TRANSITIONING A MATHEMATICS SPECIALIST PREPARATION PROGRAM INTO AN INTERACTIVE ONLINE PROGRAM: INSIGHTS FROM THE DEVELOPER AND CANDIDATE PERSPECTIVES

Aimee J. Ellington
Virginia Commonwealth University
ajellington@vcu.edu

Allison Yoder
Harrisonburg City Public Schools
ayoder@harrisonburg.k12.va.us

https://doi.org/10.25891/rs9r-ek33

ABSTRACT
This paper will describe how the Virginia Commonwealth University mathematics specialist preparation program transitioned from a face-to-face format to a fully online format. We will describe the technology and instructional methods that are used for course meetings, activities, and assignments. We will describe the development and implementation of a mathematics activity from instructors designing the activity, participants completing the activity, and instructors providing feedback on the activity. One mathematics activity will be shared that demonstrates the process of the program model that includes independent work, small group work, and in-class discussions. We will describe one participant's experience as she developed and implemented a capstone externship project in the preparation program and how activities in this program inspired her classroom practice more broadly.

KEYWORDS
mathematics teacher leaders, mathematics specialists, professional development, online learning, technology enhanced instruction

Professional development and career advancement programs for teachers come in many different forms. In the 21st century, online digital platforms play a significant role in the delivery and implementation of these kinds of experiences. In addition to providing a wider variety of opportunities, online learning also allows participants to learn in the environment in which they are most comfortable and at times that are convenient for them, which are important factors when designing programs for adult learners (Knowles et al., 2015). A flipped classroom is an instructional model that provides participants with opportunities to work on course content on their own time prior to engaging in student-centered, in-class experiences (Stapleton, 2020), allowing for more dynamic interaction through small group and whole class activities. A community of inquiry (Garrison et al., 1999) is a social constructivist learning experience model for online instruction that emphasizes the importance of establishing cognitive, social, and teaching presence to ensure that all participants have a satisfying and meaningful learning experience.

This paper describes the transition of a mathematics specialist preparation program from a face-to-face format into an online format that incorporates a flipped classroom model and utilizes a community of inquiry. We share information about the program including a sample mathematics activity and the program's capstone experience. We describe the experiences of one candidate in the program including her in-school externship project. We begin by briefly describing the history of the mathematics specialist movement in Virginia and the origins of the preparation program featured in this paper.

Early Statewide Work on Mathematics Specialist Preparation

Under the leadership of the Virginia Mathematics and Science Coalition (VMSC), in 2002 a new approach to K–8 mathematics teacher leadership began to emerge in Virginia and was soon followed by recommendations for the specialized preparation individuals should complete before assuming the leadership role. Over several years through the work of two different statewide working groups comprised of school district mathematics supervisors, K–8 teachers, and higher education faculty, the role of the elementary mathematics specialist was first defined and then refined to also include the unique demands of middle school mathematics education. During this time, the Virginia Commonwealth University (VCU) Mathematics Outreach office under the leadership of Dr. Bill Haver and Dr. Reuben Farley received a series of four large-scale National Science Foundation (NSF) grants to develop a mathematics specialist preparation program and study the impact of mathematics teacher leadership in Virginia's K–8 schools. The courses were developed and offered in face-to-face formats through several state grants and the first in the series of NSF grants. This work was a collaborative effort of four institutions of higher education and 45 urban and rural school districts in Virginia. With the support of the next three NSF grants, the courses were refined and adapted as the program was completed by several cohorts of teachers across the state. Almost all of these initial course offerings took place in face-to-face formats including 5-week summer residency programs, 2-week intensive summer courses, and semester courses. There was one notable exception in which a cohort of teachers in rural districts completed the program in a blended format including both online and in-person components. More information about the foundational work that led to the mathematics specialist movement in Virginia and early efforts to prepare mathematics specialists can be found in VMSC (2016).

