6-2021

# Handbook of Research on Transforming Teachers' Online Pedagogical Reasoning for Engaging K-12 Students in Virtual Learning

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# Chapter 20
# Transforming K–12 Mathematics Classroom Teacher Pedagogy Through Virtual Number Talks

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## ABSTRACT

*Number Talks is a popular K-12 mathematics routine utilized in classrooms across the United States. Number Talks allows teachers to elicit and respond to students' mathematical thinking through the development of an encouraging classroom community and provide opportunities for students to engage in critical thinking, collaboration, communication, and creativity. In this chapter, the authors report their "virtualization" of the Number Talks routine and the development of a teacher learning cycle that supports implementation of this practice. The virtualization of Number Talks is illustrated through the pedagogical transformation of one teacher, who begins the teacher learning cycle skeptical of the value of Number Talks and ends with an innovative Virtual Number Talks practice that benefited both students and teachers in her school. This teacher's implementation of Virtual Number Talks and engagement in the "4C" of 21st century learning demonstrate a transformation of pedagogy that uses technology to create rich online mathematics learning experiences.*

DOI: 10.4018/978-1-7998-7222-1.ch020

## INTRODUCTION

Few, if any, common face-to-face classroom mathematics routines are considered widely for virtual implementation. Further, little, if any, initial teacher preparation or continuing education and professional development courses account for virtual teaching and learning of K-12 mathematics. Yet both—considerations for implementing common classroom mathematics routines online and teacher preparation for virtual environments–have become especially important due to the ongoing global pandemic and the rapid shift to and continued prominence of online teaching and learning. Transitioning classroom routines from face-to-face settings to virtual spaces can allow for continuity of instruction and assurance that instruction continues to focus on content. Further, when comparing online learning to face-to-face, there become novel approaches to instruction and learning not previously available. Perhaps in the most basic sense, technology can be used to replicate physical tools or face-to-face instructional activities with digital tools or environments with "no functional change" (Puentedura, 2013). That is, the technology provides a nearly direct *substitution* for the face-to-face routine (Puentedura, 2013) that is *replicated* nearly unchanged (Wang & Torrisi-Steele, 2015). At the other end of the spectrum, technology may be used to *redefine* in-person instruction (Puentedura, 2013), such that the virtual routine is a *transformation* of the face-to-face routine (Baran et al., 2011). One such redefinition is to use the technology in instructional activities in ways previously not envisioned with physical tools, thus a *transformation* of instructional activities through technology (Barlow et al., 2020). Regardless of the particular technology (e.g., applications) chosen to move instructional routines online, infusion of technology in classroom practice increases the demand on teacher knowledge and expertise.

In this chapter, the authors argue that starting with a common classroom routine and supporting teachers' learning specifically of this activity for virtual implementation provides technology-specific learning and skill development opportunities for virtual field experience. The development of these types of learning and skills began with the selection of a classroom routine that engages teachers in pedagogical, content, and the more specific and intersecting pedagogical content knowledge (Shulman, 1986) and connects students to essential content and skills for the 21st century (e.g., the "4Cs," National Education Association, 2012).

## BACKGROUND

Number Talks are a K-12 mathematics classroom routine that engages students in 5- to 15-minute discussions about the mental mathematics strategies used to solve intentionally designed computational problems (Humphreys & Parker, 2015; Parrish, 2010; Parrish & Dominick, 2016; Sun et al., 2018). These "short, mathematical, whole-class discussions during which students solve problems and share their ways of seeing and reasoning about mathematics" (Gerstenschlager & Strayer, 2019, p. 363) were first introduced in the mid-1990s (Humphreys & Parker, 2015). General internet searches of "Number Talks" deliver millions of results, reflecting popularity and interest that has grown over the past few decades (Flick & Kuchey, 2015). Matney et al. (2020) referred to the proliferation of Number Talks "among teachers, schools, districts, within professional development communities, and on social media" (p. 1) and the common acceptance of Number Talks as an effective classroom instructional routine.

For a Number Talk, teachers typically select or design problems to be solved mentally (in the sense of Parrish's (2010) *Number Talks: Helping Children Build Mental Math and Computation Strategies,*

*Grades K-5*). Students use normed hand signals (e.g., "silent thumbs" Sun et al., 2018) to communicate they are thinking, have a solution, and have one or more solution strategies. The teacher first solicits solutions, recording them on the board. Then, a conversation about students' strategies follows. Students are tasked to communicate their mathematical thinking, justifying their solutions and strategies (Gerstenschlager & Strayer, 2019; Parrish, 2011). While students offer their thinking verbally, the teacher's role is as a facilitator, to guide student thinking with purposeful questioning. Through recording of students' strategies, the teacher also supports comparisons and connections between strategies.

Number Talks were selected as the classroom routine for teachers to implement online for a variety of reasons. One motive for utilizing Number Talks extends to Matney et al.'s (2020) assertion that the Number Talks "instructional practice is dense with probability and richness – found to be valuable by many teachers" (p. 6). Further, teachers would be allowed ample opportunity for technology skill development with the implementation of frequent Number Talks. Given that the routine is short, and that teachers are encouraged to implement them frequently when face-to-face, an iterative cycle of teacher learning that includes implementation of Number Talks would not be unreasonable. However, the main purpose for selecting Number Talks for a virtual field experience was the clear opportunity Number Talks provide for teachers to engage in teaching routines identified as "necessary to promote deep learning of mathematics" (National Council of Teachers of Mathematics, 2014), such as, "implement tasks that promote reasoning and problem solving, facilitate meaningful mathematical discourse, pose purposeful questions, build procedural fluency from conceptual understanding, support productive struggle in learning mathematics, and elicit and use evidence of student thinking" (p. 9).

To support teachers' learning and skill development for implementation of Number Talks in online settings, referred to as Virtual Number Talks, a Virtual Number Talks Teacher Learning Cycle (VNT TLC) was designed by the authors. The VNT TLC was implemented in pre- and in-service teacher education courses, resulting in teachers' iterative planning, implementing, and reflecting on their own Virtual Number Talks with K-12 students (Joswick et al., 2020). The VNT TLC serves as a foundation for transforming teachers' knowledge for teaching mathematics, especially online. The impact of the VNT TLC is illustrated through the transformation of one teacher's pedagogy, who was at first skeptical of Number Talks and ends up with an innovative Virtual Number Talks routine, which benefits all Grade 6 teachers and students in her school. The authors suggest transforming K-12 mathematics classroom teacher pedagogy through a "virtualization" of routines: the co-development of classroom routines that are planned for, tested, and implemented in virtual environments and the infusion of virtual teaching and learning of K-12 mathematics in initial teacher preparation or continuing education and professional development courses.

