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Accelerating Preservice Secondary Mathematics Teachers' Noticing of Student Needs

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Serving diverse student populations equitably is a focal concern for mathematics educators (Association of Mathematics Teacher Educators, 2017), particularly given recent teacher shortages in high needs schools. Teacher preparation programs are tasked with preparing new teachers to thrive in these settings. In this paper, we examine what preservice, secondary mathematics teachers found valuable engaging in structured mentoring and guided reflective opportunities that integrate theory into practice. Participants engaged in authentic experiences including learning assistantships along with traditional practicum experiences. Participants completed guided written reflections throughout the semester, in addition to meeting regularly with a faculty mentor. We utilized Wenger-Trayner and Wenger-Trayner's (2014) value framework to examine the data and share findings that suggest most participants developed an awareness of mathematical content knowledge, pedagogical content knowledge, and knowledge of students (Ball et al., 2008) at an earlier phase of their training than may be expected in traditional teacher preparation programs.

Keywords: preservice teacher development, reflection, mathematics teacher development

The recruitment of highly qualified mathematics teachers is a pervasive issue in K-12 education (Darling-Hammond et al., 2016; Ingersoll & Perda, 2010). Prior to the COVID-19 pandemic, nearly every state reported shortages of highly qualified mathematics teachers (United States Department of Education Office of Postsecondary Education, 2017), with attrition rates for math and science teachers nearly 70% greater than this average, particularly in high poverty, urban settings (Carver-Thomas & Darling-Hammond, 2019; Sutcher et al., 2019). A recent study (Institute of Educational Sciences, 2022) found 45% of public schools had one or more vacancies nationwide, with major disparities for schools serving students living in poverty. These figures, in conjunction with declining enrollment rates in teacher preparation programs (Partelow, 2019), highlight a critical need to recruit, train, and retain highly qualified mathematics teachers.

Serving students in urban, high needs settings requires educators keep students' background knowledge and cultures at the forefront of their planning and teaching. However, beginning teachers' concern often rests in their own inadequacies, situational responses, supervisor feedback, and classroom management (Fuller, 1969; Fuller & Brown, 1975). Further, mathematics teachers require high levels of pedagogical content knowledge (PCK) and mathematical content knowledge (MKT) (Ball et al., 2008; Schulman, 1986). In response to this need, our university developed a layered model of authentic teaching and learning experiences, where preservice teachers (PSTs) engaged in both learning assistantships in college math courses as well as in traditional K-12 classroom practicums. We paired these experiences with structured reflective opportunities, seeking to answer the question: *What do PSTs value about field experiences and learning assistantships when paired with targeted mentoring and reflection as part of their teacher development?*

Literature Review

Shulman (1986) developed the idea of pedagogical content knowledge (PCK) to differentiate among content knowledge, curricular knowledge, and effective teaching strategies and representations for students. In the field of mathematics education, PCK is defined in three parts: knowledge of content and the curriculum, knowledge of content and teaching, and knowledge of content and students (Ball et al., 2008; Hill et al. 2008). Master teachers with strong PCK can interweave students' prior knowledge with mathematical concepts and create a clear infrastructure for students to decipher and build their comprehension, which van Es et al. (2017) and Lebak (2022) describe as "ambitious pedagogy."

Fuller (1969), and later Fuller and Brown (1975), identified three phases of concern for novice teachers: (a) self-survival (awareness of self), (b) teaching situation (awareness of task), and (c) pupil (awareness of student-impact). Over time, teachers gradually move away from solely focusing on their own actions and toward how students grapple with content. Specific to mathematics teaching, the goal is for PSTs to shift away from examining non-mathematical classroom matters, such as engagement or classroom management, and toward mathematical teaching and learning (Mewborn, 1999; Roller, 2016). These shifts often take time for novice teachers to make but can be supported through structures such as targeted mentoring and reflection (Feiman-Nemser, 2001; Mewborn, 1999). Powell (2014; 2016), for example, found that PSTs increased their take up of these stages of concern in undergraduate methods courses, particularly the task-oriented stage, however he found little change between or among stages across the span of a semester-long course. More research is needed about the contextual factors that influence PSTs' stages of concern and impact their development over time.