This work culminated in a teaching license endorsement for mathematics specialists and a rich and rigorous program to prepare generalist teachers for this leadership role. In these early years, twelve state universities established master's degree programs to prepare K–8 teachers to be mathematics specialists. The Virginia Board of Education also realized the importance of the mathematics specialist role to K–8 education and recommended one specialist for every 1,000 students.

In 2017, the VCU Mathematics Outreach office received an NSF Noyce Teacher Scholarship Program grant to modify the existing VCU face-to-face mathematics specialist preparation program into a fully online professional development and certification program and to enroll a cohort of teachers serving in high-need school districts across the state. In addition, program graduates served for three years as mathematics teacher leaders in their school districts.

VCU Mathematics Specialist Preparation Program

Through the statewide work described above, VCU developed a 36-hour master's degree program consisting of (a) six core mathematics courses designed so candidates develop a deep understanding of the K–8 mathematics content; (b) three mathematics education leadership courses in which candidates develop the skills necessary to work with all members of the educational team (i.e., teachers, principals, parents, children, central office personnel, members of the community, etc.) and, most especially, work with adults; and (c) a capstone experience in the form of a two semester externship during which candidates design and implement a research-based, in-school project using the knowledge and skills they acquired through the prior course work. Activities and assignments throughout the program target specific areas of need for mathematics specialists including (a) advanced middle school mathematics content; (b) methods for helping teachers work with diverse populations of students (i.e., English language learners, gifted students, students with learning disabilities, etc.); and (c) analysis and implementation of the current trends in mathematics education research.

The courses in the program directly align with the standards set forth by the Conference Board of Mathematical Sciences (CBMS, 2010), the Association of Mathematics Teacher Educators (AMTE, 2013), the National Council of Teachers of Mathematics (NCTM, 2012), and the Teacher Leader Exploratory Consortium (TLEC, 2008). The mathematics courses provide an in-depth study of the content covered by the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Specific details about each of the courses in the program can be found in VMSC (2016).

The instructional team for each mathematics course consists of a VCU mathematician or mathematics educator and an experienced mathematics specialist. Candidates conduct an in-depth study of K–8 mathematics and also connect the concepts and skills to teacher practice. Assignments and activities also allow candidates to make connections to higher-level mathematics. Throughout the courses, candidates engage in making conjectures, developing generalizations, and making mathematical arguments in order to deepen their understanding of the content. In particular, they build a working knowledge of the properties of arithmetic, proportional relationships, geometry, algebra, probability, and statistics. Class time is spent in small group and whole group discussions anchored in written and video case studies of children's mathematics thinking; cooperative group work around mathematics content and pedagogy; and analyzing children's work, including case studies from candidates' practice.

The instructional team for each mathematics education leadership course consists of a mathematics educator and a district mathematics supervisor or an experienced mathematics specialist. Candidates conduct an in-depth analysis of their own teaching and learn to coach one-on-one and in small groups. The leadership courses develop candidates' skills related to working with adult learners and deepen their mathematics content and pedagogical content knowledge as they refine their philosophy about mathematics teaching and learning. The courses are interactive and project based. Discussions often begin with individual reflection, followed by pair conversations, expanding to small group and then whole group sharing.

Transition from Face-to-Face to Online

Our goal was to convert the existing mathematics specialist preparation program into an online program while maintaining the rigorous content and interactive nature of the activities and assignments in each of the courses. The online version of the program consists of technology-enhanced active learning mathematics and mathematics education leadership courses and employs a modified flipped classroom model to provide an accessible and interactive learning environment for candidates. The instructional model is described in more detail below.

The transition process took place over three summers and two academic years. Two separate course redesign teams, one team for mathematics courses and one for mathematics education leadership courses, worked to transition the courses to an online format. The team evaluated the existing content and pedagogical strategies; explored online learning technologies for delivering material, facilitating discussions, and completing activities; and made the necessary revisions to all aspects of the courses being taught during that year. The conversion was an iterative process. In addition to receiving guidance from course designers with extensive experience in making this type of transition and who specialize in online program development, the redesign teams considered the feedback gathered from candidates and instructors during the first year when selecting instructional tools and developing activities and assignments for the courses taking place during the second year.

