Impact of the Design of an Asynchronous Video-Based Learning Environment on Teacher Noticing and Mathematical Knowledge

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In this paper, we share the design and impact of a set of two-hour online mathematics professional development modules adapted from face-to-face vide-based materials. The "Video in the Middle" (VIM) modules are aligned with principles of authentic e-learning and can be combined in a variety of ways to form professional development pathways that meet the unique needs of a wide range of professional learning settings and contexts. VIM modules aim to support teacher noticing of student thinking and increase their mathematical knowledge for teaching. The VIM materials are designed to be used in any of three flexible asynchronous formats: independent, locally facilitated, or developer facilitated. Preliminary research results indicate that teachers appreciated the variety of formats, found the modules useful and engaging, and learned to appreciate and use visual methods for solving problems, including using color to distinguish and highlight the relationship between numeric, algebraic, and geometric models.

Keywords: teacher professional development, online professional development, video-based learning, teacher noticing, mathematical content knowledge

INTRODUCTION

Incorporating video within a learning environment offers great potential for pre- and in-service teachers to unpack the relationships among pedagogical decisions and practices, students' work, and the disciplinary content (Borko et al., 2011; Brophy, 2004; Harford & MacRuairc, 2008; Rich & Hannafin, 2009; Rosaen et al., 2008; Santagata et al., 2007; Sherin, 2007). With video, teachers have the opportunity to observe and study the complexity of classroom life, to reflect on their own instructional decisions, and to integrate multiple domains of knowledge to solve problems of practice (Blomberg et al., 2013; Borko et al., 2011). Recent reviews of the literature on video use in professional development (PD) point to the value of video as a tool for improving instructional practice (Gaudin & Chaliès, 2015; Major & Watson, 2018). While careful attention to the design of educative experiences around the use of video is important, the design should also include enough flexibility that the experiences are relevant and responsive to the local context, allow key stakeholders to play a role in decision making, and encourage participants to take ownership of their learning (Darling-Hammond & Sykes, 1999).

As video technology and online video sharing have become more accessible and widespread, video-based professional learning is well-positioned to leverage the benefits of digital platforms (Teräs &

Kartoglu, 2017). Digital professional learning allows pre-and in-service teachers access to professional learning resources that may not be available to them locally and can also support those who are reluctant to share ideas in face-to-face settings in becoming more comfortable doing so in digitally mediated interaction (Dede et al., 2009). Digital professional learning is considerably more scalable than comparable face-to-face PD, and in many cases is subject to fewer monetary and logistical constraints for teachers (Killion, 2013). Research to date on online professional development has shown some positive effects for teachers, even compared to face-to-face formats (O'Dwyer et al., 2010). Most research comparing online, and face-to-face versions of PD has found that well-designed online courses utilizing high-quality learning materials intended for individual use can produce learning outcomes that are similar to or better than face-to-face options (e.g., Fisher et al., 2010; Fishman et al., 2013). This paper reports on the design and preliminary findings from a project that is adapting face-to-face mathematics PD materials to an asynchronous digital format that was pilot tested with both pre- and in-service teachers.

EMBEDDING VIDEO WITHIN A PROFESSIONAL LEARNING OPPORTUNITY

Classroom video clips, by themselves, are unlikely to foster professional learning without being intentionally integrated into a PD program or course (Blomberg et al., 2013). Along with the purposeful selection of video clips, a central component of designing effective PD materials is determining how to embed the video within the broader curriculum to accomplish identified learning goals. It is important to situate the video within a framework that supports detailed analysis and interpretation, thereby providing access and opportunities for teacher learning across the totality of the PD experience. Both the video and the activities surrounding the video should be designed to target predetermined learning goals for both the PD curriculum as a whole and each individual session (Blomberg et al., 2013).

Many, but not all, video-based mathematics PD programs have teachers engage in specific activities before and after watching the focal video (e.g. Borko et al., 2015; LeFevre, 2004; Santagata, 2009). For example, prior to watching a clip, PD facilitators may ask the teachers to solve and discuss the math problem shown in the video in order to develop content knowledge, motivate teachers to notice particular elements of the content contained within the clip, and attend to specified activities such as a unique solution method or teacher questions that prompt extended student reasoning. After viewing the video, there may be a guided discussion and, perhaps, follow-up activities in which the teachers relate what they have seen on the video to their own classroom practice. The discussion and follow-up activities extend teachers' thinking and analysis by probing more deeply into topics or issues presented within the video.

