THE STORY OF VCAST-SIG: COLLABORATIVE APPROACHES THAT ENHANCE MTE PROFESSIONAL KNOWLEDGE AND TEACHER LEARNING

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Like K-12 mathematics teachers, for whom effective instruction requires a full suite of pedagogical and mathematical knowledge and skills, Mathematics Teacher Educators (MTEs) also need a professional knowledge base to facilitate the development of future educators capable of supporting K-12 students' mathematical learning. In this paper, we theorize about contributors to the development of a Community of Practice (CoP) who were engaged with developing and implementing a common set of instructional materials. We discuss how using the materials in various contexts and interacting with the user community provided a much-needed network of MTEs focused on enhancing their students' mathematical learning experiences as well as their own professional development in terms of teaching, research, and curriculum development.

Keywords: Teacher Educators, Professional Development, Preservice Teacher Education, Mathematical Knowledge for Teaching Teachers.

Introduction

University-based mathematics teacher educators (MTEs) play a critical role in enhancing the quality of mathematics teachers. Like K-12 mathematics teachers, for whom effective instruction requires a full suite of pedagogical and mathematical knowledge and skills, MTEs also need a complementary set of knowledge, practices, and skills to facilitate the development of future educators capable of supporting K-12 students' mathematical learning. MTEs' specialized knowledge, termed as mathematical knowledge for teaching teachers (MKTT), for example, includes an understanding of how teacher candidates (TCs) best learn mathematics and how they think about students' mathematical thinking. MTEs need to have an awareness of and be able to notice the beliefs about mathematics teaching and learning that teacher candidates hold (Beswick & Goos, 2018; Superfine & Li, 2014a). They also need to understand how pedagogical modeling in university mathematics and mathematics education classrooms can support the preparation of TCs for teaching K-12 mathematics.

Research indicates that MTEs learn through reflecting on their practice as well as from their own research with teachers (e.g., Jaworski, 2001; Masingila et al., 2018). By reviewing their teaching practices and reflecting on their beliefs, assumptions, and outcomes of student learning, MTEs have the potential to understand and improve their practice (Appova & Taylor, 2019; Chapman, 2008; Zaslavsky & Leikin, 2004). While past research has documented the nature of MTEs' knowledge and the benefits of MTE's professional development, how MTEs come to engage in activities that help them grow in their practice has received less research attention.

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In this paper, we discuss the development of a Community of Practice (CoP) within a group of MTEs engaged with VCAST learning materials and how the community organically emerged within the group. We describe and explore factors that appear to have contributed to the development of a CoP (referred to here as the VCAST-SIG) through the collaborations of a group of nine MTEs from seven different institutions across the United States. The factors we describe emerged from broad themes identified across members' reflections on their individual practice and how those practices were impacted through participation in the VCAST-SIG. Findings highlight how the VCAST-SIG stimulated an agentive process for MTEs' thinking about their practice and continuous improvement focused on students' learning and engagement with mathematics.

Context of the Study

VCAST is an NSF-supported design-based curriculum project which drove the emergence of our CoP, and has, to date, been implemented in 16 universities across the United States. VCAST project was designed to support MTEs in their efforts to prepare secondary mathematics teachers by providing materials through which MTEs can engage secondary TCs with meaningful opportunities for learning from student thinking. A key focus of the project is to support TCs' development of both the knowledge and the dispositions needed to attend to and productively respond to the depth of students' mathematical thinking. This often entails mathematical flexibility and a willingness to learn from one's own students, especially when those students' ideas differ from the more conventional mathematical ideas that dominate traditional mathematics coursework and instruction.