Online Program Structure

While each course covers different mathematics and mathematics education content and has different requirements, all of the courses in the program use similar methods for content delivery and student preparation for whole class synchronous meetings. Each course has synchronous and asynchronous components. The amount of time spent in synchronous whole class meetings is significantly less than a traditional face-to-face class. Information is organized sequentially in the online course management system according to each synchronous whole class meeting, called course sessions. Each session contains 4–8 hours of prerequisite work for candidates to complete prior to the synchronous meeting.

Prerequisite activities are carefully sequenced so that candidates can complete the activities independently or in small groups without instructor support. Activities are grounded in the principles of a community of inquiry (Garrison et al., 1999). A significant aspect of teaching presence is designing and facilitating educational experiences. While facilitation is primarily a role for course instructors, each course includes opportunities for candidates to assume the role of facilitator, with increased responsibility in later courses in the program. All readings and activities include prompts to help candidates initiate cognitive presence to explore ideas and concepts. Social presence is purposefully integrated in all sessions through small group collaboration and providing an open, judgment-free environment for small group and whole group discussions.

They begin their preparation by completing individual activities including reading case studies about children doing mathematics, writing responses to posed questions, and completing mathematics activities. The class is divided into small groups each one consisting of 3–4 cohort candidates. Each group meets online (through Blackboard Collaborate, Zoom, etc.) at least once a week at a time that fits the schedules of all group members to discuss activities, share ideas, and complete additional small group activities. Individual and group responses to all prerequisite work are uploaded into an online course management tool (e.g., Blackboard or Padlet) for easy access by everyone in the course. Before each synchronous session, the instructional team reads through the candidates' responses to prerequisite assignments and activities to gain insight into candidates' understanding of the concepts and to find ideas that should be reinforced or misconceptions that need to be addressed. In addition to addressing any pressing issues, time during the whole class meeting is spent working on activities that reinforce the most important concepts studied during that course session. An outline of prerequisite work for a sample Rational Numbers and Proportional Reasoning course session appears in Figure 1 below.

Figure 1
Rational Numbers and Proportional Reasoning Prerequisite Work Outline

1. Revisit Math Activity 1.3 **Interpretations of 3/4** in the Concurrent Work: Session 1 folder. Make note of any adjustments you would make to your sort based on the 5 ways to interpret a/b: (1) part-whole comparison, (2) quotient, (3) measure, (4) operator, (5) ratio/rate.
2. For Math Activity 2.1, read the handout, *Some Thoughts on the History of Mathematics* and individually answer the questions for addition and subtraction and solve the problems for multiplication and division.
3. In small groups, complete Math Activity 2.2, Lamon, Chapter 6, p. 143 problem 5 parts a, b, c & d. For each part, give a brief explanation for what happens when the fraction is changed using the specified conditions. Provide an example to support your reasoning.
4. Read YMW Chapter 6, pp. 92 - 107. Individually, develop responses to the Focus Questions. In small groups, discuss your responses to the questions. Be prepared to share your ideas during our next class meeting.
5. On YMW page 95, Fosnot and Dolk paraphrase a statement from Liping Ma "One could argue that if we taught the algorithms conceptually, more understanding would develop." The authors then pose several questions. In your small groups, in 3-4 sentences, craft a statement that addresses one of the authors' questions (see below).
   Groups Un & Deux: Should the algorithm be the goal of computational instruction?
   Groups Trois & Quatre: In today's world, do we want learners to rely on paper and pencil?
   Groups Cinq & Six: Is the algorithm the fastest, most efficient way to compute?
   Groups Sept & Huit: When are the algorithms helpful? When does one pull out a calculator?

Note: Lamon refers to the book *Teaching Fractions and Ratios for Understanding*, 3rd Ed. YMW refers to the book *Young Mathematicians at Work: Constructing Fractions, Decimals, and Percents*.

