www.ijemst.net

Pre-Service Teachers as Researchers: A Mentorship Model

Melike Kara
Towson University, United States

Kimberly Corum
Towson University, United States

To cite this article:

Kara, M., & Corum, K. (2023). Pre-service teachers as researchers: A mentorship model. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 11*(1), 237-251. https://doi.org/10.46328/ijemst.2351

International Journal of Education in Mathematics, Science and Technology

2023, Vol. 11, No. 1, 237-251 https://doi.org/10.46328/ijemst.2351

Pre-Service Teachers as Researchers: A Mentorship Model

Melike Kara, Kimberly Corum

Article Info

Article History

Received:
04 February 2022
Accepted:
20 October 2022

Keywords

Teacher education
Mathematics education
Undergraduate research
Model eliciting activities

Abstract

In this paper, we share a mentorship model we developed and implemented while collaborating with pre-service teachers (PSTs) on their Model Eliciting Activity projects and the outcomes of the mentorship model in terms of PSTs' growth as teachers as well as researchers. For their projects, PSTs designed and developed their own mathematical modeling tasks and later analyzed student work collected during task implementations to better understand their students' reasoning. The PSTs' reflections were collected to assess the effectiveness of the program and to report their professional growth. The PSTs who participated in this mentorship model identified core teaching practices (e.g., questioning, facilitating discussions) and they improved their knowledge of student thinking and reasoning. They were also able to analyze rich data and identify trends in student learning. The findings from this study affirm that engaging in undergraduate research provides PSTs with opportunities to improve their teaching practice as well as their understanding of research processes.

Introduction

> *"Well-prepared beginning teachers of mathematics recognize that the processes of data collection, analysis, and reflection and the corresponding revision to classroom practices are systematic and continuous and grow in sophistication with teaching experience."* (Association of Mathematics Teacher Educators [AMTE], 2017, p. 16)

Participating in research activities can enhance undergraduate students' learning experience during their college education and provide them with opportunities for professional growth (Jahan & Aly, 2018). "Research experience allows undergraduate students to better understand published works, learn to balance collaborative and individual work, determine an area of interest, and jump start their careers" (Madan & Teitge, 2013, p. 1). For pre-service teachers (PSTs), these research experiences support their professional development as both action researchers and effective classroom teachers. Despite its potential benefits, there are limited examples of undergraduate research in education programs (Devore & Munk, 2015) and education majors are often underrepresented in undergraduate research (Manak & Young, 2014). In this paper, we share a mentorship model we developed and implemented while collaborating with PSTs on their Model Eliciting Activity (MEA) projects and the outcomes of the mentorship model in terms of PSTs' growth as teachers as well as researchers. For their projects, PSTs designed and developed their own mathematical modeling tasks and later analyzed student work collected during task implementation to better understand their students' reasoning.

Background and Rationale

In their Standards for Preparing Teachers of Mathematics, AMTE (2017) states that teacher preparation programs need to attend to developing beginning teachers' mathematical content knowledge, curriculum knowledge, and knowledge of how students learn. Regarding content knowledge, well-prepared teachers should have a solid understanding of core mathematical concepts and mathematical practices, as well as have productive mathematics dispositions that celebrate the sensibility, usefulness, and worthwhileness of mathematics. Regarding curriculum knowledge, well-prepared teachers should be able to read, analyze, interpret, and enact mathematics curricula and related literature (e.g., content trajectories, standards documents), as well as assess student understanding and use assessment data to modify their instruction. Regarding knowledge of how students learn, well-prepared teachers should be able to anticipate and attend to students' thinking and be able to analyze student thinking in terms of specified learning goals (AMTE, 2017). Undergraduate research that is integrated in teacher education programs could be a promising way to attend to developing beginning teachers' mathematical content knowledge, curriculum knowledge, and knowledge of how students learn mathematics.

By engaging in undergraduate research related to MEAs, PSTs can deepen their mathematical content knowledge related to mathematical modeling as well as practice teaching mathematics with real-world contexts (COMAP & SIAM, 2016). Engaging in research on developing and implementing MEAs and later analyzing students' work from these MEAs promotes PSTs' understanding of modeling tasks and their place in the curricula, particularly culturally responsive curricula. Furthermore, teaching is a reflective practice and well-prepared teachers should be able to analyze their teaching using evidence of their students' learning and engagement (AMTE, 2017). Conducting undergraduate research related to students' mathematical thinking and learning, particularly in the context of MEAs, affords rich opportunities beyond formal coursework for PSTs to gain such well-preparedness and become developing reflective practitioners early in their program. Additionally, by conducting teaching and learning related research, PSTs better conceptualize research designs common in the mathematics education field.

Therefore, our goals for the PSTs who participate in this mentorship program are to: (1) advance their mathematical content knowledge by designing and developing modeling activities, (2) improve their pedagogical content knowledge by teaching mathematics in informal settings (i.e., settings outside of PSTs' regular internship or clinicals which are already part of the program), and (3) strengthen their understanding and analysis of student thinking and learning (Ball, Thames, & Phelps, 2008).

Potential Benefits of Undergraduate Research

Our definition of undergraduate research aligns with the definition proposed by the Council of Undergraduate Research (CUR): "An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" (Wentzel, 1997, p. 163). We expand upon this definition by the unifying features of mentorship, originality, acceptability, and dissemination (Osborn & Karukstis, 2009). *Mentorship* defines the collaborative interaction between the faculty mentor and the student. *Originality* expects students to make meaningful and authentic contributions. *Acceptability* requires students to apply techniques and methodologies that are recognized by the discipline. *Dissemination* implies the research project must include a final product for which the process and results are peer reviewed for sharing at venues of the discipline.