VCAST curriculum materials are organized into modules, each of which focuses on the mathematical concepts embedded within a non-standard task and has three distinct parts, an asynchronous Online Component, a synchronous In-Class Component, and an asynchronous Exit Ticket (Cavey et al., 2020). Each module engages TCs in the following activities: a) solving a challenging mathematics task, b) watching video clips of secondary students solving the same task, c) engaging in repeated cycles of analysis, inference, prediction, and reflection about student thinking, and d) solving an adjusted version of the task. While TCs are expected to work individually during both the Online Component and Exit Ticket, they engage in collaborative analysis, inference, prediction, and reflection about student thinking during the In-Class Component. The curriculum project, with its emphasis on TCs' mathematical development, engaged MTEs in a variety of professional development opportunities, including summer training prior to module implementation and ongoing asynchronous training support during implementation.

Theoretical Background

Mathematical Knowledge for Teaching Teachers

MTEs require a specialized and multi-dimensional knowledge base, mathematics knowledge for teaching teachers, for effective work and preparation of K-12 mathematics teachers (e.g., Beswick & Goos, 2018; Superfine & Li, 2014a; Jackson et al., 2020). Many TCs enter their college mathematics coursework with a procedural focus and views on mathematics teaching which stem from their past experiences with procedure-oriented mathematics learning (Mason, 2010). To better prepare TCs to meaningfully support K-12 students' mathematical learning, MTEs need to know which mathematical ideas should be made explicit for TCs and how to raise awareness of how these ideas are represented, communicated, and co-constructed during

instruction. MTEs' knowledge base should encompass the challenges or misconceptions TCs might have, the range of ways in which TCs think about students' mathematical work, what TCs value in the work of mathematics teaching, and the views on mathematics and mathematics teaching TCs might hold (Superfine & Li, 2014a).

Before MTEs can support TCs and help them make a shift toward more student-centered instructional practices, they need to understand their TCs' thinking about mathematics and mathematics teaching. MTEs also need to know how to engage TCs in mathematical explorations in ways that supports TCs' learning of mathematics and connects their experiences as mathematics students to their future work as mathematics teachers. To support TCs' mathematical reasoning at high cognitive levels, MTEs need to know the mathematics content TCs learn and to understand how TCs engage with this content (e.g., Beswick & Goos, 2018; Superfine & Li, 2014b).

In this paper, we describe how participation in the broader curriculum project and the subsequent VCAST-SIG provided a platform for MTEs developing the varied aspects of MKTT. The professional development opportunities not only allowed the members of the VCAST-SIG to expand their mathematical knowledge for teaching (Ball et al., 2001) but also further develop their mathematical knowledge for teaching teachers (MKTT). In this context, MKT is the content that MTEs aimed to help TCs learn, while MKTT refers to developing TCs' understanding of and connection among ideas and developing awareness of student thinking (Superfine & Li, 2014b).

Framework of Inquiry

VCAST-SIG was initiated organically by MTEs through informal relationships that were built as we participated in the larger curriculum project. To document and theorize how participants of the curriculum project became inducted and immersed in the VCAST-SIG, we adopt a sociocultural approach, particularly drawing from Lave and Wenger's (1991) situated learning theory. Within this domain, we use the concept of a CoP as a framework to describe how the VCAST-SIG fostered a robust community of scholars focused on advancing prospective teachers' mathematical learning. Learning within a CoP is stimulated by members' engagement in a social and co-constructed activity situated in a particular context (Lave & Wenger, 1991). To document and theorize how members of the CoP grew in their MKTT knowledge, we use the following components of the knowledge strategy framework (Wenger, 2000): a) Build a community, b) develop an inclusive social learning system to strengthen the community, and c) sustain momentum by applying knowledge, reassessing, reflecting, and renewing engagement.