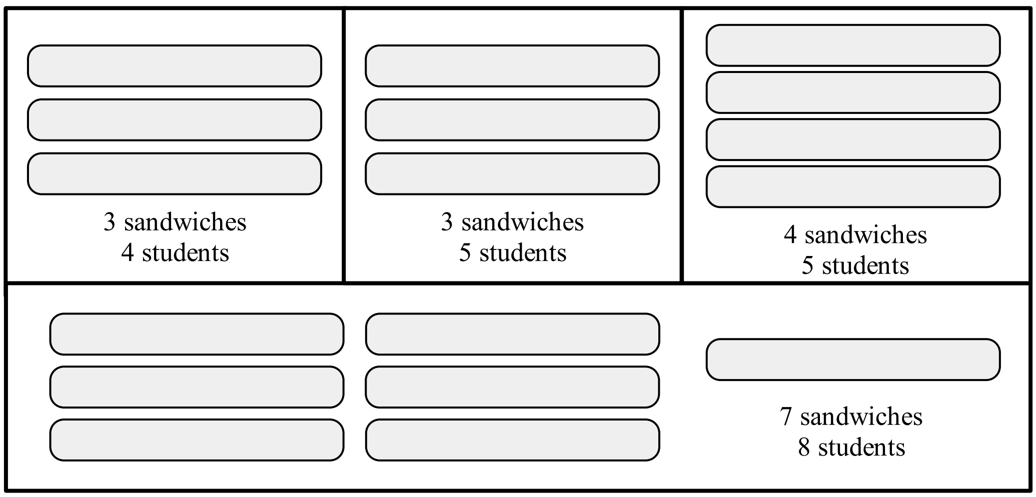
To illustrate the course session structure used throughout the program, we share a mathematics activity from one of the courses and one candidate's experience with completing the activity as part of course session prerequisite work and working with a small group of candidates to develop a deep understanding of the mathematics under study.

Sample Mathematics Activity

Rational Numbers and Proportional Reasoning is typically the third mathematics course candidates complete in the preparation program. The course begins with the following rich task:

> A class of fifth graders go on a field trip. They split into four groups and go to four different locations. Each group takes a number of submarine sandwiches with them. In the picture below, you can see the number of sandwiches each group received and the number of students in the group. Is this distribution of sandwiches fair? Why or why not? Solve the problem using a representation. Explain the reasoning behind your solution strategy without using a standard algorithm.

Figure 2
Fifth-Grade Field Trip Submarine Sandwich Distribution



Purpose of the activity

This problem, adapted from Fosnot and Dolk (2002), provides candidates with the opportunity to explore fair sharing, equivalence, and other proportional relationships. Candidates begin by solving the problem individually. They are encouraged to try multiple approaches to find a solution and to draw pictures as they explore different solution strategies. Then, in small groups, they share their strategies and develop one solution to post in an online course management tool. After they have reasoned through the problem for themselves, they read a chapter in Fosnot and Dolk which presents a case study of children exploring fair sharing and equivalence as they also solve the problem in small groups and then share their ideas and strategies with the whole class.

This problem was chosen to start this course because it is a rich task based on concepts that are frequently revisited throughout the course. For example, in addition to fair shares and equivalence, other concepts that are explored are common denominators, common fractions, and the connections between fractions, division, and multiplication. Also, by delving into the Fosnot and Dolk (2002) case study, candidates have the opportunity to discuss children's thinking about proportional relationships and ways to engage children in working through and discussing rich tasks like this problem. One candidate's experience with this activity is described in Figure 3.

To many, this problem may be a simple one exploring ideas of fair sharing or division. This is how some program candidates saw the problem at first glance. But like many rich mathematics tasks, the exploration can go much deeper than the concepts that are obvious on the surface. By studying the work that other groups posted to the course management system, candidates saw new ways to solve the problem that they would not have thought of otherwise. During the whole class discussion, the class explored other big ideas like fraction equivalence and comparison. This problem also provided a strong foundation for exploring other rational numbers concepts and proportional reasoning strategies in subsequent course sessions.