We label this intentional sequencing of video viewing such that it occurs between designated activities with specified learning goals a "video in the middle" design (Seago et al., 2018). In video-based mathematics PD that incorporates this design feature, video is located in the middle of the learning experience, sandwiched between activities such as mathematical problem-solving and pedagogical reflection. We will describe how we use this sequence in more detail when we discuss the Video in the Middle project that is the focus of this paper, and we will describe how the specific sequence looks in action. Our goal is not to argue that this design feature is new to the field of professional development, but simply to highlight and label it, and consider how the design is likely to support pre- and in-service teachers' learning.

THE VIDEO IN THE MIDDLE PROJECT

The Video in the Middle (VIM): Flexible digital experiences for mathematics teacher education project has been funded (NSF; #1720507) to design, develop, and research online professional development/teacher education modules. The VIM project draws upon the face-to-face *Learning and Teaching Linear Functions: Videocases for Mathematics Professional Development* (NSF; ESI-9731339) video and ancillary resources (e.g., lesson graphs, transcripts, mathematics and video commentaries) to develop 40 two-hour VIM modules intended to develop teachers' mathematical knowledge for teaching algebra and noticing skills. These modules serve as the component ingredients for creating suggested sequences and pathways of multiple VIM modules based on learning goals such as conceptualizing and representing slope, distinguishing between and connecting recursive and closed methods and presentations, and exploring the impact of shifting the starting point (y-intercept) of a sequence. The VIM modules are designed to be offered in three different digital delivery formats: (1) independent, (2) locally facilitated groups, and (3) VIM staff facilitated groups. The different formats offer unique affordances for teachers and provide users with both flexibility and choice.

Conceptual Frameworks

The design and development of the VIM asynchronous modules are conceptually grounded in two main bodies of research related to teacher learning in PD. First, the development of professional knowledge that consists of deep and connected mathematical content knowledge, the knowledge of students' thinking and how students learn the content, and knowledge of pedagogical practices and norms to support student learning. Second, the development of a professional vision that consists of teachers' ability to notice, analyze and reason about features of classroom interactions. In this section, we briefly discuss these two research areas with a focus on how they relate to the design and impact of the VIM asynchronous PD.

Mathematical Knowledge for Teaching

Ball and colleagues have identified and elucidated "mathematical knowledge for teaching" (MKT) as the professional knowledge that mathematics teachers must have in order to do the mathematical work of teaching effectively (e.g., Ball & Bass, 2002; Ball et al., 2005; Hill et al., 2008). This conception of knowledge of mathematics for teaching is multifaceted and includes both content and pedagogical content knowledge. MKT includes a sophisticated understanding of effective instructional practices and student thinking related to specific mathematical content and comes into play during all phases of teaching. For example, during instructional planning teachers draw upon their MKT to select curricular materials and sequence content to facilitate student learning, to predict how their students will approach specific mathematical tasks, to consider the needs of linguistically and culturally diverse students, and to anticipate student errors. As they conduct lessons, MKT enables teachers to recognize instructional affordances and constraints of different representations, to interpret incomplete student ideas, to anticipate opportunities to address language or cultural references, and to consider how to respond to various correct or incorrect pathways students explore. After completing a lesson, MKT is central to teachers' reflections on the learning that did or did not take place, and to their consideration of how to plan for and improve future lessons.

For both pre- and in-service teachers, incorporating video within the learning environment supports opportunities for teachers/students to develop their MKT by unpacking the relationships among pedagogical decisions and practices, students' work, and the disciplinary content (e.g., Barth-Cohen et al.,2018; Bloomberg et al., 2013; Bloomberg et al.,2011; Borko et al., 2011; Rich & Hannafin, 2009; Rosaen et al., 2008; Santagata et al., 2007). Collectively viewing and discussing video clips allows for the complexities of classroom practice to be stopped in time, unpacked, and thoughtfully analyzed, helping to bridge the ever-present theory-to-practice divide and support instructional reflection and improvement. In the classroom, teachers must constantly draw on their MKT to make individual in-the-moment decisions, while viewing video during PD allows them the opportunity to collectively deconstruct and discuss familiar experiences and to actively generate new understandings about content, pedagogy, and student thinking (Cullen, 1991; Korthagen et al., 2001).

The VIM module design incorporates MKT by providing multiple and varied experiences to examine and compare a variety of mathematical methods and representations, and to analyze the complex relations between content, pedagogy and student thinking.