Methodology

A group of nine MTEs that participated in the VCAST curriculum project came together to form the VCAST-SIG. After a year of involvement with the initial curriculum project, we were struck by what appeared to be a CoP that developed among both the creators and implementers of the VCAST curriculum modules. This led us to wonder, "What are the characteristics of our CoP? What factors contributed to the development and success of our CoP? How does participation in a CoP impact us professionally?" To address such questions, we selected a methodology which would involve members of VCAST-SIG acting as both investigators and participants. We chose a phenomenographic approach as it "describes the meaning for several individuals of their lived experiences or a concept or a phenomenon" (Creswell, 2007, p. 57). In this study, the phenomenon was the emergence of a CoP through our work with VCAST. In developing an understanding of our "common experiences" in the emergence of VCAST-SIG,

we strive to determine the factors that led to our CoP and to share those practices with others. Members of the VCAST-SIG come from a variety of demographic and professional backgrounds that included teaching-intensive, research-intensive, and teaching-research-balanced positions. Four out of nine participants were a single MTE in their respective departments.

Data Collection and Analysis

Our data comes from semi-structured (Orgill, 2002) interviews conducted with each participant. The interviews were conducted and recorded using Zoom. The goal of the interviews was to better understand, through the experiences and narratives of the members, how the CoP developed, understand the impact of our interactions within the CoP, as well as how the CoP impacted our individual professional growth. The interview protocol was formulated drawing upon the concept of building professional learning communities (Kruse et al., 2009). The protocol consisted of nine questions that elicited information about members' demographics and academic background, collaboration within the CoP, and reflection on members experiences with the CoP.

Consistent with the phenomenographic research methods, we engaged in multiple stages of data analysis including familiarization, compilation, and classification (Han & Ellis, 2019). We first watched all nine interviews and read the interview transcripts. Next, each member compiled participants' responses to interview questions on a separate tab on a shared spreadsheet. We each consolidated the raw data by documenting our preliminary observations on the spreadsheet, highlighting quotes from the interview that we found relevant to the study questions. This process enabled us to delineate codes specific to themes deduced from the interview protocol (Kruse et al., 2009). As we engaged in this process, we noticed that the deduced themes did not accurately reflect the depth and complexity of participant responses and that the categories also fell short of addressing the key study questions. Hence, we adopted a more open and rigorous approach to further classify data and induced additional themes to the spreadsheet based on participants' initial categorization of the interview responses. These additional themes were developed using codes derived from the data. Below, we present examples of coding related to the induced and deduced themes.

Deduced Theme (DT): Knowledge for teaching teachers.
Code: MTE noticed, described and reflected on TCs engagement with modules
MTE Quote: TCs were very engaged with some materials, and they took it very seriously and they themselves were very reflective, and so they thought a lot about their own practice. One of my students from the first year did her senior capstone project by taking the hexagon task and interviewing students in a local high school.

MTE Quote: [I'm] using what we've done in VCAST with student analysis. I have put that into my practice a lot more than I ever did in the past. I do that now with my little seventh graders.
Code: Transfer of VCAST Pedagogy to another teaching context
Induced Theme (IT): Pedagogical shift.

Shifting our approach to classify data allowed for a more focused and richer analysis, resulting in the development and refinement of codes and themes. Data analysis revealed more than twenty-five codes related to induced themes and deduced themes.

Findings

Informal opportunities to share what we had learned with other MTEs in the VCAST curriculum project led to a series of joint professional endeavors to engage in a deep reflection of our learnings. Partnering with other instructors across the U.S. who shared the same vision, work ethic, and positive commitment to helping improve the secondary mathematics teacher preparation was powerful, especially since the range of universities and teacher candidates was so much broader than what is typically found in one campus setting. It was our commonalities that brought us together at first, and then the variation between us enriched that experience. This variability proved to be beneficial and offered a variety of opportunities for members' professional growth, which we highlight in the following paragraphs.

Pedagogical Shifts

The first theme, which highlighted how membership in the VCAST-SIG afforded participants with learning opportunities, stemmed from MTE observations of shifts in their own instructional practices, especially regarding course assessments. MTEs reported designing and implementing tasks that encouraged TCs to avoid a "tunnel vision" that can occur when TCs try to solve a problem the "right way." MTEs prompted TCs to analyze student work samples and make connections between TCs' own and the student's understanding. Furthermore, MTEs reported making conscious decisions to engage TCs in exploring theoretical underpinnings of mathematical concepts and discussing mathematics education research. These instructional shifts were intended to leverage the ideas TCs recognized in students' solutions to support TCs' understanding of students' mathematical development. The extension of VCAST pedagogy and assessment to other mathematics courses involving non-teacher education majors was another unforeseen but welcome outcome of VCAST curriculum implementation.