Figure 3
A Candidate's Experience with Completing the Submarine Sandwich Activity

> As a middle school teacher, I often solved the mathematics activities throughout the courses with strategies I use with my students. My approach to this problem was no different. I started with a visual representation of each set of sandwiches (see Figure 2) and divided each sandwich into pieces based on the total number of students in the group. Every student could be given a piece from each sandwich and I could determine how much each student received by combining the unit fractions. Lastly, by comparing each fraction, I determined that across the groups, students received different fractional parts of a sandwich, thus it was not a fair distribution. After solving the problem one way, I would explore other ways to solve the problem, asking myself, "how might other students, younger or older, try to solve this problem?" This was often a challenge for me, thus working with a small group of candidates was essential to explore different ways of thinking and to deepen my understanding. Solving this problem involves ideas of fair share, division, equivalent fractions, and proportional relationships. It could be solved with manipulatives, models, or traditional algorithms. The rich and meaningful connections became more clear through the small group and whole class discussions.

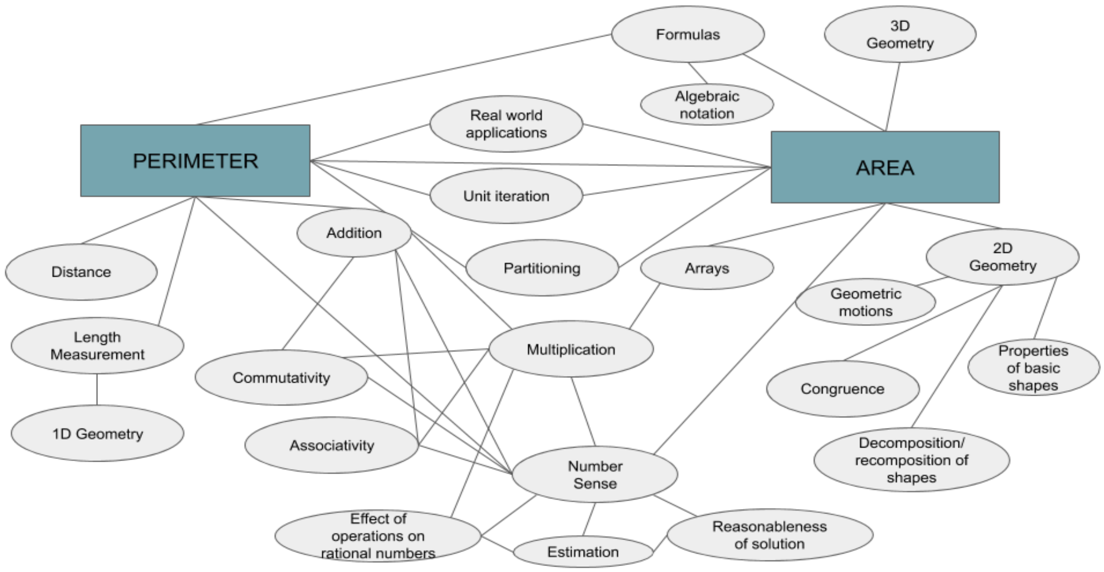
Externship

The externship is a two-semester capstone experience in which candidates have the opportunity to integrate and apply what they have learned throughout the program through a practical, school-based project. An overarching goal is for candidates to further develop the skills and practices of a reflective practitioner by grounding their project goals in the appropriate mathematics education research, revising the project as needed, and using data they collected during project implementation to analyze and reflect on the entire process, including the project's impact on the participating teachers or students. During the first semester, through a series of course sessions consisting of prerequisite work and small-group and whole-class discussions, as well as individual consultations with a course instructor, candidates develop an action research project and write a detailed proposal for the project. They then implement the project during the second semester and write a detailed final report. Information about the various components of the externship and one candidate's externship experience are presented below.