In virtualizing classroom routines, the SAMR (Substitution, Augmentation, Modification, and Redefinition) model (Puentedura, 2013) describes ways to *enhance* or *transform* classroom practices for online learning. Recently, the SAMR framework has been used to describe technology use within virtual classrooms during the rapid shift to remote instruction due to COVID-19 (Barlow et al., 2020). The first of the SAMR model's four categories is *substitution,* where technology tools are used to replicate physical tools or interactions with no fundamental change to the instructional activity (Puentedura, 2013). The second of the framework's categories is *augmentation*, where replication of face-to-face instruction with tech tools or environments has improved the task in some way. *Modification,* the third category in the SAMR model, describes use of technology that calls for substantial redesign of in-person instructional tasks, and *redefinition,* the fourth category in the framework, refers to implementation of technology in instructional activities that were previously not possible with physical tools. Taken together, the *substitu-*

*tion* and *augmentation* categories have described technology use that *enhances* instructional activities, and *modification* and *redefinition* refer to technology use that *transforms* instructional activities (Barlow et al., 2020).

## Key Elements of Number Talks

To operationalize Number Talks for teachers, teacher training, and students, the authors have enumerated four key elements as shown in the Table 1: classroom environment and community; purposeful computation problems; class record; and class discussion. This list is a synthesis and adaptation of those found in Parrish (2010, 2011), Sun et al. (2018), and Matney et al. (2020).

*Table 1. Key elements of Number Talks*

| Key Elements | Teachers | K-12 Students |
|---|---|---|
| 1. Classroom Environment and Community | • Create a physical space in the classroom to gather for the talk (e.g. sitting on a rug, sitting at desks), which includes a display board (e.g. whiteboard) and allows students to interact with the teacher and each other easily<br>• Collaboratively develop with students a culture of sharing one's ideas, listening to peers, attempting to mentally solve problems, and asking questions<br>• Establish norms for Number Talk interactions (e.g. "silent thumbs" or hand signals, ways to volunteer to speak), and share the routine process with students | • Collaboratively develop, with the teacher and peers, a culture of sharing one's ideas, listening to peers, attempting to mentally solve problems, and asking questions<br>• Learn norms for Number Talk interactions (e.g. "silent thumbs" or hand signals, ways to volunteer to speak), and the routine process generally |
| 2. Purposeful Computation Problems | • Select or design a sequence of problems that can be computed mentally and is appropriate for students | • Solve problems mentally<br>• Reflect on strategy used to solve and other possible solution strategies<br>• Cue the teacher to communicate solutions and strategies have been developed |
| 3. Class Record | • Use a display board to show the problem or sequence of problems to all students<br>• Record student solutions and strategies on the display board using equations or visual models, accurately representing student thinking<br>• Organize the record for ease of reference during the discussion | |
| 4. Class Discussion | • Provide wait time between posing the problem and soliciting student solutions<br>• Elicit solutions from the students<br>• Elicit strategies, justification, agreement, and disagreement from students, seeking multiple strategies<br>• Encourage student communication<br>• Do not engage in direct instruction<br>• "Accept, respect, and consider all answers" (Parrish, 2011)<br>• Pose productive questions<br>• Facilitate conversation that considers connections between strategies or between strategies and visual models | • Share thinking, solutions, and strategies with peers and teacher<br>• "Accept, respect, and consider all answers" (Parrish, 2011)<br>• Show agreement or disagreement with peers<br>• Defend answers, work to notice similarities/differences in answers |

## Mathematical Content and Skill

Number Talks, as an instructional strategy, inherently allow teachers to facilitate mathematical discussions and engage students in meaningful interactions and sense-making. Number talks are rooted in student investigation of multiple strategies (Parrish, 2011). Conversations focused on student thinking and sense making (SMP 2: Reason Abstractly & Quantitatively and SMP 3: Construct viable arguments and critique the reasoning of others, National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) give opportunities for students to discuss developing conceptions, compare ideas with one another, and make connections between strategies (Parrish, 2011; Sun et al., 2018). Through the discussion of multiple strategies, Number Talks have the potential to help address misconceptions and limited, procedural views of mathematics, which Sun and colleagues (2018) argue contribute to gaps in students' basic understanding of number and operations.

Number and operations concepts and skills are a major emphasis of K-12 mathematics teaching and learning. By grade 12, every student should be enabled to "understand numbers, ways of representing numbers, relationships among numbers, and number systems," "understand meanings of operations and how they relate to one another," and "compute fluently and make reasonable estimates" (National Council of Teachers of Mathematics, 2000). While Number Talks can be used at all grades to support essential mathematics content and skill development, Number Talks are not tied directly to curricula. Teachers can plan and implement Number Talks that augment their existing curriculum to support the needs of their particular students. By providing a venue in which students can share and discuss their solution strategies, Number Talks create opportunities for students to "clarify thinking, investigate and apply mathematical relationships, build a repertoire of efficient strategies, make decisions about choosing efficient strategies for specific problems, and consider and test other strategies to see if they are mathematically logical" (Parrish, 2011, p. 203). Sun et al. (2018) elaborate that by engaging in Number Talks, student engagement, along with content, is supported.

## Twenty-First Century Skills

The Number Talks mathematics classroom routine embodies the "4Cs": *communication, collaboration, critical thinking,* and *creativity* (National Education Association, 2012). During Number Talks, students mentally solve computation problems (*critical thinking* and *creativity*) and communicate their solutions and strategies to their peers and teacher (*communication* and *collaboration*). Students make sense of strategies and explore connections between strategies throughout the discussion (*creativity, communication,* and *critical thinking*). Teachers must clearly *communicate* their expectations for the students and the problems to solve, in addition to asking probing questions that elicit student ideas. The norms used to set Number Talks expectations support student and teacher *collaboration*. Teachers use *critical thinking* and *creativity* to carefully select productive problems to pose and further *critical thinking* and *communication* to translate students' verbal solutions to written representations for all to see.

# "VIRTUALIZATION" OF NUMBER TALKS

When faced with the global pandemic and the rapid shift to and continued prominence of online teaching and learning, the authors conceptualized the "virtualization" of mathematics classroom routines. This

"virtualization" has two distinct, yet interrelated parts. The first part is to virtualize a common face-to-face classroom routine—that is, to reimagine the routine for virtual teaching and learning. This is the definition of Virtual Number Talks. The second part is to reimagine teacher preparation and training to include this new virtual classroom routine embedded in a Teacher Learning Cycle.

