger.

Fernando seemed to shift his disposition about productive struggle. We contend that he already experienced productive struggle in aspects of his life, but GMS experiences in this classroom may have helped him to uncover and apply them to school experiences. In any case, we enjoyed hearing that he would rather do something hard because it makes his brain grow!

Survey Trends. Consistent with qualitative data, the surveys showed increases in awareness of and appreciation for GMS ideas. Examples: "I like work that I will learn from, even if I make a lot of mistakes" (pre: 9 students; post: 13 students); and, "When something is hard, it makes me want to do it more" (pre: 6 students; post: 13 students). See Appendix C for more details.

Concluding Thoughts

Revisiting the research question, we assert that practices from this first-grade classroom suggest that *a focus on GMS and productive struggle has potential to support mathematical problem solving and rigorous mathematics in linguistically diverse elementary classrooms.* This small-scale action research project does not provide definitive evidence for how best to support EBs with mathematics, but it does suggest practices that are worth pursuing with aims of developing "a positive mathematics identity and affect in students as doers of mathematics" (NCSM & TODOS, 2016, p. 5). Related to these ideas, we reiterate that strengths associated with bilingualism suggest potential for productive struggle and growth mindset that could support mathematical problem solving. We also repeat the concern that mathematics instruction for EB students too frequently focuses on procedures and vocabulary. The action research suggests that teachers can work to capitalize on the strengths of their linguistically diverse students to press for rich mathematical problem solving.

To impact equity and excellence in mathematics, the lessons and activities described in this article are only beginnings. We recognize that it is important to demonstrate positive, growth mindset attitudes *every* day. It is also critical that students have opportunities to engage in rich mathematical problem solving within the context of classrooms that are linguistically responsive. Based on this action research and our experience, we advocate that teachers work to build from students' strengths outside the classroom in order to promote growth mindset and productive struggle within the classroom. We believe that such focus could help students to experience "the tension and enjoy the triumph of discovery" (Pólya, 1945/1985, p. v). with mathematical problem solving. We believe that such experiences support equity and excellence in mathematics and we invite you to browse the resources in Appendix B to support the journey.

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Discussion And Reflection Enhancement (DARE) Post-Reading Questions

1. What are your thoughts about how emerging bilingual students are positioned to engage in productive struggle and problem solving? Have your ideas shifted after reading this article?

2. Many of the practices described in this article could be considered “just good teaching.” How do they relate to issues of equity and excellence – particularly related to emerging bilingual students? (or do they?)

3. What are next steps for you related to using and/or investigating growth mindset ideas to support your students – especially students in linguistically diverse classrooms?

4. What ideas do you have for helping teachers, students, and school systems to recognize that all students should and can persevere; should and can problem solve, and should and can do rigorous mathematics?

5. As a “try this,” we encourage you to explore the resources in Appendix B, discuss them with others, and share other resources that you come across. For example, you might choose a video to view together or rich problems to solve and then to discuss.

Appendix A – Examples from Growth Mindset Lessons

Brainy

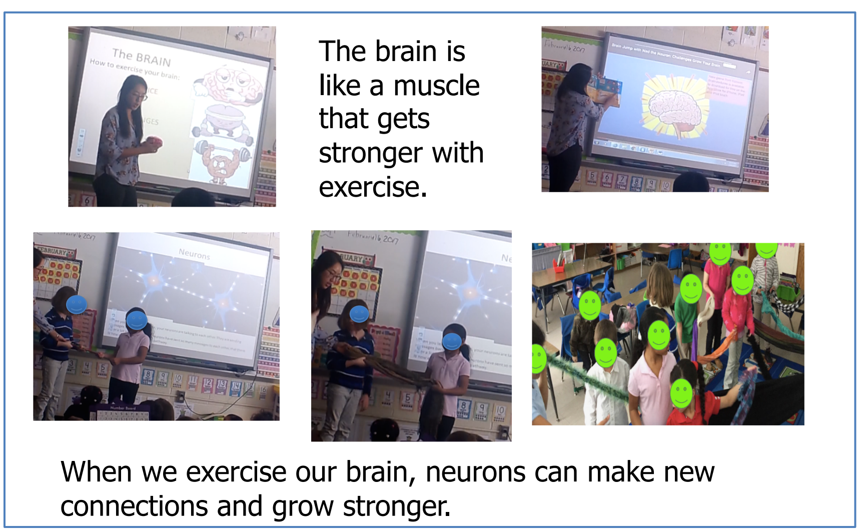
As noted earlier, the first few GMS lessons helped students to learn about neuroscience and plasticity of the brain in developmentally appropriate ways. "Brainy" (made of modeling clay) was an example resource listed in Table 1. In Figure 1, Fernando (mentioned in the article) shows Brainy in the process of being developed. With new learning and challenges, additional coils of modeling clay were added. To show that mistakes "light up the brain," lights were added and that could be blinked on to celebrate mistakes and productive struggle.

Figure 1
"Brainy" (made of modeling clay) was introduced while learning about the brain.