Proposal Writing

The first semester begins with a prerequisite activity in which candidates develop a knowledge package for one of the mathematics concepts presented in Liping Ma's (2010) book detailing differences between elementary school teachers' understandings of mathematics in the United States and China. A knowledge package is a way of thinking about a mathematical topic as "group-by-group rather than piece-by-piece" (Ma, 2010, p. 18). Creating a knowledge package requires an understanding of what ideas and procedures support the mathematical topic of focus. Figure 4 shows an example of a knowledge package. The rectangles contain the mathematical topics of focus, and the supporting ideas and procedures are shown in ovals with lines representing the connections between concepts.

Figure 4
Knowledge Package for Linear and Area Measurement



As the semester progresses, candidates spend time developing a knowledge package for the mathematics concepts featured in their project as well as conducting an in-depth review of the content and pedagogy literature for their topic. Based on this foundational work, candidates develop a detailed project proposal. They develop professional and pedagogical goals as well as a set of guiding questions to be answered by completing the project. The goals, supported by the literature review, provide a framework for both the mathematical and pedagogical work to occur during the implementation. The detailed implementation plan includes a description of the setting of where the project will occur as well as a list of daily learning objectives and activities. Candidates spend at least 120 hours preparing lessons and activities, analyzing data, and developing the final report. The proposal includes a timeline which outlines how each hour will be spent, spanning several months from preparation to final reflection. The plan includes research-based tools for evaluating the project outcomes and data analysis. Sample lesson plans are included as appendices to the proposal. The complete proposal is approved by the externship supervisor before the project is implemented.

Proposal Implementation

Early in the second semester, candidates make any final revisions to the proposal and prepare for implementation. They share the proposal with the school building principal or district supervisor and receive feedback on the plan. Each candidate is assigned a university supervisor who oversees and evaluates the externship. The candidates meet in an online whole group session to share their proposal goals and project questions and briefly outline their plans for implementation. Throughout the implementation and data analysis phases, each candidate participates in a series of online check-in meetings with their university supervisor to discuss their progress and get feedback. The number and frequency of meetings depends on the nature of the project. At the end of the semester, candidates meet online as a whole group to share their project results through a 20-minute presentation and answer questions about the project and receive feedback from the group. One candidate's experience developing and implementing the externship is described in Figure 5.

Figure 5
A Candidate's Externship Experience

The focus of my externship project was on teaching concepts of linear and area measurement through the math workshop model of instruction. Math workshop consists of three main components: number sense routines, mathematical tasks, and small group learning. This project took place in my sixth grade classroom with a high population of English Learners. The use of math workshop provides an opportunity for greater differentiation and the ability to support all students at their diverse levels of mathematical understanding. I first developed the knowledge package for the key area and perimeter concepts (see Figure 4). This helped me to better understand the necessary background knowledge for students to deeply understand these concepts. Using the knowledge package as a resource, I created a pre and posttest to help me determine the students' current level of understanding and to show their growth after instruction.

Students who struggle mathematically often rely heavily on formulas in the study of geometry and do not develop a deep understanding of the concepts. My goals for the project were to develop number sense routines, mathematical tasks, and small group learning activities that would assist students in building a conceptual understanding of area and perimeter without emphasizing the traditional algorithms. Using the results of the pretest, I created small group mathematics activities to help students progress through the knowledge package.

The instruction took place over seven days and covered three main concepts: perimeter, area of squares and rectangles, and area of triangles. The routines for each day were largely the same. Each class started with a number sense routine focused on foundational ideas of the day's work. A mathematical task was used to introduce the big ideas of each new concept, followed by small group learning and independent and partner practice. The results of this project revealed that math workshop is an effective way for a diverse group of students to learn the concepts of area and perimeter without relying on the use of formulas when problem solving.

This externship experience was a culmination of all I had learned through the preparation program. Each mathematics course pushed me to dig deeper to understand how different mathematical concepts build and connect with one another. I put my learning into action as I developed rich mathematical tasks, number sense routines, and assessments rooted in the knowledge package for linear and area measurement. Through what I learned in our education leadership courses I was prepared to support a diverse group of students, determining where they were in the knowledge package and providing them with appropriate and meaningful work to help them further develop their understanding. In addition to what I learned in this program, the relationships I developed with both candidates and professors were essential to my professional growth.