Professional Vision and Noticing

One unique aspect of pre- and in-service teachers' knowledge is their "professional vision", which refers to their ability to notice and analyze features of classroom interactions, make connections to broader principles of teaching and learning, and reason about classroom events (Seidel & Stürmer, 2014; Sherin, 2007; Sherin & van Es, 2009; Stürmer et al., 2015; van Es & Sherin, 2002). Over the years, diverse conceptions of noticing have emerged in the literature, but in general most discussions of mathematics teacher noticing involve two main processes: (1) Attending to particular events in an instructional setting (i.e., teachers choose where to focus their attention and for how long) and (2) making sense of events in an instructional setting (i.e., teachers draw on their existing knowledge to interpret what they notice in classrooms) (Sherin et al., 2011). Sherin et al. (2011) argue that these two aspects of noticing are not discrete, but rather interrelated. Teachers attend to events based on their sense-making, and how they interpret classroom interactions influences where they choose to focus their attention.

Teacher education programs that incorporate video foster the development of teachers' noticing skills (Koellner & Jacobs, 2014; Roller, 2016; Santagata & Yeh, 2014; Seidel & Stürmer, 2014; Stürmer et al., 2015; van Es & Sherin, 2002). As they attend to and make sense of cases of instruction, teachers are also likely to consider the implications for own practice (Koh, 2015). In other words, what teachers notice appears directly relevant to how they elect to carry their learning into their classrooms (Sherin & van Es, 2009). Participants in PD do not all make sense of their experiences in the same way; rather, individuals bring differing knowledge and beliefs about teaching and learning, students, content, and curriculum to bear on what they notice (Erickson, 2011; van Es, 2011). This individual diversity impacts what they notice, how they engage in the professional development, and what they take and use in their own practice.

A noticing conceptual frame is used within the VIM asynchronous module design to support the analysis of classroom interactions and reason about teaching and learning within the viewing and analysis probes of the video clips embedded within the modules. In addition, the bridge to practice activities that end each module are designed to connect teachers' learning to their classroom practice.

VIM Module Design and Development

Each VIM module contains the same set of activities embedded in the video in the middle design, placing a video clip at the center, or "in the middle," of professional learning as teachers take part in an online experience of mathematical problem solving, video analysis of classroom practice, and pedagogical reflection (Figure 1). The overall structure of this design is consistent across all VIM modules and is intended to support teachers professional learning opportunities around mathematical knowledge for teaching (Ball & Bass, 2002) and teacher noticing of student thinking and teacher-student interactions (van Es & Sherin, 2002).

FIGURE 1
VIDEO IN THE MIDDLE PD ACTIVITIES

Pre-Video Activities:
1. Introduction: Module Goals (mathematical, pedagogical, instructional) 2. Explore Math Task and Reflect in Journal 3. Community Wall: Share Your Work on the Math Task (on a community wall) 4. Consider Other Solutions and Perspectives 5. Explore Math Task and Reflect in Journal
Video Activities:
1. Review the Context of the Lesson (examine where the video clip is situated within the lesson) 2. Watch Video and Reflect in Journal 3. Reflect on the Lesson Graph and Solution Methods Documents 4. Examine Video Transcript and Share Your Thoughts 5. Watch Video Again with Math Educator Annotations 6. Watch Video and Reflect in Journal 7. Reflect on the Lesson Graph and Solution Methods Document
Post-Video Activities:
1. Community Wall: Reflect on Your Learning (e.g., "I used to think…. Now I think…") on a community wall. 2. Bridge to Practice: Connecting Your Learning to Classroom Practice 3. Reflect in Your Journal

The underlying VIM design principles are consistent with the nine principles of authentic e-learning as defined by Herrington et al. (2010). Figure 2 illustrates the nine elements and how each is exemplified within the learning design of the VIM modules.