Knowledge for Teaching Teachers

The second theme outlines how MTEs enhanced their own knowledge of teaching teachers by becoming more aware of what and how their TCs engaged with mathematics and student thinking. Regarding TC learning as students, MTEs reported an increased awareness of multiple problem-solving approaches to tasks and their own ability to make connections among them. When TCs engaged with the VCAST asynchronous online tasks, they experienced productive struggle which deepened their mathematical content knowledge. MTEs also reported changes in the depth of TC conversations about different approaches, reflecting a better conceptual understanding of the key ideas of a task. Regarding TC development as potential teachers, MTEs saw a change from concentrating on student errors to speculating and pondering their thought processes. Though TC development was a key outcome of VCAST material implementation, noticing this growth, being able to use in-class conversations to amplify TC learning, and the VCAST material's emphasis on evidence-based analysis and humility have impacted MTEs and their own capacity to support TC development. Involvement with VCAST materials, allowing TCs to engage with student thinking, and engagement in discussions and reflection sessions, have helped MTEs bolster questioning strategies, become better listeners, better understand how TCs engage in productive mathematical struggle and develop additional directions for future teaching.

Mathematical Learning

This theme involves MTE observations about their own mathematical learning. Although MTEs reported a range of new understandings specific to each of the four modules, three broad categories related to that learning emerged. First, when MTEs felt they already possessed a high level of expertise with the mathematics of a task, implementation of the modules revealed

unanticipated conceptual complexities for students. This served to either expose or reorient MTEs' attention toward the foundational concepts embedded within each task. Second, analyzing the modules' range of student evidence with candidates deepened MTEs' capacity to describe, draw connections between, and compare different types of student reasoning. Lastly, for module tasks that were less familiar and more difficult, MTEs reported learning additional mathematics along with their candidates and being humbled by the challenges they themselves encountered.

Engagement in Scholarship

The final theme pertains to MTE's acknowledgment of heightened interest in research. While some MTEs' workloads or work contexts did not necessitate their participation in research, their involvement in VCAST-SIG allowed them to occasionally venture outside of their comfort zones and attempt scholarly activities. Their engagement in the research was sparked by the desire to improve their classroom instruction and the act of seeing how well the VCAST research complemented and improved their pedagogical goals. Members' differing research backgrounds brought forward ideas for improving the implementation of the VCAST modules. By infusing aspects of culturally responsive pedagogy, student identity, and affective domain, MTEs sought to strengthen TCs' reasoning and explanation skills. Furthermore, the diverse research interests increased VCAST-SIG's awareness of opportunities to disseminate their work to broader audiences. Having access to the different perspectives of MTE instructors, the ability to "peek inside" the classrooms of community peers, and to read literature related to other MTEs' research agendas has broadened participants' own perception about what it means to prepare teacher educators well.

Implications

Stepping back and reviewing how the VCAST-SIG became a CoP reveals factors that mirror the "knowledge strategy" framework for building a CoP (Wenger, 2000).

Build a Community

The VCAST-SIG members continued to build on the foundation provided by the curriculum project through a) reflective discussions sharing their module implementation experiences, b) refining and finding additional application for the VCAST modules (Cavey et al, 2021) and c) by gathering, analyzing, and documenting evidence (Chapman, 2008) that demonstrated a growth in their TCs' mathematical knowledge MKT, and teaching dispositions (Cavey et al., 2020). This sense of accomplishment strengthened MTEs' connection to the VCAST-SIG. Consistent with research findings (Olanoff et al., 2021; Goos & Bennison, 2019), in our study, we noticed that effective CoPs are grounded in participants' common goals. *For those pursuing their own CoPs, we suggest finding a common need or goal that will bring together professionals who subscribe to the goal and then provide opportunities for contributions that advance these goals.*

