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THE DEVELOPMENT OF ELEMENTARY MATHEMATICS SPECIALISTS IN A TWO-YEAR GRADUATE PROGRAM

Corey Webel
University of Missouri

Phi Nguyen
University of Illinois-Chicago

Eric Partridge
University of Missouri

In this paper we share some ways that a cohort of 24 elementary teachers developed over the course of a two-year Elementary Mathematics Specialist certification program. We analyzed pre-, mid-, and post-program interviews to examine the development of the teachers' visions for high quality mathematics instruction and their views about themselves as mathematical leaders. In addition, we conducted end-of-program focus groups with a subset (n = 13) of the cohort, in which we asked them to describe specific elements of the program that helped them develop as teachers and leaders of mathematics. We found that teachers named several common elements of the program as impacting their knowledge, practice, vision, leadership, and confidence, including specific course assignments and the cultivation of a supportive community within buildings and across the cohort.

INTRODUCTION

Elementary Mathematics Specialist (EMS) programs are generally designed to develop teachers' capacity for 1) high quality mathematics instruction and 2) leadership to support the improvement of mathematics instruction in their school and districts (de Araujo et al., 2017). While research has found that EMS programs can produce increases in knowledge, productive beliefs, and reform-oriented practices for teachers (e.g., Myers et al., 2020), there is less known about development of leadership capacity and how elements of EMS programs contribute to this. In this paper, we report findings on EMS development in relation to two program goals—instructional vision and leadership—and examine participants' perspectives about how they developed and what elements of the EMS program supported this development.

CONTEXT

The context for this study is an EMS program comprised of 24 graduate credits over two years that included five content courses (number and operations, rational numbers, measurement and geometry, algebraic reasoning, and data and probability) and two leadership courses. It was co-designed by faculty at multiple institutions across the State of Missouri in the United States of America based on the recommendations provided by the Association of Mathematics Teacher Educators (2013). It is typically offered as a hybrid program, with online components and approximately five synchronous meetings each semester. The cohort described in this study received funding as part of a National Science Foundation (NSF) grant that paid 1) their tuition for the two-year program, and 2) yearly stipend for the following four years to teach in a high-need school district and engage in leadership activities. The funding also allowed the program to offer the two leadership courses, typically offered online in an asynchronous format, as weeklong in-person Summer Institutes (2019 and 2021). These Institutes engaged Fellows in a variety of collaborative learning experiences related to teaching mathematics and leading efforts to improve mathematics teaching and contributed to the development of a professional community. This community continued to develop over the course of the program,

particularly as COVID-19 forced teachers into online spaces and reduced their opportunities for collaboration in schools.

Participants were recruited from two districts to become "Fellows" and enroll in the EMS program at one of two partnering universities in Missouri; 13 Fellows attended Institution #1 and taught in District 1; 11 Fellows attended Institution #2 and taught in District 2. All Fellows were female, and ranged in years of experience from 0 to 16.

Space limitations preclude an exhaustive description of program components, but the goals focused on developing participants knowledge for teaching mathematics (Ball et al., 2008), their teaching practices (National Council of Teachers of Mathematics, 2014), their visions for mathematics instruction, their leadership capacity, and their understanding of the relationship between systems of education and mathematics instruction, including the role of curriculum resources in the United States. To support the development of practice and professional community, assignments required participants to enact instructional routines such as number talks, number strings, and sorting tasks with their students, and to engage in conversations with their peers to plan and debrief these enactments. Other assignments asked participants to focus on the experiences of their students, by, for instance, collecting and analyzing student survey data or focusing attention on a "target student" to identify specific strengths and needs (Webel et al., 2021). Finally, participants were asked to create Leadership Action Plans to address specific challenges they faced in their school buildings (if more than one teacher taught at the same school, they co-created a plan to enact as a team). They submitted regular updates on their plan over the course of the two-year program, including information about what was going well and what obstacles they had encountered.