Conclusion

The VCU mathematics specialist preparation program was successfully transformed to an online format utilizing interactive and collaborative learning experiences. All 26 members of the cohort who participated in the initial implementation of the online version of the program successfully completed the program. Candidates expressed satisfaction with their experiences in completing the course work and their preparation to serve as mathematics teacher leaders. Many individuals stated that the online learning experience was better than they could have ever imagined.

The online model included all of the activities and assignments that had been developed for the face-to-face mathematics specialist preparation model and met all of the requirements for Virginia's K–8 mathematics specialist add-on endorsement. Based on the principles of a community of inquiry (Garrison et al., 1999) but, most notably, social presence (e.g., open communication, group collaboration, and bonding), technology virtually connected a group of teachers from across the state and helped the cohort to develop and grow into a tight-knit professional learning community. The flipped classroom model including independent work, small group activities, and whole class discussions helped candidates to explore concepts and ideas in a variety of meaningful ways. The externship allowed the candidates to put what they learned into practice. The result of this experience was a new cohort of strong mathematics teacher leaders across the state, who are prepared to coach and mentor other teachers in mathematics content and pedagogical best practices. While online best practices were not explicitly taught during this program, they were constantly modeled during each course. Therefore, an unexpected but important by-product of this experience is that the candidates were fully prepared to transition to online instruction in their schools when schools unexpectedly had to close in March of 2020 due to the COVID-19 pandemic. This model of professional development was extremely successful and is replicable with other programs and in other contexts.

Acknowledgment

This paper was developed in part through the project *The Virginia Mathematics Specialist Initiative: An Online Program to Prepare K–8 Mathematics Teacher Leaders for High-Needs School Districts* with support from the National Science Foundation, Noyce Track 3 Award 1660774. The opinions expressed here are those solely of the authors and do not reflect the opinions of the funding agency.

References

Association of Mathematics Teacher Educators. (2013). *Standards for elementary mathematics specialists: A reference for teacher credentialing and degree programs*. http://amte.net/sites/all/themes/amte/resources/EMS_Standards_AMTE2013.pdf

Conference Board of the Mathematical Sciences. (2010). *The mathematical education of teachers II*. https://www.cbmsweb.org/the-mathematical-education-of-teachers/

Fosnot, C. T. & Dolk, M. (2002). *Young mathematicians at work: Constructing fractions, decimals, and percents.* Portsmouth, NH: Heinemann.

Garrison, D., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87 – 105.

Knowles, M., Holton, E., & Swanson, R. (2015). *The adult learner: The definitive classic in adult education and human resource development*. London, UK: Routledge.

Ma, L. (2010). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. New York, NY: Routledge.

National Council of Teachers of Mathematics. (2012). *NCTM CAEP standards—elementary mathematics specialist.* http://www.nctm.org/Standards-and-Positions/CAEP-Standards/

National Governors Association Center for Best Practices and Council of Chief State School Officers. (2010). *Common core state standards for mathematics. Common core state standards (college- and career-readiness standards and K–12 standards in English language arts and mathematics).* http://www.corestandards.org/

Stapleton, L. (2020). Flipping the mathematics classroom. In Z. Walker, D. Tan, & N. Koh. (Eds.), *Flipped Classrooms with Diverse Learners*. London, UK: Springer.

Teacher Leader Exploratory Consortium. (2008). *Teacher leader model standards*. https://www.ets.org/s/education_topics/teaching_quality/pdf/teacher_leader_model_standards.pdf

Virginia Mathematics and Science Coalition. (2016). *Virginia's mathematics specialist initiative: Overview of program and course annotated syllabi for preparing mathematics specialists*. http://vamsc.tklapp.com/wp-content/uploads/VMSI_AnnotatedSyllabi_Final.doc.pdf