As previously discussed, in K-12 mathematics teaching, Number Talks (Humphreys & Parker, 2015; Parrish, 2010) are a commonly used, face-to-face classroom routine (Matney et al., 2020). The authors contend that essential elements of Number Talks, such as the focus on mental mathematics that, therefore, may not require students to have writing implements or share written work, make the routine particularly productive for online environments. Further, since Number Talks need not be directly tied to regular classroom content (Sun et al., 2018), this routine is especially suitable for virtualization.

Number Talks present a unique learning opportunity for mathematics teachers, challenging their pedagogical and content knowledge (Mishra & Koehler, 2006; Shulman, 1986). Implementing these in classrooms with K-12 students provides a rich opportunity for teacher learning and development. Pre-service and in-service mathematics teacher education courses and professional development often include this routine, especially emphasizing important pedagogical content knowledge (Shulman, 1986) specific to cultivating rich classroom mathematical discourse and community, which includes eliciting and responding to students' conceptualizations (Parrish, 2011). Implementing this routine online requires additional technology-specific knowledge and skill, subsequently addressed in the Teacher Learning Cycle.

## Virtual Number Talks

Virtual Number Talks are an adaptation of the face-to-face mathematics classroom Number Talks routine for online environments. To implement Virtual Number Talks, planning for technology use must be made in addition to standard instructional planning that would be required for Number Talks. When planning face-to-face Number Talks, a teacher must consider the physical space for the discussion, where students can see the classroom board with the problem. When planning Virtual Number Talks, this consideration is modified. For example, the teacher may need to plan for conferencing software (e.g., Zoom) and a display (e.g., Google Slides). There are four main technology planning considerations—student hardware, video conferencing software, displays, and interaction tools—which are elaborated in Table 2.

Recall, in a very basic sense, technology can be used to replicate physical tools or face-to-face instructional activities with digital tools or environments with "no functional change;" that is, the technology provides a nearly direct *substitution* (Puentedura, 2013) for the face-to-face routine that is *replicated* (Wang & Torrisi-Steele, 2015) nearly unchanged. This idea is illustrated with an excerpt from Mr. Rodrigo's virtual fifth grade classroom. The students had technology hardware allowing them to be on video, while the class was connected through Zoom conferencing software. The teacher used the conferencing software digital whiteboard as a display and traditional Number Talks hand signals were used for interactions.

*Table 2. Virtual Number Talks technology planning considerations*

| Technology | Guiding Questions | Potential Tools | Considerations |
|---|---|---|---|
| Student Hardware | What devices will your students have access to during the Virtual Number Talk? | Smart Phone<br>Table<br>Stylus<br>Computer<br>Web<br>Camera and Microphone (built in or external) | • Which tools do you and your students have access to?<br>• Do you need to teach students how to use their devices?<br>• Do students have access to cameras and microphones?<br>• Will students write with a mouse/trackpad, on a touch screen device, or with a stylus? Is the device screen large enough for students to write on and view their writing?<br>• Do students have the fine motor skills needed to write/type? |
| Video Conferencing Software | How will you and your students meet for the Virtual Number Talk? | Zoom<br>Microsoft Teams<br>Google Meet | • What conferencing software does your school allow? What conferencing software are you and your students most familiar with?<br>• Does your conferencing software allow for breakout rooms?<br>• What reaction buttons are available in your conferencing software? |
| Displays | How will you display the Virtual Number Talk problems to students? | Paper/Whiteboard<br>Document Camera<br>Google Slides/ PowerPoint<br>Digital Whiteboard (e.g., Jamboard, whiteboard.fi)<br>Desmos Activity | • Which tools are you and your students most familiar with?<br>• Will you use visual models in your Number Talk? Are you able to create the visual models on paper or a digital white board? Will you use static or dynamic visual models?<br>• Will you display problems by sharing your screen or by sending a link to an app (e.g. Google slides)? Are your students able to toggle between multiple screens? |
| Interaction tools | How will you elicit and record student thinking? | Conferencing Software features (e.g., breakout rooms, chat)<br>Desmos<br>Nearpod<br>Digital Whiteboard/ Writing space (e.g., Jamboard, whiteboard.fi, Google Slides) | • Will you use traditional Number Talk hand signals or reaction buttons for students to indicate solutions or strategies?<br>• Will the discussion be solely whole group, or will you incorporate turn-and-talk via breakout rooms?<br>• Will students share strategies and solutions verbally? Via chat? Via another tool (e.g. Desmos, Nearpod, digital whiteboard)?<br>• Will students work on the same task at the same time, or do you want to incorporate flexible pacing?<br>• Will the teacher record student thinking, or will students record their own thinking? |

**Mr. Rodrigo:** *[Students were just challenged to use mental math to individually solve a task, which was presented on their screens through the whiteboard feature. Mr. Rodrigo observes students' hand signals, showing a "thinking" fist]. Cesar, Francie, and Juan are still thinking.*

[Valeria has a thumb up]. *I see Valeria has a solution and strategy for four minus one and one fourth.*

[Alejandro has a thumb and finger uncurled from his fist]. *Alejandro has a solution and at least two strategies.*

[All students now show hand signals with solutions and strategy ideas.] *Oh! Cesar, Francie, and Juan, you all have solutions now! Great!*

*I'd like to hear just the solution, just the answer to four minus one and one fourth from…Miguel. Miguel, will you "unmute" and answer please?*

**Miguel:** *I got two and three fourths.* [Students use sign language to show they agree with Miguel's solution.]

**Mr. Rodrigo:** *I see lots of agreement with Miguel. Miguel said the answer is "two and three fourths."* [Mr. Rodrigo writes "$2\frac{3}{4}$" on the digital whiteboard.]

*Use the 'raised hand' reaction feature if you have a different answer.* [Waits and no hands are raised.] *So, we all got two and three fourths.*

*Okay, Sara, will you share a strategy with us? Tell us a way you solved this problem. Go ahead and 'unmute.'*

[The teacher continued to facilitate a conversation with students during which they shared multiple ways of solving $4 - 1\frac{1}{4}$. Through careful questioning, Mr. Rodrigo's instructional goal was to help students develop an understanding of more sophisticated strategies and make connections between different solution strategies.]