Research on teacher preparation consistently points to the need for PSTs to have authentic teaching and learning experiences in classrooms to support retention in the profession (Darling-Hammond, 2005) and to help them develop effective teaching practices (McDonnough & Matkins, 2010), including culturally responsive pedagogies (Ladson-Billings, 2021). Traditionally, field experiences (practicums) are incorporated into teacher preparation programs as opportunities for PSTs to apply what they are learning in methods courses (Darling-Hammond et al., 2002; Ellerbrock et al., 2018; Garza et al., 2013). Learning assistantships offer an alternative model for engaging in teaching and learning experiences, whereby undergraduate students act as learning assistants (LAs), supporting undergraduate peers and faculty instructors in college courses versus K-12 classrooms (Ellerbrock et al., 2018). LA programs can reduce student-teacher ratios, support faculty in incorporating active learning practices, and offer increased supports for student-centered learning (Otero et al., 2006), and increase the content knowledge of LAs as they engage with near peers (Gomez Johnson et al., 2021; Closer et al., 2016; Talbot et al., 2015). Research also indicates that LAs later recruited to K-12 teaching positions exhibit more reform-based practices than their peers (Gray et al., 2016). Authentic teaching experiences, including both field experiences and learning assistantships, create avenues for PSTs to actively partake in community-based classrooms with experienced mentor teachers. When collaborating and reflecting with these mentors, PSTs can discover the realities of educating students in real time (Ellerbrock et al., 2018; Garza et al., 2013).

Opportunities to reflect *in* practice and *on* practice (Schon, 1987) can be facilitated through both formal and informal means. Effective reflective opportunities can help PSTs hone their skills in determining what is worth taking note of related to teaching and understanding students and making connections between pedagogical theory and practice (van Es et al., 2017; Kersting,

2008). One of the goals of reflective activities in PST programs is to develop their professional noticing to progress more quickly through Fuller and Brown's (1975) stages of concern in anticipation of working with students in diverse settings. Therefore, it is important for researchers and teacher educators to identify effective elements of such reflective opportunities to create robust opportunities for PST growth.

Theoretical Framework

Collaborative experiences support meaningful learning (Lave & Wenger, 1991), thus understanding how opportunities for PSTs to engage in authentic teaching experiences (field experiences and learning assistantships) supported through collegial structures is important to understand. In this paper, we investigate PSTs' reported value participating in such experiences and examine how engaging in structured reflections after the fact influenced their capacity to shift from focus on self to students during instruction (Fuller & Brown, 1975).

Situated learning theory (Lave & Wenger, 1991; Wenger, 1998) proposes learning is an intrinsic factor of collaborative participation between agents in an organization. Value can be viewed as connected and flexible such that researchers can examine participant experiences in their social and academic contexts (Wenger, 1998; Wenger et al., 2011). Wenger et al. (2011) and Wenger-Trayner & Wenger-Trayner (2014) identified five value cycles: immediate (in the moment), potential (for the future), applied (tested implementation), realized (actualized implementation), and transformative (broader dissemination to others) value. Naming specific aspects of learning experiences that PSTs find valuable, and interrogating how those are linked to their development along the stages of concern can help teacher preparation programs maximize opportunities for PSTs to evolve and develop their MCK and PCK. This study is part of a larger study at a mid-sized, urban, midwestern university investigating undergraduate PSTs participating in a STEM education scholarship program. In this paper, we analyze the guided reflective opportunities that augmented PSTs' early authentic teaching and learning experiences to support their mathematics teacher development.

Research Methodology

The NebraskaMath Noyce project, a National Science Foundation (NSF) Robert Noyce Teacher Scholarship project (Grant No. 1852908), seeks to recruit, train, and retain high-quality mathematics teachers. The authors of this study are members of the project leadership team. This study is part of a larger investigation into the value that PSTs experienced during program activities (e.g., professional development, community of practice, mentorship). Qualitative research methodology was utilized to allow us to uncover participant conceptions of value and developmental stages of concern (Charmaz, 2008) by exploring "how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences" (Merriam, 2009, p.5) through the collection of rich, descriptive data (Yin, 2018). We used qualitative methods to examine the research question: *What do PSTs value about field experiences and learning assistantships when paired with targeted mentoring and reflection as part of their teacher development?*

Context and Participants

In Fall 2020, the Noyce scholarship program began integrating learning assistantships in undergraduate mathematics courses as part of the experiential component of the program. By Fall 2021, the project leadership team began to proactively consider PST and faculty pairings so

that each undergraduate student was placed in active learning mathematics courses where they would engage with students and observe evidence-based practices each day.