FIGURE 2
ELEMENTS OF AUTHENTIC E-LEARNING (HERRINGTON ET AL., 2010) AND THEIR APPLICATION IN THE VIM MODULE DESIGN

Principles of Authentic e-Learning	Exemplified in the Design of Each VIM Module
Authentic context reflects the way knowledge is used in real life, preserving the complexity.	Unedited video clips of un-staged mathematics classroom interactions, highlighting the relationship between content, teacher, and students.
Authentic tasks have situationally relevant content and offer opportunities for practical implementation.	Teachers examine mathematics tasks within the context of a lesson, view and analyze a video clip of the lesson, and consider implications for their own practice.
Access to expert performances by having the opportunity to observe how experts solve problems as well as learn with and from their colleagues.	Teachers have opportunities to consider a mathematician's perspective on the mathematics task and a mathematics educator's perspective on the video clip, as well as the perspectives of their peers.
Promoting multiple perspectives by sharing different viewpoints and experiences.	Teachers share their work on the mathematics task with others, consider other solution methods, comment on their peers' work, and receive feedback on their own solution methods.
Collaborative construction of knowledge is characterized by collegial sharing, interaction and collaboration between participants.	Teachers explore a mathematics task and post their work on a community wall for their colleagues to view and comment on.
Reflection offers the opportunity to compare one's thoughts to the ideas of other learners, experts and mentors.	Teachers compare their mathematical work and module reflections to that of their peers, their instructional strategies to those of videotaped teachers, and their analysis to that of mathematicians and mathematics educators.
Articulation is encouraged when participants discuss their growing understanding and publicly present and defend arguments.	Teachers present their solution methods to the mathematical task on a community wall for public presentation to their peers and respond to questions or comments.
Scaffolding and coaching are available when needed.	Each module is scaffolded according to mathematical and pedagogical learning goals. Facilitators in local and project formats read and respond to teachers' journals and community wall posts.
Authentic assessment provides learners with the opportunity to be effective performers with the skills and knowledge they have acquired.	At the end of each module, teachers engage in a "Bridge to Practice" activity designed to provide them with the opportunity to use what they have learned in their own practice.

RESEARCH STUDY

During Spring 2020, middle and high school teachers were recruited across the state of California to participate in a pilot efficacy study. Of the 68 teachers who began the study, 56 (82%) completed all or nearly all study activities across the three delivery formats (Self-paced: 24, Locally facilitated: 16 VIM project-facilitated: 16) to address the following research questions:

1. *What is the impact of teachers' participation in the three delivery formats on teachers' mathematical knowledge for teaching, their noticing skills, and their teaching practice?*
2. *What is the impact on their students' performance?*

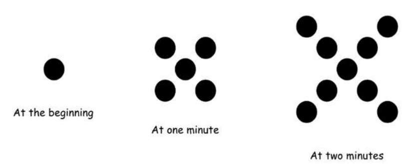
Intervention

All teachers experienced the same sequence of four two-hour modules for a total of eight hours of professional development. Figure 3 displays the mathematical task, video clip description and learning goals for each of the four VIM modules used for the research study.

FIGURE 3
THE VIM FOUR-MODULE INTERVENTION

VIM 1: James & Danielle: Representing Recursive and Explicit Approaches

Growing Dots

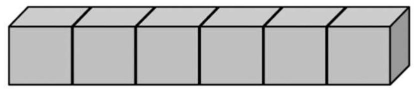


Describe the pattern.
Assuming the sequence continues in the same way, how many dots are there are 3 minutes? 100 minutes? *t* minutes?

Learning Goals	Video clip Description
• Examine, represent, and compare recursive and explicit approaches to solving linear tasks (MKT). • Listen to, interpret, and understand differing student approaches to solving the dots task (Noticing). • Think about goals and instructional decision-making in launching a task.	The teacher asks his 9th grade students to share their solutions and methods for solving growing dots 1. Danielle shares the equation $x4+1$ and shows the one as the center with a circular growth of 4 dots at each minute. James shares his equation as $x + 4$ and points to the dot sequence as he shows that 4 is added each time to the previous picture. James says that he didn't count the center because then center is not growing.

VIM 2: Breanna & Cody: Representing Mathematical Thinking

Cubes in a Line



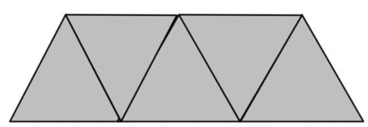
How many faces (face units) are there when 2 cubes are put together sharing a face? 10 cubes? 100 cubes?
How many faces for any number of cubes?

Learning Goals	Video clip Description
• Examine, represent, and compare the mathematics behind various solution methods (MKT). • Listen to, interpret, and understand differing student's mathematical thinking in solving the cubes task (Noticing). • Think about posing questions in orchestrating a classroom discussion.	This 3rd grade class was given the task of predicting the number of faces for 10 cubes. This segment is a whole class discussion of their predictions based on 2 students' methods. Breanna says you just count down and add 4 more so it is 42. Cody says that you multiply the cubes by 4 and add 2.

VIM 3: Lindsey's Question: Connecting Geometry to a Rule

Polygons

If I line up (sharing one side) 100 regular triangles in a row, what will the perimeter be?

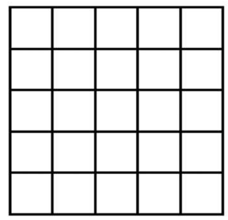


Can you create a rule for finding the perimeter for any number of triangles?