Conferencing software features such as reactions buttons and chats can be used in Virtual Number Talks. These can replace traditional interactions, like hand signals, and allow students to participate without video, or even without speaking. Turn-and-talk procedures (Chapin et al., 2009) commonly used in Number Talks can also be implemented in Virtual Number Talks using breakout room features offered in conferencing software. While a nearly direct *substitution* (Puentedura, 2013) for the face-to-face Number Talks routine is possible, *augmentations* (Puentedura, 2013) to the routine using technology may improve or *enhance* the routine in some way. Using the chat feature may encourage a student, who might otherwise not choose to speak in a face-to-face environment, to contribute their thinking to the Virtual Number Talks conversation.

A different approach to the *replication*-type use of technology for Virtual Number Talks is the use of technology which *transforms* (Baran et al., 2011) the face-to-face routine, yet maintains the essential elements of Number Talks, including teachers' opportunity to elicit and attend to student mathematical thinking (Parrish, 2011). Technology use may *modify* or *redefine* the face-to-face routine (Puentedura, 2013).

## Virtual Number Talks Teacher Learning Cycle

The Virtual Number Talks Project (Joswick et al., 2020) adapts Teacher Education by Design's principles and learning cycle (University of Washington, 2014) to support teachers in the implementation of this virtual classroom routine. The VNT TLC (as outlined in Table 3) has four main components: (a) learning, (b) planning, (c) implementing, and (d) assessing and reflecting. The components were designed such that multiple iterations, with variations, can be completed. That is, a teacher may go through multiple iterations of learning, planning, implementing, assessing, and reflecting; the total number of iterations can be adapted as desired. Variations of each iteration may include different configurations of people (e.g., individually, in small groups and large groups of peers and colleagues, and with K-12 students) and specific learning goals (e.g., further development of questioning practices).

*Table 3. Virtual Number Talks Teacher Learning Cycle (adapted from Joswick et al., 2020)*

| Component | Description |
|---|---|
| Learning | • Read about and discuss the theoretical basis of Number Talks<br>• Watch and discuss videos of K-12 Number Talks<br>• Explore technology and Virtual Number Talk resources (e.g. technology suggestions)<br>• Read about and discuss related content and pedagogical topics (e.g. questioning, connecting strategies) |
| Planning | • Select problems for Virtual Number Talk provided resources<br>• Identify technology to use when enacting Virtual Number Talk (consider student hardware, video conferencing software, displays, and interaction tools)<br>• Devise full Virtual Number Talk plan, including anticipating student solutions and strategies, questions to ask, etc., utilize planning guide<br>• Revisit previous TLC reflections |
| Implementing | • Implement rehearsal Virtual Number Talk with peers/colleagues, testing plans, and especially technology use<br>• Implement Virtual Number Talk with K-12 students<br>• Video record Virtual Number Talks for peer and self-review |
| Assessing and Reflecting | • Give and receive feedback from peers/instructor on Virtual Number Talk video, utilizing guiding questions<br>• Watch Virtual Number Talk Video and reflect on Virtual Number Talk implementation and iteration of TLC, considering eliciting student thinking, supporting students to make sense of others' thinking, setting norms, questioning, recording student strategies with equations or visual models, connecting strategies, and implementing technology tools<br>• Identify what went well and improvement from previous VNT TLC iterations<br>• Identify changes and goals for future implementation |

To illustrate the VNT TLC, consider an introductory or first iteration of the cycle. For learning, teachers could read about Number Talks (e.g., Parrish, 2011) and watch videos of Number Talks (e.g., from Inside Mathematics). Teachers could write about their learning and discuss with their peers, in person or through online discussion forums. In the planning stage, the teachers could consider what an appropriate Number Talks would be for their students, follow an established planning guide (e.g., The Learning Space, n.d.), and then consider how their implementation of the Number Talks could be facilitated in the virtual space. As previously discussed, technology considerations may include student hardware, video conferencing software, displays, and interaction tools. Further writing and discussing of these plans could take place. For the implementation phase, teachers could meet in small groups, online, and try to enact their Virtual Number Talks as planned, using each other as students. This Virtual Number

Talks rehearsal (see Horn, 2010 for more on rehearsals) affords teachers the opportunity to practice their Virtual Number Talks facilitation, including a test of their technology plans. Each teacher in the small group would have the opportunity to lead, to participate in the talk as a student, and to give and receive feedback on their rehearsal. With video records of their meetings, teachers and their peers can revisit the rehearsal Virtual Number Talks and assess elements like opportunities for students to share strategies, the teachers' recording of student thinking, and the actual facilitation compared to the written plans. As a final step, and in preparation for another iteration of the VNT TLC, teachers reflect on the assessment of the Virtual Number Talks, their learning through the TLC iteration, and set goals for growth and improvement. This written reflection becomes a reference in their future learning and planning.

## The Virtual Number Talks Project

The VNT TLC has been implemented in four mathematics teacher education courses that varied in audience, including initial teacher preparation and the continuing education and professional development of practicing teachers (most of whom were unfamiliar with Number Talks), undergraduate and graduate levels, grade/content bands (K-6, PreK-8, and PreK-12), institution location, and course modality (asynchronous and synchronous online and hybrid learning environments). Each course had a required field experience component that was challenging to fulfill traditionally during the global pandemic and was replaced with online experiences such as facilitating Virtual Number Talks with K-12 students. The number of iterations and goals for each iteration of the TLC varied across classes. To date, 184 pre- and in-service teachers have completed 395 Virtual Number Talks with over 1000 K-12 students.

## Illustrating the VNT TLC in Practice: Ms. Janet

Ms. Janet participated in the VNT TLC as part of the coursework for a master's level pedagogical content course for in-service mathematics teachers in autumn 2020. The full series of VNT TLC assignments implemented in the course is illustrated in Table 4. At the time, Ms. Janet was in her first year of teaching sixth grade mathematics virtually at a Title 1 middle school in a self-contained bilingual classroom. Ms. Janet holds an early childhood through 6th grade generalist certification and had four years of teaching experience. Most of her prior experience was teaching bilingual third grade students in a self-contained classroom at a charter school. To illustrate the VNT TLC in practice, Ms. Janet's experience with assignments aligned with each of the five main components of the VNT TLC is described.

### Individual and Peer Group Learning

During the individual learning phase of the VNT TLC, teachers engage with readings and videos that introduce the theoretical basis, application, and use of Number Talks in the classroom. The accompanying reflection assignment focuses on the major components of a Number Talk such as the development of a safe community of learners, facilitation of mathematical discussion, procedures for sharing and assessing student thinking, and the teacher's role during facilitation (Parrish, 2011; Sun et al., 2018).