Develop an Inclusive Social Learning System to Strengthen the Community

VCAST-SIG members hold different roles within their mathematics departments, so the group provided an opportunity for members, including lone MTEs in their respective departments to engage in cross-institutional peer interaction and collaboration. In addition to the variation in MTE roles, there were also significant differences in the student populations that the members taught. Due to the diversity of the student groups, the VCAST-SIG was able to assess the effectiveness of the VCAST modules for students with diverse learning goals and the potential for expanding the applications of the skills to non-TCs and math courses that are not specifically geared toward education. Members of the group who are primarily involved in

teaching have expanded their areas of interest in research, either by broadening the scope of their existing research or by concentrating on scholarly work that addresses the intersection of the VCAST curriculum and its implementation and reflection on their pedagogical practices. Thus, we emphasize *the significance of collaborating beyond members' departmental responsibilities and experiences to provide perspective to discussions and uncover connections and applications that other group members might not have considered.*

Sustain Momentum

Beyond the curriculum project, the reflective structures and discussions continued to be an integral part of the VCAST-SIG. Community development came from the inclusion of multiple points of contact to connect through both synchronous modalities, such as Zoom meetings, and asynchronous modalities, such as Google docs and spreadsheets and resources posted on the VCAST-SIG's shared folder. The monthly Zoom meetings encouraged MTEs to reflect on their practice, established a sense of accountability for the group, and served as a springboard for developing new goals. Each member chose their own path to address these goals with support from other group members. Members added personal reflections, pedagogical activities, and manuscripts on MTE professional development to the shared online folder and it gradually transformed into a rich repository of knowledge. *Once a community has been established, it is vital to put in place structures for reflection, repository for ideas, and establish accountability to prime members for upcoming community discussions.*

Conclusion

The VCAST-SIG continues to expand on their work that first brought them together by focusing on both teaching and scholarship. This momentum was built on various achievements, interactions, and reflections that occurred throughout the knowledge strategy cycle. Participation in the project is different from other venues of professional collaboration due to its unique blend of opportunities to engage in the design-based cycle of curriculum development, scholarship, and a community of practice which shares the same goals while also highlighting a diverse range of paths toward those goals. It has broadened participants' perspectives on mathematics, teaching, and the preparation of teachers by layering in new focuses on culturally responsive pedagogy, the benefits of self-study and reflection, different instructional strategies, and tools suitable for remote use. There is also a renewed focus on the value of attending to an individual's mathematical understanding - whether it's the MTEs' own understanding, the VCAST material's featured secondary students' understanding, or the understanding of teacher candidates.

Engaging in this work has strengthened our community by clarifying for ourselves, (1) what factors drew us together (institutional isolation, opportunity to work on a common problem of interest, and the added isolation of the COVID-19 pandemic), (2) what factors contributed to our continued growth and development (relationship-building, contributions respected and valued, diversity of perspectives), and (3) what outcomes are associated with our participation (shifts in teaching and scholarship, observed shifts in TC learning, and shifts in our perspectives on the teaching and learning of mathematics). By sharing our work, we aim to advance our collective knowledge of ways to support MTEs' professional development, thereby enriching the mathematical and pedagogical learning experiences of our TC's.

References

Appova, A., & Taylor, C. (2019). Expert mathematics teacher educators' purposes and practices for providing prospective teachers with opportunities to develop pedagogical content knowledge in content courses. *Journal of Mathematics Teacher Education*, *22*(2), 179-204.

Cavey, L.O., Naresh, N., DuCloux, K.K. & Totorica, T. (2021). Eliciting dispositions for teaching in the context of a video-based intervention for secondary teacher candidates. The 43rd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Philadelphia, PA, United States.