Learning Goals	Video clip Description
• Make sense of how two different approaches to the general rule for the task connect to its geometry (MKT). • Examine how a teacher responds to students' ideas and questions (Noticing). • Consider how you might purposefully plan your questioning in order to elicit student thinking.	During the 7/8th grade whole class discussion of the triangle problem, Kristen says that the perimeter for any number of triangles would be the number of triangles plus 2. The teacher writes $t + 2 = p$ on the overhead. She asks the class why the rule says we're only adding $t + 2$ when every time we add a triangle, we are adding 3 edges. Nick responds that two sides get closed off. Chris says that you have the top and bottom and you add two for the ends. Lindsey asks, "Why isn't it plus 4?"

<table>
<tr><th colspan="2">VIM 4: Siri & Tiffany: Using and Connecting Mathematical Representations</th></tr>
<tr><td colspan="2">Pool Border

Find the number of 1 by 1 tiles required to surround a 5 by 5 pool.


Pool

Find a rule to predict the number of tiles required to surround a square pool of any size. See if you can express that rule as an equation. Be prepared to explain how your equation relates to the pool and border.</td></tr>
<tr><th>Learning Goals</th><th>Video clip Description</th></tr>
<tr><td>● Connect the structure of a visual representation to a mathematical equation (MKT).
● Notice and discuss the role of the teacher in enabling students to communicate and represent their mathematical ideas (Noticing).
● Use and connect mathematical representations (MKT).</td><td>After the 8th grade students work in groups on the Pool Border task, the teacher asks Siri and Tiffany’s group to share their equation, $n = s4 + 4$, with the class. They explain that if you decompose the border into sides and corners, and group one side and one corner together, you have 4 of them. They share that this is the same thing as adding $s + 1$ four times, which they share as their second equation.</td></tr>
</table>

Study Participants

Across all conditions, participants taught grade levels ranging from 6 to 12 (some teachers taught multiple grades). The participants’ years of teaching experience ranged from beginning (27 teachers with less than 5 years of experience) to experienced (40 teachers with more than 6 years of experience).

Measures

Teacher measures included an online pre-post video and student work analysis, weekly online teacher logs, teacher interviews, and PD embedded pre-post community wall posts and comments. A pre-post online quiz was created to assess student’s conceptualization of linear functions.

Artifact Analysis

Teachers were given a pre-post online Artifact Analysis measure designed to examine teachers’ mathematical knowledge for teaching as well as their noticing skills. The Artifact Analysis is a three-part instrument in which teachers:

1. Solve a mathematical task, predict student solution methods, interpret student solution methods, and analyze different representations.
2. View and answer a series of increasingly specific questions about several short videos of a class discussion centering on students’ presentation of their various solution methods.
3. Comment on three pieces of written student work for the same task.