METHODS

Data was collected via interviews at the beginning (Year 0), middle (Year 1), and end (Year 2) of the EMS program. To assess the development of participants' visions of mathematics instruction, we administered the Visions of High-Quality Mathematics Instruction (VHQMI) interview protocol (Munter, 2014), in which participants describe what they would look for in a mathematics lesson to determine whether the instruction was high-quality. To assess the Fellows' development of their conceptions of themselves as leaders, we asked them to describe their ideas about possible leadership activities in which they would like to engage, what they would want to keep in mind in a leadership role, and what they were excited and apprehensive about regarding such a role. In the Year 1 and Year 2 interviews, we also asked whether anything had changed in terms of how they engaged in leadership or were seen as a leader in their school or district. To investigate the Fellows' views about the impact of the program on their own development, we conducted six focus groups with the 13 Fellows at Institution #1. We asked how the program helped them address teaching challenges, how their teaching of mathematics had changed, what specific readings, ideas, or activities had made the biggest impact on them, and what challenges they were still facing related to teaching and leadership in mathematics.

To analyze the development of Fellows' visions, we focused on four VHQMI rubrics (Munter, 2014): *role of the teacher*, *mathematical tasks*, *patterns of classroom talk*, and *nature of classroom talk*. For each dimension, we used the rubrics to assign a score (0 to 4) to represent the sophistication of discourses teachers employed to characterize "ideal classroom practice" (Munter, 2014) at the beginning of the program and after one year.

To categorize Fellows' conceptions of themselves as leaders, we used an open coding process that resulted in the labels *Apprehensive*, *Emerging*, *Optimistic*, *Cautiously Confident*, and *Established*. These characterizations varied along dimensions of 1) confidence in themselves as leaders and 2) awareness of the nuances and responsibilities of leadership work. For example, Established Fellows exhibited high levels of both confidence and awareness, Optimistic Fellows exhibited high levels of confidence but moderate levels of awareness, and Apprehensive Fellows exhibited relatively low levels of each. In this paper we compare results from the Year 0 and Year 2 interviews.

To analyze the focus group sessions, we created and refined categories for how Fellows described their development across five dimensions: *Knowledge*, *Practice*, *Vision*, *Leadership*, and *Confidence*. Within each category, we listed elements of the program, including assignments or activities, that were referenced as supporting their development. We then compared elements identified across the six focus groups to characterize ways that Fellows perceived the program as supporting their development.

FINDINGS

Visions of high-quality mathematics instruction

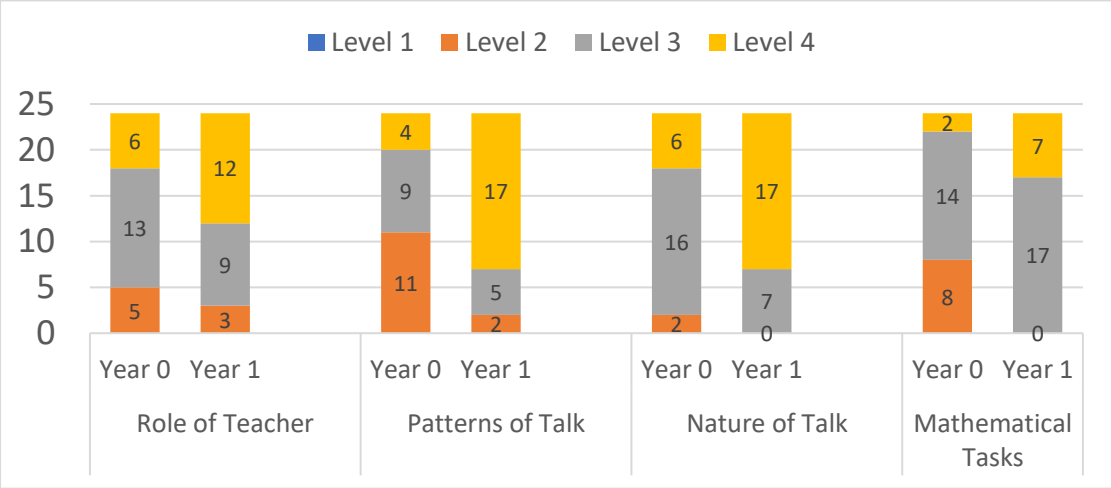

Figure 1: Development of Visions for High Quality Mathematics Instruction

Figure 1 shows the VHQMI ratings for Fellows from Year 0 to the end of Year 1. In all the categories, more participants were rated at Levels 3 or 4 than in Year 0. In "role of the teacher," "patterns of talk," and "nature of talk," at least half of the Fellows were rated at the highest level, 4, after their first year in the program, and only a few Fellows were at level 2.