Cavey, L. O., Libberton, J., Totorica, T., Carney, M., & Lowenthal, P. R. (2020). VCAST learning modules: A functions & modeling course innovation. In J. Goodell & S. Koc (Eds.), Preparing STEM teachers: A replication model (pp. 259-275). Information Age Publishing.

Ball, D. L., Lubienski, S., & Mewborn, D. S. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), Handbook of Research on Teaching (pp. 433–456). Washington, DC: American Educational Research Association.

Beswick, K., & Goos, M. (2018). Mathematics teacher educator knowledge: What do we know and where to from here? *Journal of Mathematics Teacher Education*, *21* (5), 417-427.

Chapman, O. (2008). Mathematics teacher educators' learning from research on their instructional practices: A cognitive perspective. In B. Jaworski & T. Woods (Eds.). *The international handbook of mathematics teacher education: The mathematics teacher educator as a developing professional* (Vol 4, pp.115-134). Rotterdam: Sense Publishers.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches*, (2nd Ed.). Thousand Oaks: Sage Publications.

Goos, M. & Bennison, A. (2019). A zone theory approach to analysing identity formation in mathematics education. *ZDM Mathematics Education 51*, 405–418. https://doi.org/10.1007/s11858-018-1011-8

Han, F., & Ellis, R. A. (2019). Using phenomenography to tackle key challenges in science education. Frontiers in Psychology, 10, https://doi.org/10.3389/fpsyg.2019.01414

Jackson, B., Hauk, S., Tsay, J.J., & Ramirez, A. (2020). Professional development for mathematics teacher educators: Need and design. *The Mathematics Enthusiast 17*(1 & 2), 537-583.

Jaworski, B. (2001). Developing mathematics teaching: Teachers, teacher educators, and researchers as co-learners. In F.-L. Lin & T. Cooney (Eds.), *Making sense of mathematics teacher education* (pp. 295–320). Dordrecht: Kluwer.

Kruse, S., Louis, K. S., & Bryk, A. (2009). Building professional community in schools. 13 Parameters: A Literacy Leadership Toolkit, *Research Resource Book*. (pp. 159-163). Pearson Education.

Lave, J., & Wenger, E. (1991). *Situated learning. Legitimate peripheral participation*. Cambridge: University of Cambridge Press.

Masingila, J. O., Olanoff, D., & Kimani, P. P. (2018). Mathematical knowledge for teaching teachers: Knowledge used and developed by mathematics teacher educators in learning to teach via problem solving. *Journal of Mathematics Teacher Education*, *21*(5), 429-450.

Mason, J. (2010). Attention and intention in learning about teaching through teaching. In R. Leikin & R. Zazkis (Eds.), *Learning through teaching mathematics: Development of teachers' knowledge and expertise in practice* (pp. 23-48). Dordrecht, Netherlands: Springer.

Olanoff, D., Masingila, J. O., & Kimani, P. M. (2021). Supporting mathematics teacher educators' growth and development through communities of practice. In M. Goos, K. Beswick (eds.), *The learning and development of Mathematics Teacher Educators* (pp. 147-166), Research in Mathematics Education, https:://doi.org/10.1007/978-3-030-62408-8_8

Orgill, M. K. (2002). *Phenomenography*. Retrieved January 2008 from http://www.minds.may.ie/~dez/phenom.html

Superfine, A.C. & Li, W. (2014a). Developing mathematical knowledge for teaching teachers: A model for the professional development of teacher educators. *Issues in Teacher Education*, *23*(1), 113-132.

Superfine, A.C. & Li, W. (2014b). Exploring the mathematical knowledge needed for teaching teachers. *Journal of Teacher Education*, *65*(4), 303-314.

Wenger, E. (2000) Communities of practice: The key to knowledge strategy. In *Knowledge and Communities* (pp. 3–20). https://doi.org/10.1016/B978-0-7506-7293-1.50004-4

Zaslavsky, O., & Leikin, R. (2004). Professional development of mathematics teacher educators: Growth through practice. *Journal of Mathematics Teacher Education*, *7*(1), 5-23.