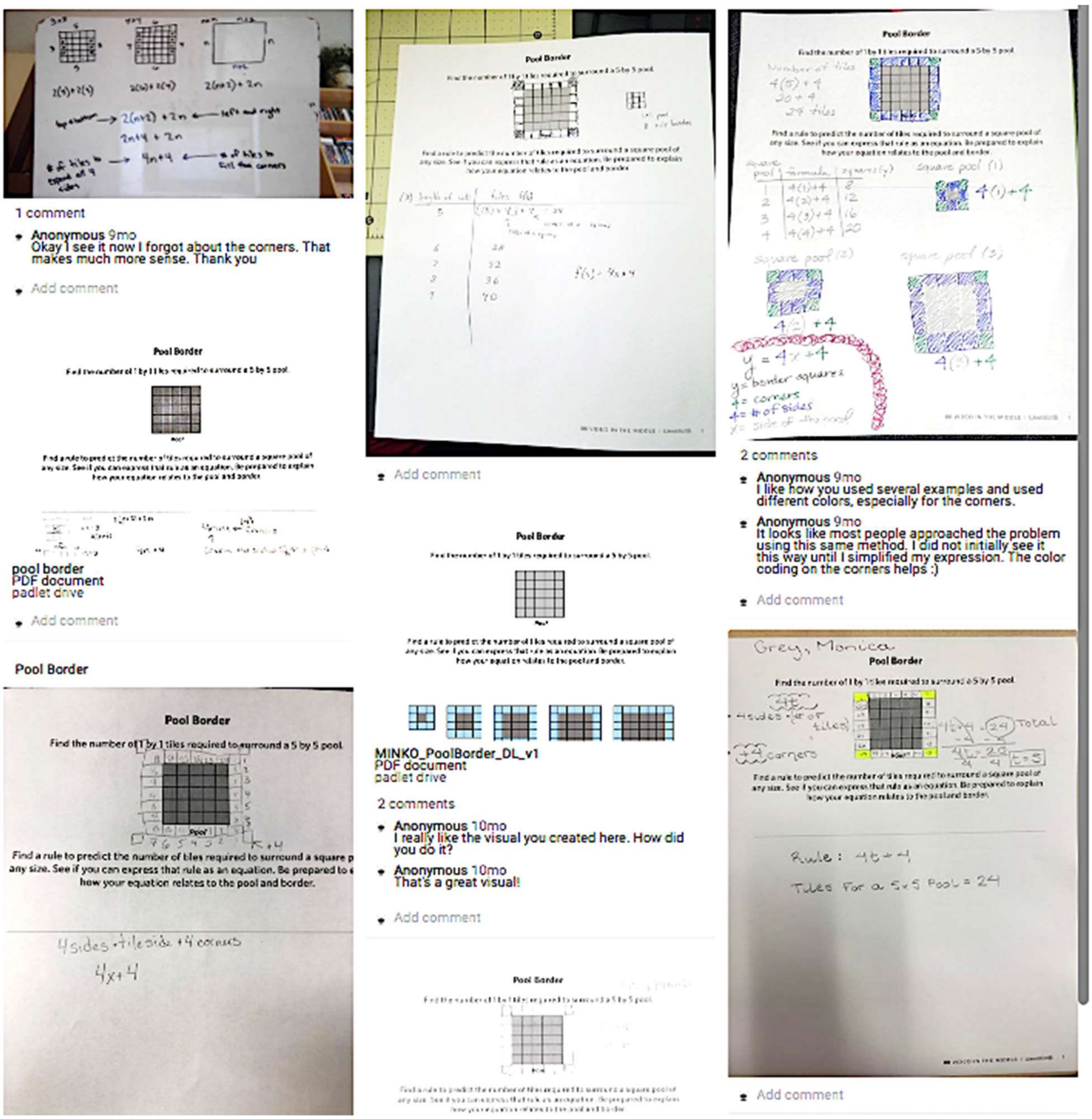
Weekly Online Logs & Teacher Interviews

Online logs, designed to gather data on teachers’ self-reported instructional practice, were completed weekly by participating teachers. Logs documented how teachers reported implementing key MKT and noticing skills highlighted in the module learning goals in their classrooms. In addition to completing the weekly logs, fourteen teachers participated in interviews about their experiences with the VIM modules.

Embedded Measure of VIM Community Wall Responses

Within each module, teachers worked on the associated mathematical task and uploaded an image of their work. Teachers (and, in the facilitated conditions, facilitators) then viewed, commented on, and asked questions about others' solution strategies (Figure 4).

FIGURE 4
VIM COMMUNITY MATHEMATICS TASK WALL



Two types of community wall pre-post responses were analyzed for VIMs 1 and 4: (1) Posted mathematical work and teacher comments/questions regarding each other's methods, and (2) posted reflections from the module experience.

Student Online Quiz

A half-hour targeted online student quiz was created to assess students' conceptual understanding of linear functions and their ability to use their understanding to solve problems and communicate their reasoning. The quiz was delivered via Google Form and included three questions, each of which included a multiple-choice question as well as a short-constructed response item. The pre quiz was completed by 5,070 students. However, due to the COVID-19 pandemic and schools moving to remote instruction after week 6 of the study, we were unable to administer the post student quiz measure or to conduct teacher observations as planned. All other data—the artifact analysis teacher pre-post measure, weekly teacher logs, and community wall responses and reactions—were completed. Post teacher interviews were conducted via telephone.

In this paper, we share our early analysis of the RCT teacher log data, teacher interviews, and community wall mathematics task responses. In addition, we share community math wall data from a pilot pre-service setting. We are currently in the process of analyzing the RCT pre-post artifact analysis measure and pre-post community wall reflections responses and anticipate having results by spring 2021.

Results

Weekly Online Logs

Teachers were asked to complete a weekly online teacher log consisting of eight questions focused on mathematical content taught, student interaction structures, and instructional strategies used during that week. Three Likert-style questions asked teachers to reflect on their teaching experience each week and select one of four answers (not at all, to a small extent, to some extent, to a great extent).