*Table 4. Ms. Janet's Virtual Number Talk Teacher Learning Cycle assignments*

| Assignment Number and TLC Component | Teachers will… | By… | To… |
|---|---|---|---|
| 1. *Individual* Learning | Understand the theoretical basis, application, and use of Number Talks in the mathematics classroom. | Reading an article and watching a video Number Talk example, responding to written reflection prompts. | Activate prior knowledge, experience, and develop a substantial background in Number Talks. |
| 2. *Peer Group* Learning | Develop an advanced understanding of Number Talks. | Watching and reading more on Number Talks, and following prompts to engage with peers in discussion. | Further develop background knowledge of Number Talks, and begin conceptualizing implementation of a Number Talk with own selected students. |
| 3. *Individual* Planning | Analyze various technological modalities and mathematical content for implementation of a Virtual Number Talk. | Watching a Virtual Number Talk and investigating resources for teaching and learning online. | Prepare for a Virtual Number Talk rehearsal that will be completed with peers. |
| 4. *Peer Group* Implementation | Illustrate, discuss, and compare various approaches to a Virtual Number Talk amongst peers. | Facilitating a Virtual Number Talk with a small group of peers that is recorded. | Practice the first Virtual Number Talk that will be done with K-12 students. |
| 5. *Individual* Self-Assessing, Reflecting, & *Individual* Planning | Review and reflect on the experience of conducting their first Virtual Number Talk with peers. | Watching their own Virtual Number Talk rehearsal video and responding to written reflection prompts. | Learn from Assignment 4 experience and adjust plans as needed for first Virtual Number Talk with students. |
| 6. *Peer Group* Learning & *Individual* Planning | Develop a deeper understanding of norms for classroom discussions. | Watching and reading on norms for classroom discussions, and following prompts to engage with peers in discussion. | Further refine plans for first Virtual Number Talk with students. |
| 7. *K-12 Student* Implementation | Facilitate first Virtual Number Talk with K-12 students. | | |
| *8. Peer Group* Learning & *Individual Planning* | Provide peer-feedback on colleagues' first Virtual Number Talk. | Watch colleagues' first Virtual Number Talk video, reading their plans, and completing an observation protocol. | Receive feedback on implementation of first Virtual Number Talk. |
| *9. Individual* Reflecting & Planning | Reflect on first Virtual Number Talk, peer feedback, and learning thus far in the TLC. | Complete a reflection journal with specific prompts. | Create goals and begin planning for the second Virtual Number Talk. |
| *10.Peer Group* Learning & *Individual* Planning | Develop a deeper understanding of relevant student strategies. | Watching and reading more on student strategies, and following prompts to engage with peers in discussion. | Further refine plans for second Virtual Number Talk with students. |
| *11.Peer Group* Implementation & Peer-assessing | Illustrate, discuss, and compare various approaches to another Virtual Number Talk amongst peers. | Facilitating a second Virtual Number Talk with a small group of peers that is recorded.<br>Watching colleagues' second Virtual Number Talk rehearsal video, reading their plans, and completing an observation protocol. | Practice the second Virtual Number Talk that will be done with K-12 students.<br>Receive feedback on implementation of second Virtual Number Talk rehearsal. |
| *12. Individual* Self-assessing, Reflecting, & Planning | Reflect on second Virtual Number Talk rehearsal peer feedback, and learning thus far in the TLC. | Watching their own second Virtual Number Talk rehearsal video and completing an observation protocol. Complete a reflection journal with specific prompts. | Further refine plans for second Virtual Number Talk with students. |

Before engaging with the readings and video, Ms. Janet described her prior experience with Number Talks. Her previous school sent teachers to a Number Talks professional development, and she had facilitated the routine in her third grade classroom. Ms. Janet felt that the routine was effective for students who were comfortable with academic language and who had conceptual understanding of mathematics; however, she felt that the routine did not benefit all students, particularly those who are English Language Learners (ELLs) or who have a more procedural understanding of mathematics. "I noticed that it made a lot of my students who struggle quite insecure and overwhelmed listening to their peers explain their mental process" (Assignment 1). She described the implementation of Number Talks as "easy" but noted that "the same students were always the ones solving or participating" (Assignment 1). After engaging with the reading framing Number Talks with a theoretical base and watching a video of an exemplar Number Talk, Ms. Janet described the routine as one "that encourages mental math and strengthens numerical reasoning, while building community" (Assignment 1).

In the peer group learning phase of the VNT TLC, teachers read another article about Number Talks, watched additional videos of exemplar Number Talks, and then engaged with peers through discussion boards. Teachers were prompted to discuss their questions and anticipated challenges of facilitating the routine. This assignment allowed teachers to further develop their knowledge of the Number Talks routine, to brainstorm initial ideas for conducting their own virtual Number Talks, and to discuss implementation ideas with their peers.

As Ms. Janet engaged with peers in the discussion board, she expressed again concerns about implementing Number Talks with ELLs and students who rely on mathematical procedures, and she expressed concern about implementing the routine in a virtual setting. Ms. Janet also described facilitation strategies she learned through the reading and videos. In particular, she felt that having students discuss strategies through the Think/Pair/Share routine could improve Number Talk implementation. Ms. Janet wrapped up her discussion board engagement by stating that "I'm still not crazy about number talks but I am excited to challenge myself to making it work for my ELLS" (Assignment 2).

## Planning

In the first iteration of the VNT TLC, planning assignment prompts focused on the major components of a Number Talk: problem selection, anticipation of student strategies, and questioning techniques. Teachers were also prompted to consider the technology tools they would use for eliciting student participation and recording student strategies on screen. Ms. Janet selected 13+17 and 22+32 as the problems for her first virtual Number Talk. She did not provide anticipated student strategies for these problems, and she listed primarily general, binary response questions to facilitate student discussion during the Number Talk: "Would someone like to share their answer?" "Is there another way to solve?" "Which strategy was easier for you?" "Can you expand on that?" (Assignment 3). Ms. Janet expressed apprehension about implementing the virtual Number Talk due to her school's "very strict virtual learning structure" (Assignment 3). Ms. Janet planned a replication (Puentedura, 2013) of a traditional Number Talk by facilitating the routine synchronously on Zoom and using the whiteboard feature to record students' strategies. Ms. Janet did not include details of how she would use the technology to record strategies or elicit student participation.