Participants included nine undergraduate students who served as Learning Assistants (LAs) in Fall 2021. Five participants had completed at least one formal field experience at the time of the study (however, these early experiences were limited by the COVID-19 pandemic). Two participants had completed one field experience, while the remaining four participants had not engaged in a field experience at the time of the study. Participants were placed as LAs in one to two mathematics courses where their roles primarily involved encouraging and supporting students through one-on-one or small group engagement. The participants were paired with eight mathematics faculty members who taught using active learning techniques in their undergraduate mathematics courses (e.g., college algebra, quantitative reasoning, precalculus). These faculty members also met with the LAs outside of class to mentor them in areas such as lesson planning, personal and academic life check ins, and reflection on events from the week.

Data Collection and Analysis

We collected 10 reflection journal entries from each participant (totaling 90 reflections). A member of the research team also conducted a focus group with participants at the end of the semester. We aggregated and de-identified all data from the journals and focus group transcript to ensure the anonymity of study participants and, where appropriate, pseudonyms are used in this report. Reflective journals were a program requirement not only as a data source, but also to support the literature on PST development (e.g., Collins, 2006; Shulman, 1987; van Es & Sherin, 2008). Reflections can frame PSTs' thinking around their teaching practice and can offer a unique opportunity for them to highlight both seemingly large and small occurrences during teaching moments across the semester. Participants were prompted to write their reflections around one of the eight following categories:

1. Learning Assistantship Reflections- based on…participation & engagement in campus math courses.
2. Professional Development (PD)- based on…Noyce Math or campus-offered PD workshops, book study, colloquium, etc.
3. Community of Learners- based on…interaction with other Noyce Math participants or study groups.
4. Outreach- based on…community or campus activity where you were able to work with youth or on a project.
5. Mentoring- based on…interactions with a faculty mentor, whether formally assigned or informal partnership (can also include practicum mentor).
6. Learning Mathematics- based on… experiences as a student of mathematics.
7. Leadership- based on…personal leadership experiences where you took initiative to organize your peers or create a new process/project/event.
8. Lesson Plans- based on…creation of a lesson for your learning assistantship experience, a practicum lesson reflection, or other tutoring planning.

We used a combination of directed content analysis (Hsieh & Shannon, 2005) and thematic analysis (Clarke et al., 2015), mapped onto our theoretical framing of the Wenger et al. (2011) value framework (Jakopovic & Gomez Johnson, 2021; Gomez Johnson et al., 2021), to derive meaning from participants' written reflections and the focus group interview. Via directed content analysis, we leveraged prior research related to key concepts (e.g., teacher preparation, PCK, MCK) as our initial *a priori* codes, using the five value types (immediate, potential, applied, realized, and transformative) to develop common working definitions and examples of

each code (Hsieh & Shannon, 2005). We first deductively coded value to find areas of saturation (LeCompte & Schensul, 2013). We then reanalyzed the data using a thematic lens. Thematic analysis is an appropriate approach for answering research questions about people's lived experiences and perspectives on particular topics (Clarke et al., 2015). In the second cycle of coding, we examined data for themes that emerged, which we unpack in the following section.

Findings

Participants had access to both K-12 classrooms (practicum) and undergraduate math courses (learning assistantships) where they participated in authentic learning and teaching activities. While participants were intentionally placed in "active learning classrooms" with master teachers as LAs, their field experiences varied greatly in the level of mentorship and quality of instructional practices they observed and enacted. In our analysis, we found participants most often valued what they learned about their developing understanding of learners' needs. Participants reported immediate value (i.e., experienced in-the-moment awareness) in the following four areas as they participated in authentic experiences and guided reflection: the importance of building relationships, student motivation and confidence, the importance of students' mathematical background knowledge, and the role of differentiated instruction. PSTs discussed these topics, considering their impact in the classroom along with their level of satisfaction teaching and learning.

Building Relationships

Participants noticed the ways in which building relationships with students impacted the overall experience of working with students and helping them learn. For example, James reported that his "first goal was to learn every name," and while it was often a challenge, he continued "redoubl[ing] my efforts because during my third week there, I got the evil eye from a student when I asked for his name yet again." After learning names, he remarked on the impact that act had on students' reactions to his instruction. Along with learning names, participants also described how building relationships meant getting to know learners as "whole people," which involved creating a safe space for students to take risks and show that instructors can be caring adults who care about their success (Stipek, 2010). As Monica noted, "One thing that I am confident in is that my students will know... that I accept each of them just as they are... I am not just there to teach them Math." Monica, along with other participants, shared their increased awareness of students' perceptions of PSTs' investments in them as individuals and the positive impact this had on the classroom environment overall.