Two questions showed increases from week one to week six. With the question "I am able to apply VIM ideas when working with my district's adopted materials," there was a 14% increase from week one to six in teachers answering, "To a great extent". With the third question (""I am able to understand student methods different from my own"), the percentage of teachers answering "To a great extent" increased by 18%, with a 21% increase from week 1 to week 5. While teachers reported teaching less linearity content in the later weeks, virtually all were still working on completing VIM modules, so we predict this increase was due mainly to what teachers were experiencing in the PD modules.

Teacher Interviews

Of the 56 teachers who completed the study, nine teachers were randomly selected for interviews in June and July 2020, three from each condition. We also requested interviews with the ten teachers who did not complete the study and received five positive responses. All teachers interviewed who completed the study expressed that they found the VIM PD modules engaging and useful. When asked to highlight specific ways in which the PD had impacted their thinking or practice around teaching linear functions topics, the following were mentioned more than once:

- Changing questioning strategies and patterns to "focus" student thinking on the learning goal, rather than "funneling" towards a particular strategy or conclusion.
    - The language of *focusing* and *funneling* was included in VIM 3 Bridge to Practice activity in which participants examined a chart comparing how two different teachers use the Triangles task in their classroom and facilitated the class discussion by asking questions of students by focusing or funneling (Herbel-Eisenmann & Breyfogle, 2005).
- A greater focus on students' mathematical thinking and reasoning (vs. finding answers)
- Adjusting participation structures and lesson formats to give students more time to work collaboratively

- Desire to use more "open" or visual math tasks, usually thanks either to seeing these tasks used in real classrooms or to feeling more confident in their ability to use them effectively
- Renewed commitment to supporting productive struggle (e.g., letting students struggle with a problem for longer, and asking probing questions rather than giving answers when students are stuck)
- A greater emphasis on multiple representations, including connecting representations through color and probing questions
- Increased openness to multiple ways of seeing and describing linear growth and mathematical structure
- Openness to using manipulatives with older students

These interview responses are particularly interesting as they do not align with teachers' responses to the weekly log question asking teachers to what extent they used VIM instructional strategies (linking algebraic expressions and equations to visual or geometric models; highlighting connections across representations; using color to connect elements of linear expressions across multiple representations; encouraging and highlighting multiple solution methods; and questioning and probing to elicit students' mathematical ideas). The positive interview responses may indicate the need for a second study with greater numbers of teachers in order to determine whether this finding holds at scale.

When asked to comment on features or elements of the VIM modules that they found most beneficial, the videos, lesson graphs (documents summarizing the structure and activities of the lesson, so teachers can situate the video segment in the broader context of the lesson), and community walls were all mentioned by a majority of teachers. Many commented that watching a video of a real classroom helped them better understand what teacher moves described in the PD would look like and how real students might respond. In particular, seeing a video of elementary students working on one of the tasks gave some teachers confidence that their middle school students could approach and benefit from it. Many also expressed that it was helpful to see a variety of ways tasks could be approached or solved, whether in the videos, the solution methods document, or in other participants' work posted on the community walls.

As we hypothesized, teachers in different conditions described different affordances of each. For example, most teachers in the facilitated groups appreciated receiving feedback from a coach in their district or a VIM facilitator, while those in the self-paced group enjoyed the flexibility of being able to complete the modules at their own pace. As one self-paced participant said, "I like this particular experience because I can go at my own pace, and it was still almost like it was facilitated because there were questions that you had to answer."

The benefits of asynchronous, online PD became even more pronounced as the pandemic worsened in March and teachers found themselves shifting to remote instruction with little time to prepare, while also juggling family health concerns and supporting their own children's remote learning. Many expressed gratitude both for the opportunity to complete the PD experience even under shelter-in-place orders as well as the ability to fit their module work around other professional and family obligations.

Teacher Community Walls

Community mathematics wall participation was high in all three conditions. In the locally facilitated condition, 80% of participants posted their mathematical work in the first VIM module and 95% posted their work in the final VIM module. In the self-paced group, 88% of the participants posted their mathematical work for the first module and 100% posted in the final module. In the VIM project facilitated group, 100% of the participants posted their work in both the first module and last modules. The VIM project facilitated group had the least amount of pre non-facilitator comments, but a similar number of total comments to the other two conditions (Table 8).