## Peer Group and K-12 Implementation

In the peer group implementation phase of the VNT TLC, teachers engaged in rehearsals of their virtual Number Talks. Teaching rehearsals create opportunities for both "teachers' collaborative pedagogical problem solving" and "emotional support for the teaching problems" (Horn, 2010, p. 234-235). Only one other peer attended Ms. Janet's peer group meeting for the rehearsal assignment, so Ms. Janet and her peer used the meeting to engage in an in-depth discussion and trial of the technology tools they planned to use for their Virtual Number Talks. Ms. Janet described her plan to use the video conferencing software's whiteboard feature and demonstrated use of textboxes to type students' strategies to avoid the challenges of writing or drawing with a track pad. She demonstrated writing students' names next to their strategy and allowing students to add hearts or emojis on the whiteboard to show agreement with a strategy. Ms. Janet and her peer discussed strategies for creating a safe classroom environment such as not requiring camera use so students that share would not "feel like everybody's watching them" (Assignment 4). Ms. Janet's peer was extremely positive and supportive of Ms. Janet's ideas, and communication between the two was professional, cordial, and personal.

In the K-12 student implementation phase of the VNT TLC, teachers apply knowledge gained through the learning and planning phases by facilitating a virtual Number Talk with K-12 students. After engaging in the learning, reflecting, collaborating, and refining prompted by the initial phases of the VNT TLC, Ms. Janet revamped her initial Number Talk plan. Instead of replicating an in-person Number Talk on Zoom, she utilized technology in a novel way to transform the routine for the online environment. An illustration of Ms. Janet's facilitation of a Virtual Number Talk using the technological tool Flipgrid, an app that allows users to record short videos and respond to one another through typed or video recorded comments, is provided (Assignment 7).

**Ms. Janet:** *Alright class, for today's homework, we are going to do another Number Talk using Flipgrid. Remember, I am not asking you for just the answer. I am asking you to tell us how many ways you can solve this problem. The problem we are discussing in Flipgrid is how many ways can you solve 4 X 25. Arissa, I see your hand raised, do you have a question?*

**Arissa:** [has used the hand raised reaction button on Zoom and unmutes herself] *Can we do like last time and draw our solution on the screen and then talk about what we drew and how it helped us? Cause I like to use a number line sometimes.*

**Ms. Janet:** *Yes, you are more than welcome to draw your strategies and show them in your Flipgrid video, just be sure to explain how you used it or how it helped you. Felipe, do you have a question too?*

**Felipe:** [showing his raised hand to the camera and unmutes] *When I was watching Luisa's video, she put pictures and had a filter on her screen. Can we do that?*

**Ms. Janet:** *Yes, you can personalize your screen if you would like with colors, filters, and pictures. Just be sure that we can still see you and that you are discussing your mathematics strategies. You can look at the example video I posted to show you how to use Flipgrid to see the different features that you can use. Also, that video explains my expectations for talking like a mathematician and using mathematics vocabulary. Remember you only get 2 minutes for your video, so make it count! I think you had a good time with our last Number Talk because everyone responded, some people multiple times, and we had almost 2 ½ hours of engagement. Flipgrid also told me that we had 75 views altogether on our videos! That means you are watching videos multiple times, which is good!*

### Individual Assessment and Reflection

The final components of a full iteration of the VNT TLC are peer-assessments and self-reflection on the Virtual Number Talk facilitation. Ms. Janet stated she was surprised by her student's use of academic vocabulary and the creativity of their video responses (Assignment 9). She described her learning of the specific solution strategies used by many students in her class (the distributive property and decomposing into tens). Ms. Janet was pleased overall with the effectiveness of her Flipgrid Number Talk for all her students, including those who speak Spanish. She noted a high level of engagement with the routine and planned to extend the routine by having students elaborate on their explanations with academic vocabulary or visuals (Assignment 9).

## ILLUSTRATING PEDAGOGICAL TRANSFORMATION: MS. JANET & THE "4Cs"

The VNT TLC was designed to engage preservice and inservice teachers in a virtual field experience that builds pedagogical skills related to the "4Cs"— *collaboration* with peers to rehearse and refine their practice, *communication* by facilitating Number Talks discussions synchronously or asynchronously, *critical thinking* through solving problems related to virtual instruction and analyzing the effectiveness of their instructional practice, and *creativity* through exploring innovative uses of technology to facilitate Number Talks. Facilitating Number Talks also provided preservice and inservice teachers an opportunity to help their K-12 students develop skills related to the "4Cs"—*critical thinking* through mathematics problem solving, *creativity* through invention of solution strategies beyond algorithms and memorized facts, *communication* of mathematical thinking, and *collaborating* with classmates to discuss strategies and representations and explore connections between mathematical ideas. Ms. Janet's pedagogy was transformed by participating in the VNT TLC and engaging in each of the "4Cs."

### Collaboration

The VNT TLC included two types of intentionally designed opportunities for peer collaboration: discussion boards and rehearsals. Discussion board assignments focused on assigned readings or videos and prompts that allowed teachers to process the material through their asynchronous discussions with one another. Early discussion boards related to building teachers' introductory understanding of Number Talks, and later discussion boards focused on developing knowledge of elements of the routine, including norm setting, questioning techniques, and eliciting and connecting students' strategies. Teaching rehearsals (Horn, 2010) allowed teachers to explore technology uses, practice facilitation, and anticipate student responses.

Through Ms. Janet's participation in an early discussion board assignment, she discussed with peers her concerns about Number Talks based on her prior experiences implementing the routine in her classroom. In response to a peer who suggested using simpler problems to improve the success of the routine, Ms. Janet stated, "I don't think the issue was the level of math, I think it was communicating the process. I would often have students who couldn't really explain past simply giving me the answer" (Assignment 2). Through this discussion, Ms. Janet was able to analyze that the source of difficulty with Number Talks for some of her students was not the level of mathematics, but the communication of mathematical thinking. In response to a different peer who described prior positive experiences with

implementing Number Talks, Ms. Janet responded, "I am glad it worked well for you in the end. I won't say that it didn't benefit some of my students but I felt overall I had a good group that just really felt overwhelmed trying to communicate their mathematical process" (Assignment 2). Ms. Janet observed the benefit of Number Talks but also recognized that not all students in her class had benefitted from Number Talks in her previous experience. She remained skeptical by the end of the discussion but was willing to try and make the Virtual Number Talks assignments work for her students.