The Role of Student Confidence and Motivation

Additionally, participants identified in-the-moment situations where students lacked confidence or motivation, resulting in various student behaviors. Several participants recognized student engagement as a concern and made conjectures about why students might elect to not participate during instruction, as well as ponder their role in addressing classroom engagement. As Anthony wondered, "As a teacher, how can I approach a student who is having difficulties in a class to the point that they give up?" In our data other participants, like Nicole, indicated that specific strategies might be necessary to support and engage learners, whether it be offering one-on-one support, continuing to foster positive relationships, or noticing other aspects of a student's reality that might be influencing their willingness to participate in math class.

Participants indicated that at times this may be more about culture, context, and experiences (Ladson-Billings, 2021; Safir & Dugan, 2021), and less about a student's intrinsic interest in mathematics. Helen reported observing differences in the learning environments between upper-level mathematics classes and on-or below-level mathematics classes,

> The honors students seem eager to learn and the "general ed" classes... seem to lack motivation. It makes me wonder how much of that is due to school culture/teacher expectation and how much of it is the student themselves.

In her reflection, Helen pondered how the classroom environment and student backgrounds might influence both behavioral and educational experiences. Several participants noticed that larger, system level factors may lead to inequities in classrooms (Ladson-Billings, 2021).

Students' Mathematical Background Knowledge

Participants also valued opportunities that highlighted the role student background knowledge plays in their classroom interactions. For example, Leslie explained her struggle to identify the appropriate level of difficulty as a new teacher, "It is such a scary thing when you show something to them that's too advanced for them, they just shut down...but then if you give them something that's way too easy, they might get mad at you." She noticed that, without an accurate prior assessment of a student's mathematics level, significant consequences can occur without knowledge of where a student is situated on a learning trajectory. While PSTs learn about theory such as Vygotsky's zone of proximal development (1978), seeing the application when students have a broad range of prior knowledge raises a new level of consideration for PSTs. This can. be rare for new teachers, who typically are not yet at the stage of concern where they notice how students interact with content (Fuller, 1969; Mewborn, 1999).

Differentiation in Action

A final theme for several participants was the recognition that students often do not have the expected level of background knowledge, along with the fact that within any given class this understanding likely exists along a continuum. Some realized their role as a teacher was to respond with different strategies or approaches than they may have experienced in their own learning (Ball et al., 2008; Hill et al., 2008). Monica shared a moment where she wrongly assumed what an adult learner was struggling on a particular concept. "That was way more advanced than he was ready for, and I was like, oh okay, we have to take another step back and I looked at that." Monica noted that as a teacher she needed to reframe her thinking.

For many early career mathematics teachers, identifying moments where differentiation is needed can be challenging. Participants in the study identified the need to tailor content and identify specific, effective teaching strategies. Eddie shared that, "You have to have multiple different tools to be able to teach students. Some students just don't understand something that 15 people will, and you have to work a little harder...for that one student." James reflected on his observation of his mentor teachers' approaches to this, and talked about how their decisions impacted learners. James mused, "The students that got the easy one are worried they aren't properly prepared for the hard one...[and]...the group with the hard one felt rushed by everyone else." James' noticing of students' reactions to the differentiated problems allowed him to consider how he might approach differentiation in ways that were similar or different to this experience. This example helps to illustrate the depth at which James, among other participants, noticed and analyzed the impact of differentiation on learners.

Implications

Preparing the next generation of mathematics teachers requires both the art and science of teaching. For many PSTs, the realities of the myriad roles they play, along with the knowledge, skills, and dispositions they need to develop can be overwhelming. Early opportunities for PSTs to interact with students in a variety of environments and to reflect on these experiences can illuminate key areas of concern for teaching. In terms of immediate value, the most prevalent takeaways for our participants revolved around the students themselves. As they grew to understand how to teach content, they noticed key elements of understanding learners necessary for successful teaching. Pinpointing areas such as background knowledge, motivation and confidence, and engagement, can provide PSTs with a drawing board of essential components for their future planning. Furthermore, these features of understanding students can facilitate their development as effective teachers qualified to teach in diverse settings.

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