In the "role of the teacher" dimension, of the 18 Fellows who were not already rated at level 4, 10 had higher ratings at the end of the first year than at the start of the program. For example, five Fellows were initially rated as 2, which indicates a "teacher as monitor" conception, in which a high-quality mathematics lesson involves providing opportunities for children to work together on mathematical tasks, but the teacher is described as starting lessons by demonstrating or leading discussions on how problems should be solved and is treated as the primary source of knowledge, the "adjudicator of correctness." For example, Candace talked about starting with "a little bit of that direct instruction" and then "a lot of group work." She emphasized the role of talk because "it's crazy how much they can learn from each other. But she also talked about "pulling a group of students" to say, "hey, I just

want to make sure you understand this." This description conveys the idea that a teacher presents material, monitors students as they work, and intercedes or pulls students as they experience struggle. The emphasis is on ensuring that students are "getting it" as they work on problems.

After a year in the program, Candace's description of the teacher's role had shifted to a "teacher as facilitator" (level 3) conception. She described a high-quality lesson involving the teacher

> not even leading the student into the answer maybe they're looking for, but just putting out the 'tell me more about this' or 'why did you do it this way?' and having the student explain their math, not what the answer is but the process of getting to that answer.

Candace also talked about the importance of the teacher "just sitting and listening to the kids…and if we're confused, just being like, tell me more, keep going, instead of trying to push them to the answer." In this description, Candace is less concerned about monitoring the correctness of the children's work, and instead encourages students to work through their confusion. She conveys more trust in their ability to resolve their own misconceptions through conversation.

Growth was also seen in the "patterns of talk" category, which addresses the structure of mathematical conversations—whether they occur as a whole class or small group, and whether they have a calculational or conceptual orientation. For example, in her Year 0 interview, Erin was rated at a Level 2 for patterns of talk, in which student-to-student discourse is valued, but only in the context of small group work, not as a vital component of whole class discussion. Erin talked about her use of small groups for "math stations. Those are my times for more exploration time or practice time… I'm working with specific skills that I know kids are missing." She talked about how other student can play games or work on other tasks while "I'm pulling a small group and teaching those missing skills." These descriptions suggest that the focus of these small group conversations was to enable students to correctly solve problems rather than to wrestle with ideas, and whole group discussions of ideas were not emphasized in Erin's description of high-quality instruction.

At the end of her first year, Erin was rated at a 4 for patterns of talk. She talked "posing a problem or task" and "letting them explore", and then the teacher would monitor their thinking to plan for the whole class discussion (e.g. "I want you guys to share your strategy when we go back to the whole group"). She talked about the importance of asking

> questions like, 'How did you see that, how did you get that? Can you tell me more? Can you explain more?' And getting the kids to do most of the talking. Or, 'I heard you say that you disagree. Can you tell me why you disagree?' And really encouraging students to do most of that.

Erin did talk about students working in small groups/partners in this interview, but these were designed to serve the whole class conversation rather than being spaces for her to fill in missing gaps.

> ...giving them different opportunities to partner talk. I think that's super powerful for them to feel confident and building that, 'if I can tell a partner, first, then I can share with the whole group.' So partner talking and then engagement and just the idea of like using hand signals like I agree or, I have one strategy, two strategies, three strategies..."

In general, Erin's description of the patterns of talk a high-quality lesson changed markedly over the first year of her EMS program, moving from a structure emphasizing small group work as the setting for resolving mathematical misconceptions to one in which the whole class conversation was designed to support mathematical argumentation about the ideas that students generated in small groups. These kinds of change patterns were evident for most of the Fellows across the sample (Figure 1).

Fellows' conceptions of themselves as leaders

Regarding conceptions about leadership, over the two years of the program, we saw a decrease in the number of Fellows characterized as Apprehensive and Emerging, and an increase in the number characterized as Optimistic, Cautiously Confident, and Established.

	Apprehensive	Emerging	Optimistic	Cautiously Confident	Established
Year 0	2	9	4	4	3
Year 2	0	3	6	8	5

Table 1: Characterizations of Fellows' conceptions of themselves as leaders

For example, Janet, who moved from Emerging to Cautiously Confident, talked about her growth:

> When I started, I didn't really think of myself as a leader. I'm kind of quiet. I think about what I want to say. I always thought that was not a good characteristic of a leader. But really, it's good because, maybe I'm more approachable. I'm not saying 'you have to do it this way.' Let's talk about it.

Janet originally described her quiet personality as a limitation, but grew to recognize it as an asset, suggesting an expanded view of leadership that can include a quiet personality. She ended the interview discussing her excitement for working with colleagues and sharing new strategies for more equitable approaches to grouping children for mathematics.