TABLE 1
PARTICIPANTS' POSTS, COMMENTS, AND METHODS IN MODULE 1 AND 4

	Module 1				Module 4			
	Posts & Comments		Methods		Posts & Comments		Methods	
Condition	Posts	Comments	Visual	Numerical	Posts	Comments	Visual	Numerical
Locally Facilitated *Mod 1: 25* *Mod 4: 21*	20	18	6	14	20	16	17	2
Project-Facilitated *Mod 1: 17* *Mod 4: 16*	17	Part: 12 Fac: 14	1	16	16	Part: 16 Fac: 7	14	2
Self-paced *Mod 1: 25* *Mod 4: 20*	22	26	4	18	20	14	17	1

The most notable pre-post results emerged in the analysis of the visual versus numerical methods used by teachers. Specifically, by condition:

- *Locally facilitated*: Visual methods increased from 3% of the total methods posted in module 1 to 89% in module 4; numerical methods decreased from 70% of the total methods posted in module 1 to 11% in module 4
- *VIM project facilitated:* Visual methods increased from 6% of the total methods posted in module 1 to 94% in module 4; numerical methods decreased from 82% of the total methods posted in module 1 to 6% in module 4
- *Self-paced:* visual methods increased from 18% of the total methods posted in module 1 to 85% in module 4; numerical methods decreased from 82% of the total methods posted in module 1 to 6% in module 4

The large majority of methods across all conditions in the VIM 1 community mathematics task wall responses were numerical, while the large majority of methods across all conditions in VIM 4 were visual. We hypothesize that this result could be related to a number of things:

- The VIM learning goals highlighted multiple methods with an emphasis on visual methods.
- The solution methods resource for each VIM highlights visual methods as well as the links between numeric and visual representations.
- The participants had repeated exposure to the various student visual methods in the four VIM module video clips.
- The participants had repeated exposure to each other's methods with each of the four VIMs.

These **community wall** results map onto the **teacher log** results showing an increase of 14% from week 1 to week 6 in teachers responding: "To a great extent" to the statement, "I am able to understand student solution methods that are different than my own". These results also correspond to the **interview data**, in which teachers indicated:

- A greater emphasis on multiple representations, including connecting representations through color and probing questions

- Increased openness to multiple ways of seeing and describing linear growth and mathematical structure

VIM Pre-Service Pilot

While the primary focal audience for the VIM modules is in-service teachers, there was interest from pre-service educators to pilot the modules within their university teacher education settings during the global pandemic. A pilot of the same four VIM modules that were used in the RCT study was conducted in November/December 2020 with 11 pre-service students at a university in the midwestern region of the United States. As with the in-service teacher research study, the embedded measure of community wall responses was analyzed pre-post. Table 9 displays the results of the pre-service pilot mathematical task wall analysis.

TABLE 2
PRE-SERVICE PARTICIPANTS' POSTS/COMMENTS, AND METHODS IN MODULE 1 AND 4

Module 1				Module 4			
Posts & Comments		Methods		Posts & Comments		Methods	
Posts	Comments	Visual	Numerical	Posts	Comments	Visual	Numerical
11	0	6	5	11	4	11	0

Although pre-service students were more likely to use visual methods in VIM 1 than practicing teachers had been, analysis of their methods identified a similar shift from numerical to visual methods as the practicing teachers displayed in the RCT analysis. The pre-service students shifted from 55% visual methods in VIM 1 to 100% in VIM 4.

DISCUSSION

Preliminary results on teacher impact show some consistent findings across different data sources—weekly logs, post PD interviews and pre-post community mathematics task walls. Practicing teachers and pre-service teachers appeared to have learned to appreciate and use visual methods for solving problems, including using color to distinguish and highlight the relationship between numeric, algebraic, and geometric models. In addition, pre- and in-service teachers engaged with and interacted with each other by examining, commenting on, and questioning each other's mathematical work.

A surprising preliminary result was the fact that there were no substantial differences in the practicing teacher RCT study across the three conditions regarding teacher engagement and interaction on the community mathematics task wall. We hypothesized that the facilitated group would be more engaged and post more comments in response to their colleagues' methods. This did not turn out to be the case, as teachers across all three conditions commented in similar numbers and shifted from numeric to visual methods from pre to post. In the pre-service pilot group, the professor did not choose to facilitate the online community walls, so we categorized it as a self-paced unfacilitated group. The same pattern of interaction and engagement emerged as the practicing teachers, as well as the shift from numeric to visual methods from pre to post community mathematical wall responses.

IMPLICATIONS

The VIM project aims to support mathematics educators by disseminating finalized VIM modules as open education resources in a variety of flexible formats beginning in Spring/Summer 2021. The asynchronous design of the materials offers flexibility for use in pre-service and in-service settings. In addition, the VIM modules will offer PD leaders or teacher educators the choice of having participants experience the modules independently or facilitated. Preliminary findings from the VIM project suggest that even small doses of professional learning experiences help participants to gain in noticing skills and mathematical knowledge for teaching.

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