Neural Pathways Lesson

An example lesson mentioned in the article involved a simulation of neural pathways. To begin, Ms. G. asked two students to stand in the front of the classroom to represent neurons, explaining, "When you learn, your neurons are talking together and making connections. When you learned 1+1… your neurons made a connection." Ms. G. gave each student one end of a string to represent connections between the neurons, explaining that thought and learning move through the connections. As they shared other learning experiences, more strings were added to model more neural pathways. As more learning experiences were shared, more students (neurons) joined and strings were replaced with thicker "connections" (e.g., scarves instead of strings). Eventually, all students were connected by the "neural pathways." See Figure 2 for related photos.

Figure 2
Images from growth mindset lessons. Note: Happy faces are used to ensure student anonymity.



Appendix B – Resources

- See the article's reference list for relevant readings.

- Jo Boaler's (2016). *Mathematical Mindsets* book (see reference list) is an excellent mix of research, thought-provoking, and practical ideas related to GMS and math.

- **Youcubed:** https://www.youcubed.org/ This website provides excellent resources to support mathematical mindsets, including videos, tasks, resources, research, and courses. A few examples from the website follow:
  - **Jo Boaler's TedX talk** related to mathematical mindsets: https://www.youcubed.org/resources/jos-tedx-talk/
  - **Growth Mindset Card:** https://www.youcubed.org/wp-content/uploads/2017/03/Mindset-card-with-logo.pdf
  - **Mindset-boosting Videos:** https://www.youcubed.org/resource/mindset-boosting-videos/

- **NRICH enriching mathematics**: https://nrich.maths.org NRICH offers many excellent suggestions and resources for supporting rich mathematics for students.

- **The Mindset Kit**: https://www.mindsetkit.org Free online resource that includes GMS mini-lessons (short videos), sample lesson plans, discussion boards, links to articles, activities, etc.

- **Example Videos for Students:**
  - *Brain Jump with Ned the Neuron: Challenges Grow Your Brain*
    https://www.youtube.com/watch?v=g7FdMi03CzI
  - *Sesame Street do Growth Mindset*
    https://www.youtube.com/watch?v=SnrHZ_uvtxk
  - *Sesame Street: Power of Yet*
    https://www.youtube.com/watch?v=XLeUvZvuvAs
  - *Growth Mindset for Students* – Episode 1/5 (Class Dojo) https://www.youtube.com/watch?v=2zrtHt3bBmQ
  - *Meet the Robinsons—You Failed!*
    https://www.youtube.com/watch?v=AWtRadR4zYM

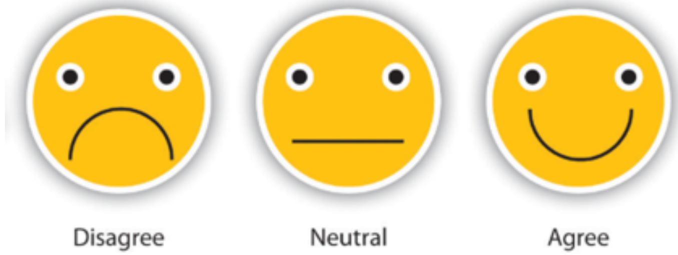
- **See Read-aloud Books in Table 1 and the Reference List.**

Appendix C – Pre- and Post-Survey Information

The survey was adapted from one available at MindsetWorks, a company co-founded by Carol Dweck (https://www.mindsetworks.com/). The original survey was intended for people aged 12 and older so Ms. G. simplified the wording, included picture icons, and asked the questions orally – to make it more developmentally appropriate for first-grade students in this linguistically diverse classroom. The questions used are listed below. The questions followed by asterisks (**) are ones that had more variability than the others.

First-Grade Growth Mindset Survey Questions

Suggestion: Focus on highlighted statements (**) because they seemed to have more variability across student responses.



- I am smart.
- I can change how smart I am.
- I like doing work that makes me think hard.
- I like doing work that is easy for me.
- I like work that I will learn from, even if I make a lot of mistakes. **
- I like my work best when I can do it perfectly without any mistakes.**
- When something is hard it makes me want to do it more.**
- When something is hard I don't want to do it, or I give up. **
- When I work hard it makes me feel like I am not smart. **

The surveys were administered to all students for whom consent forms were received and who were available on the days that the surveys were administered. Due to absences or incomplete pre- or post-surveys, data for 16 of the 21 students were analyzed. Although the sample was small and the intervention was relatively short-term, the data (surveys, interviews, observations, and student work) suggest positive trends for enhanced awareness of GMS and productive struggle. For example, there were shifts in the number of positive responses to survey questions such as, "I like work that I will learn from, even if I make a lot of mistakes," (pre: 9 students [56%]; post: 13 students [81%]) and, "When something is hard, it makes me want to do it more" (pre: 6 students [38%]; post: 13 students [81%]). All survey items showed decreases in fixed mindset responses; all except one survey item showed increases in growth mindset responses, with one response staying the same.

POETRY CORNER

In his latest mathematical poem that begins on the next page,
Lawrence Lesser (The University of Texas at El Paso) makes serious and playful reflections
about cancelling in the school mathematics curriculum,
with additional connections to our greater world.