In another example, Gina began the program with vague ideas about how she might engage in leadership: "I think just letting them know, 'Hey, I'm here. I'm doing this program. I'm more than willing to help you if you have questions.' Just being open and available for them." We characterized Gina's conceptions of leadership as Emerging, as she indicated willingness to help colleagues, but little evidence of awareness regarding the challenges and tensions involved in such work. By the end of the program, she was notably more specific about challenges and intentional in her comments about leadership. In this excerpt, Gina described her desire to help children taught by an experienced teacher:

> She's been teaching for a long time and it's hard sometimes when a younger teacher comes in and tries to offer suggestions or things that we could do differently. And I don't want to come off like, 'I'm perfect, I know everything, like, I have a degree and you don't,' but I also know, I have to help those kids. Because I, I grew up with not good math experience and I honestly I did not like math growing up because of the way it was presented to me…

In this Year 2 excerpt, Gina, now characterized as Cautiously Confident, acknowledged tensions that can come with leading, and was also more intentional about leadership as she articulates an obligation to help children whom she fears are having negative experiences with mathematics ("I have to help those kids"). Like many Fellows in our sample, there was a significant shift across Gina's interviews between concern for "my kids" (the children in their classroom) and "our kids" (the children in their schools), indicating an increase sense of responsibility for leadership beyond their classrooms.

Fellows' impressions of how the EMS program impacted their development

Knowledge. In their exit focus groups, several Fellows described how the program had provided new knowledge, often in terms of how students' mathematical conceptions develop. One teacher said,

> I think maybe I somehow knew there was some sort of progression, but never really had names or models for what it was. But I really saw my kids in what stage they were in and then that helped me see, 'Okay, here's what they're good at, here's the stage,' and how can I take them to the next developmental stage. It was just a different way to think about assessing and how much more powerful something like observing and talking to kids could be.

Later this Fellow mentioned the Cognitively Guided Instruction book (Carpenter et al., 2015), saying it was a "huge" influence on her teaching, and others referenced Graham Fletcher's videos on learning progressions (Fletcher, n.d.) as similarly helping support their understanding of the development of children's mathematical thinking. Several Fellows referenced an assignment where they interviewed students about their understanding of the equals sign and being surprised not only by how their students misinterpreted the equals sign, but also that their instruction had inadvertently reinforced this misinterpretation through their instruction (e.g., in a string of operations such as $3 + 4 = 7 - 2 = 5$). Fellows also described developing new mathematical insights, such as a justification for the doubling/halving multiplication strategy (e.g., $12 \times 15 = 6 \times 30$), described by Fellow as: "all the light bulbs went off" after "spending oodles of time…trying to prove why it worked." She continued:

> I had never thought before, I had just talked about the patterns verbally with students, but…taking it to that next step of writing out what's happening and then looking at it as a rule and asking, 'is this always true?' Those questions have been really powerful across all the grade levels.

Some shared that the program helped them realized that they had been misrepresenting mathematical ideas in their teaching prior to the program.

Practice. With regard to impact on teaching, Fellows mentioned routines such as Which One Doesn't Belong, Number Talks, and Compare and Contrast, each of which was a focus routine for one of their content courses. One teacher said,

> The Number Talks have gotten a lot better, because we did those videos, you know. It was *really hard* for me to just let them talk. And so when I was watching my video, I was like [cringing]. So that was a goal of mine, to get better at letting them talk.

She went on to say that "watching other peoples' number talks was really helpful and then also getting feedback on my number talk. That small piece really opened up the door in my classroom for math conversation." In general, teachers described the multiple iterations and reflections on each enacted routine as important to their development of expertise.

Fellows also identified being more intentional in their lesson planning and selective in their use of curricular resources. One teacher talked about struggling with the quality of her textbook, but then told a story of turning a routine problem into a Compare and Contrast routine where students examined two solutions to a task and described the similarities and differences:

> No lie, these are the best days that we have in math. It is *joyful*… They had a blast. It was so awesome, I wish I could have recorded it. One girl said, 'Actually, the first one is showing 15 groups of two-thirds,' and people were just like, 'I object!' and 'this feels like a trial where we have to support our thinking'…. Using that structure in particular has been awesome for me.