When Ms. Janet met with Ms. Veronica, a peer from the course, to complete the first rehearsal assignment, she was still thinking through various elements of her Virtual Number Talks and did not yet have a fully formed plan. An element of Ms. Janet and Ms. Veronica's rehearsal conversation that stood out was their shared sense of responsibility for their students' success. In response to Ms. Veronica's sharing of working with students on the weekends because she does not "want to fail them," Ms. Janet responded, "I feel that. That's the hardest part. We assume a lot of responsibility over each student's education. It's just like…during this time I'm just like I don't want anyone behind" (Assignment 4). Ms. Janet and Ms. Veronica both demonstrated their investment in their students through their discussion—Ms. Veronica by describing working with her students on the weekends and expressing appreciation for students' families, and Ms. Janet by describing high expectations and related "check ins" and supports, motivational practices such as playing music and creating class song play lists, and leading a book club with creative book reports to encourage students to engage in reading.

Ms. Janet and Ms. Veronica's shared stance—going the extra mile to ensure student success—set the stage for their discussion of Virtual Number Talks. They first talked through the nuts and bolts of facilitating Number Talks in the online environment, discussing tools for student participation on the video conferencing platform such as the chat feature and muting and unmuting. Ms. Janet and Ms. Veronica explored the video conferencing platform's reaction buttons and discussed how they would set expectations for use of the various buttons. Ms. Janet drew upon her previous experience with Number Talks by reenacting classroom interactions and highlighting differences in expectations in face-to-face versus online Number Talks. Ms. Janet also drew upon her technological expertise to teach her peer how to use the whiteboard and annotate features of the video conferencing platform and to demonstrate how she had used the tools in her previous online teaching. As the conversation continued, Ms. Janet and Ms. Veronica moved beyond the basics of Number Talks to discuss facilitation and questioning techniques and how to respond to student errors that may come up while facilitating their Virtual Number Talks. Both Ms. Janet and Ms. Veronica left the rehearsal feeling more comfortable with the routine.

**Ms. Janet:** *I think that this will be a good…I don't know…I'm starting to feel more hopeful about number talks.*
**Ms. Veronica:** *I'm excited just cause you've already done it*.

The rehearsal was designed to be an assignment through which teachers would practice using technology tools and develop their facilitation skills. The conversation that took place between Ms. Janet and Ms. Veronica achieved these goals and more. Ms. Janet was also able to serve in a mentorship role for Ms. Veronica by reenacting prior Number Talks experiencing, teaching her how to use technology tools, and offering feedback on course assignments.

## Communication

The communication foci of the "4Cs" are specific to *clear* communication—for articulating ideas effectively, in diverse environments, and with use of media and technologies (National Education Association, 2012). From early assignments in the VNT TLC, Ms. Janet was especially concerned with language and communication aspects of Virtual Number Talks. When talking about her previous experience with Number Talks, Ms. Janet said:

*For me, I found it to be effective with students who had language level and a grasp of conceptual math. It appeared to be ineffective with students who are learning English and who rely on procedural math. I noticed that it made a lot of my students who struggle quite insecure and overwhelmed listening to their peers explain their mental process. (Excerpt from Assignment 1)*

*I have used number talks in the past…This is a communications-based practice and I found students would struggle to articulate their strategies. The implementation of it was quite smooth. Setting expectations and norms for NT was simple and easy for my students to understand. The challenges I had with NT centered on the articulation of the mathematical processes. My school at the time (and currently) had majority ESL students [students who speak English as a Second Language] so academic vocabulary is more challenging. I just couldn't see how it benefitted my ELLs, especially the ones who relied on procedural math. (Excerpt from Assignment 2)*

Ms. Janet's choice to use Flipgrid and facilitate asynchronous Virtual Number Talks allowed her to address some of the complications of communication she had identified.

*Since my school has a unique distance learning model, I am using Flipgrid to do number talks. Students are solely in control over how to explain their strategy. Some verbally explain, some use visuals, number lines, etc. What I love about Flipgrid is that students are able to respond back to peers via comment or a video response. They can share different ideas or simply comment that they liked their peer's strategy better. It also allows me to hear from every student. With traditional number talks, teachers only call on a few students to share so you don't really get to hear from everyone. This way also makes it hard to hold students accountable. Using Flipgrid, I can norm recording as they do now for math every morning. Since I have math only Mondays and Wednesdays, I have students record their responses to the number talks prompt of the week and on Wednesdays they respond to peers' videos either as a comment or a video response. This also answers how I center the discussion around student thinking. I will respond to the student's video asking more questions and they are very excited to answer back. (Excerpt from Assignment 10)*

Ms. Janet perceived a positive impact of VNT for student communication, specifically drawing from her own experience using Flipgrid in her rehearsal VNT as a "student," students' mathematics vocabulary development, and the opportunity of "time" to process thinking that would not be as easily possible with face-to-face Number Talks.

*Using Flipgrid as a student, I learned that I am able to think of way more strategies when I'm able to fully visualize. I also think that is why Flipgrid number talks has been so successful with my ELL stu-*

*dents. I think overtime students will gradually be able to use more mental math but for now I think this has been the most helpful way. (Excerpt from Assignment 12)*

*I learned that a good number of them [students] rely heavily on basic strategies to multiply or divide. Using Flipgrid I've seen an increase in student participation, an increase in using peer strategies, and an overall increase in academic vocabulary. (Excerpt from Assignment 16)*

*I think it went well is [sic] that students really just like recording video responses and they really like the incentive to using their peers' strategy. I also normed giving "credit" to students' strategies. The only real challenge is that this of course is not done live but I think this has been great for my students whose native language is not English by allowing them more time to process. (Excerpt from Assignment 19)*

## Critical Thinking

Critical thinking is a necessary skill for problem solving to answer the current and ever-changing issues that may arise in a particular setting. To engage in critical thinking allows an individual to make a value judgement of an idea or topic (Brookhart, 2010), maintain an open mind, and persist when challenges are faced (Facione & Facione, 2013). At the onset of the course and although having a prior experience conducting classroom Number Talks, Ms. Janet was skeptical of implementation and the advantages of using this classroom routine in the virtual environment. Her apprehension evolved around two main areas. The first involved her difficulty engaging all learners in the activity when she executed Number Talks face-to-face and whether or not this issue would also arise in the online classroom. The second corresponded to her school's strict virtual learning schedule and whether this school format would allow for the time to include the Virtual Number Talks. Though the VNT TLC was specifically designed for Number Talk implementation in virtual or hybrid learning environments, Ms. Janet immediately faced a barrier to assignment completion; her school day was shortened due to remote learning, and the school schedule was so structured and inflexible that she was not able to add Number Talks to the synchronous teaching and learning in her online classroom.