Several Fellows talked about asking students to make and explore conjectures, through asking "is this always true?", referencing their algebraic reasoning course. One noted that asking that question in the context of "dividing fractions is also like a mind-blowing situation, so just asking a simple question has been really, really powerful." One Fellow shared anchor charts labeled "Math rules we think are

true" with examples like "when you add a double it will always equal an even number" to show how students were wrestling with conjectures and working to generalize their conclusions. Finally, several teachers described a key change in practice as the reduction of their use of ability grouping, expressing concerns about reinforcing status differences between students (see Webel et al., 2021).

Vision. Fellows described shifting from thinking about teaching mathematics as helping children use specific strategies to helping them engage in sensemaking. One Fellow said,

> I feel like from you know the classes and the activities that we did and the conversations I had with peers, I have like grown so much, and I feel like my teaching is really just completely changed…. I no longer try to get to every problem in the book. We often start off with just a task, where students will complete it on their own and then we'll talk about it and share strategies, and we definitely do more group work and more discussion.

These comments reflect a fairly comprehensive shift in how teacher envisioned the structure and goals of their mathematics teaching, similar to the patterns we saw in the VHQMI analysis. Fellows also emphasized greater awareness of how students were experiencing mathematics, referencing the practical measures survey assignment. One Fellow said the survey revealed that

> I'm who was talking the most, and 'is there one right way to solve the problem?,' and I had never reflected on my teaching in that way, because I was always like, 'Did my lesson go well?," you know, 'Did my kids learn something today?,' and it wasn't like 'How are they experiencing my teaching' and that was a big eye-opener.

Many Fellows described a desire to make mathematics enjoyable for students and to cultivate a positive mathematical identity. They also referenced equity, both in generic ways (e.g., thinking of all students as having assets for learning mathematics) as well as ways that were specific to students' racial, gender, and other identities. One teacher, for example, talked about mathematics providing "windows and mirrors" for students to see themselves and their classmates in and through the content.

Leadership. Leadership also surfaced in each focus group, though not as often as other themes, and Fellows were less likely to make specific connections to the EMS program relative to the other dimensions. Fellows described specific efforts they had made to influence their colleagues, such as providing building-level professional development or sharing their approaches to teaching mathematics on social media. One Fellow relayed that "the PD that we did with teachers was so huge because I honestly don't remember the last time our district had quality professional development…. I think I'm more equipped now to share with teachers in a non-threatening way." In some cases, they shared stories of being positioned as leaders by their administrators, or sharing their practices with colleagues through model teaching and peer observations:

> Like now I'm feeling, you know comfortable enough and confident enough to start inviting people into the room like 'Hey, you gotta watch this math lesson.' And I think that's the way you get people on board is you just welcome them into your classroom and…we think about it, what went well, help me reflect. Help me grow.

In other cases they talked about resisting some initiatives from administration:

> Then the people above us what they're telling us to do and we're supposed to read a script and it's gonna work in our classrooms and 'you better be on problem number six today'…. I think being educated, investing yourself in programs like this, surrounding yourself with community members that, you know, will support you, is huge and I feel like we're in a very dangerous place in education right now.

Some Fellows mentioned their improved knowledge as being vital for engaging in leadership efforts.

Confidence. Increased confidence was mentioned in all the focus groups, sometimes regarding teaching and sometimes regarding leadership, and often connected to development in an area like knowledge. One relatively inexperienced Fellow noted, "I was feeling like not a very strong mathematician when I started," and another said, "we've talked about just how much happier we feel teaching math now…. I don't feel like I'm just spraying them with information and hoping they get it." For experienced teachers, this was sometimes described as a reinvigoration —one teacher said the program helped her rediscover her "zest" for teaching. She went on to say, "in a sense, [the program] saved me. It kept me in teaching." Fellows also talked about the role of the cohort community as boosting their morale and giving them confidence to step out more visibly to share their expertise.

DISCUSSION

We found that over the course of the EMS program, Fellows developed substantially in their visions for high-quality mathematics instruction and in their conceptions of themselves as leaders. Through the focus groups, we were able to document other areas of development not captured by the VHQMI, such as increased attention to equity. Fellows connected their development to specific elements of the program, such as attention to instruction routines, learning progressions, and mathematical identity. They also often connected their increase in confidence to their development of knowledge and skills. These connections could be shared more widely with other EMS programs to inform their design and build a more robust knowledge base for what learning experiences are supportive for the varied work of EMSs. Future research could explore how methods of recruitment, such as selecting teachers from the same district or school, might empower EMSs in their leadership efforts.

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