However, in collaboration with her peers, whether in discussion boards or Virtual Number Talks rehearsals, Ms. Janet was receptive to various ideas and technologies that would resolve her skepticism of the efficacy of Number Talks for her virtual classroom. In Assignment 5, which required reflection on the Virtual Number Talks rehearsal with peers, a shift in her initial judgements of Virtual Number Talks is noted. She provided that she "was able to come up with some really engaging ideas for Virtual Number Talks, using Flipgrid, the whiteboard feature of zoom and turning cameras off and on" (Assignment 5). She said, "I do feel more confident in my plans for my Virtual Number Talks than I did before the group meeting" (Assignment 5). She further elaborated on her shifting view of Number Talks, saying:

*The part I use[d] to struggle with was the participation and engagement part. When I taught 3rd I had a lot of 1st year ELLs and that made explaining their process difficult. When preparing for my first virtual number talks, I tried to keep in mind how can I make this fun and engaging. For distance learning though, I have come up with some pretty creative ideas, [and] that has been pleasantly successful (Excerpt from Assignment 6).*

To address the added challenge of the strict schedule of virtual learning, Ms. Janet critically reflected on the task and in the end, utilized the technology to serve as a solution to the problem. In an asynchronous approach, students could record and respond to the videos on their own, saving instructional time, while still reaping the benefits of engaging in their own and others' mental math strategies. Using her critical thinking skills, she transformed the Number Talks routine using Flipgrid videos by giving students a venue for personal expression of mathematical language, which inherently lead to increased engagement.

## Creativity

Despite Ms. Janet's barrier of a restrictive virtual teaching schedule, as well as her initial hesitation about Number Talks due to her prior experience with the routine, Ms. Janet chose to view the assignment and the constraints of her school schedule as an opportunity rather than a barrier: "I am excited to challenge myself to making it work for my ELLS [English Language Learning students]" (Assignment 2). As Ms. Janet moved through the planning and rehearsal stages of the VNT TLC, she eventually came up with the idea to facilitate her Virtual Number Talks asynchronously using Flipgrid. During her VNT TLC rehearsal meeting with a class peer, Ms. Janet and her peer collaborated and brainstormed ideas together for adapting to their unique instructional situations. For example, Ms. Janet and her peer discussed "how to hold students accountable when answering and how to illustrate the student's problem-solving process" (Assignment 5) within asynchronous, Flipgrid Virtual Number Talks.

During the VNT TLC, Ms. Janet refined her Virtual Number Talks structure and eventually built the new routine into her regular classroom schedule. On Mondays she would post a problem as a "Do Now" and students would record a Flipgrid video in which they share their solution and strategy for the problem. For Wednesdays' "Do Now," students would respond to peers' videos (either peers of their choosing or certain videos selected by Ms. Janet to highlight a particular strategy). The design of the app she selected for her VNT allowed her to tap into students' funds of knowledge (González & Moll, 2001) by bringing their prior experience with and interest in popular social media platforms into the online mathematics classroom.

*I used Flipgrid, which is a platform that allows students to record short videos and comment. It is sort of like an educational TikTok. This really helped with engagement. The math department is so impressed with how much students are loving it in 6th grade that I am doing a small training over it with 5th, 7th, and 8th grade. (Excerpt from Assignment 9)*

Ms. Janet's shorter and more highly prescribed virtual class schedule was not an ideal teaching situation. Nevertheless, Ms. Janet was able to "think of problems as opportunities for solutions" and to see the constraints of her schedule as "ways to construct creative solution paths" (Stokes, 2010, p. 107). By viewing her inability to facilitate synchronous Number Talks as a "motivating challenge" rather than a "frustrating roadblock" (Acar et al., 2019, para. 9), she was able to transform Number Talks for asynchronous learning, an innovative approach she may not have taken with a more flexible school schedule or a more open-ended course assignment.

## A Note About Ms. Janet's Virtual Number Talks

Ms. Janet's choice in technology transforms her Number Talks in ways that may not adhere to the original expectations or recommendations for the routine (e.g., the solutions are not collected in real time and written by the teacher). While Ms. Janet encouraged her students to still use mental math, she and the authors recognize that many may not have used mental mathematics. Additionally, there are demands on students to record their own thinking (both in sense of the technology use and the written representation of their mathematical thinking). For Ms. Janet, these changes to the routine, and the additional time students had to think about and prepare their video responses, addressed the challenges that had previously prevented her students, particularly her ELL students, from effectively communicating their mathematical thinking.

## CONCLUSION

The authors chose Number Talks as the classroom routine teachers would utilize for their virtual field experience because of the opportunity the routine provides for engaging students in the "4Cs"—*critical thinking* through solving problems, *creativity* through generating solution strategies that move beyond standard algorithms, *communication* through explaining mathematical thinking, and *collaboration* through discussing strategies with classmates. Number Talks can help teachers address the challenge of how to focus on student thinking and build conceptual understanding in a virtual environment. Number Talks, as a face-to-face classroom routine, can be incorporated into the virtual classroom and provide an avenue for students to learn new and dynamic mathematical technologies. Virtual Number Talks maximize the impact of synchronous virtual meeting time, which has become shorter and less frequent as schools have had to reduce in-person capacity or limit screen time. Educational stakeholders looking to transform pedagogy through technology use should consider taking common routines, such as Number Talks, and use them as a starting point for technology incorporation. These short but powerful activities for engaging learners in mathematics content offer a low-stakes avenue for teachers to incorporate technology for instruction. Creating a regular Number Talk routine, whether virtual or face-to-face, will assist in maintaining consistency in any mathematics classroom and promote classroom community.

## ACKNOWLEDGMENT

We thank the Association of Mathematics Teacher Educators *Service, Teaching, & Research in Mathematics Education Fellows Program*, and specifically Dr. Matthew Felton-Koestler (Ohio University) and Dr. Jennifer M. Suh (George Mason University), for their support of our Research Interest Group. Dr. Kimberly Conner (University of Northern Iowa) and Dr. Brandon McMillian (Brigham Young University) contributed appreciably to the development of the VNT TLC and course assignments.

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. We acknowledge the significant contribution made by our pre-service and in-service teacher participants, along with their K-12 students, and are grateful for their participation. We also thank Bethany Gormley, University of Texas at Arlington Research Assistant, and Siddhesh Nikram, University of Texas at Arlington Graduate Teaching Assistant, for their support on this project.

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