Undergraduate research experiences offer students benefits that cannot be gained through formal programs alone (Taraban & Logue, 2012). Prior studies documented that engaging in research activities supports undergraduate student learning by improving research skills and providing authentic learning experiences (e.g., Kardash, 2000). Key findings from the literature on undergraduate research which highlight its potential benefits to support PSTs growth as teachers and researchers, as well as its benefits to the field of mathematics education research, are shared below.

Benefits to Support PSTs' Growth as Teachers

Undergraduate research experiences can help PSTs gain deeper conceptual understanding of content as well as pedagogical knowledge for teaching (e.g., Bauer & Bennett, 2003; Groth, Bergner, Austin, Burgess, & Holdai, 2020; Hunter, Laursen, & Seymour, 2006; Manak & Young, 2014; Osborn & Karukstis, 2009). Groth et al. (2020) found that engaging in undergraduate research provided PSTs with rich opportunities to analyze data and make informed instructional decisions when designing lessons. Such experiences resulted in improved knowledge of mathematics content and student learning of mathematics, as well as increased motivation in pursuing a teaching career/certification. PSTs reported improvements in anticipating student reasoning and strategies, predicting possible misconceptions, and being better prepared to teach both exceptional students and gifted students.

In addition to gaining teaching-related knowledge, skills, and dispositions, PSTs engaged in undergraduate research can gain or strengthen other academic skills that are applicable to their teaching career (e.g., Bauer & Bennett, 2003), such as tolerance for obstacles and working independently (Lopatto, 2004). Other teaching-applicable skills that can potentially be obtained through undergraduate research experiences include critical thinking, problem solving, adopting of professional norms, ability to put classroom knowledge into practice, and communication skills (e.g., Bauer & Bennett, 2003; Hunter et al., 2006; Hunter, Weston, Laursen, & Thiry, 2009; Kardash, 2000; Osborn & Karukstis, 2009).

Benefits to Support PSTs' Growth as Researchers

Engaging in research activities promotes undergraduate students' understanding of research processes in their field, such as how to conduct research and how to better understand research literature (Groth et al., 2020; Lopatto, 2004), as well as how to disseminate results of their research to a broader audience through national and international conferences and journal articles (Groth et al., 2020). Undergraduate research experiences also enhance students' learning in designing research, formulating/revising research questions, collecting data (Groth et al., 2020; Hunter et al., 2006; Kardash, 2000), and understanding how knowledge is constructed (Hunter et al., 2006). Furthermore, engaging in research activities has positive impacts on undergraduate students' self-perception about their ability to conduct research (e.g., Campbell & Skoog, 2004; Kardash, 2000; Lopatto, 2008) and helps them develop identities as researchers (Groth et al., 2020).

Benefits to the Field of Mathematics Education Research

One way to improve mathematics education research would be to invite practitioners to be actively involved in the research design process, such as identifying problems, generating research questions, and analyzing data (e.g., Cai et al., 2018; Groth et al., 2020; Lester & William, 2002; Silver, 2003). Building partnerships between researchers and practitioners has the potential to positively impact the field of mathematics education. Cai et al. (2018) share a model of how this type of collaboration might be realized and how the roles of teachers and researchers might be reconceptualized. Through collaboration, researchers and teachers can apply their unique areas of expertise and improve teaching and learning related to the research topic in a way that they would not be able to do by themselves. They would be able to identify problems of practice, determine appropriate learning goals for the students, conduct research, and design instruction and assessments. Such collaborations require teachers to be able to engage in these types of research activities themselves. By participating in this type of collaborative model early in their undergraduate program, PSTs can experience these research activities first-hand and develop the required skills to collaborate with researchers in their future teaching careers (Groth et al., 2020).

Mathematical Modeling

There is a growing emphasis on the inclusion of mathematical modeling in school mathematics. For example, the National Council of Teachers of Mathematics (NCTM) specifies the use of representations, including mathematical models, as one of the five process standards for PK-12 mathematics (NCTM, 2000). The Common Core State Standards for Mathematics (CCSSM) also specify "Model with Mathematics" as a Standard for Mathematical Practice in K-12 and "mathematical modeling" as a conceptual category in high school (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

While the phrase mathematical modeling has been used in many different ways, we consider the description of mathematical modeling from CCSSM which describes modeling as "the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions" (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). In this description, the focus of mathematical modeling is learning to make decisions and assumptions when interpreting a real-world scenario using a mathematical lens. These real-world scenarios are often posed using open-ended questions where students have the freedom and flexibility to create their own non-prescribed models (COMAP & SIAM, 2016).

Unlike traditional instruction where teachers often demonstrate procedural strategies and techniques, the role of the teacher when implementing modeling tasks is to encourage students to choose, develop, and apply mathematical approaches and help students think about how they might approach the problem to improve their models (COMAP & SIAM, 2016). Mathematical modeling tasks are helpful in revealing student thinking and they enable students to interpret, invent, and find solutions with students from different performing levels (e.g., Aguilar Batista, 2017; Carmona & Greenstein, 2010; Koellner-Clark & Lesh 2003; Mousoulides, Pittalis, Christou, & Sriraman, 2010).

Despite the existing literature on modeling at different grade levels, there is still a need for research on modeling in school environments. According to Stohlman and Albarracin (2016), mathematical modeling in the elementary grades is still in the early stages and more research as well as teacher training is needed. One way of meeting this need could be collaborating with PSTs to create and implement MEAs with students. Additionally, when conducting research about MEAs, PSTs will be able to focus on their own areas of interest and utilize mathematics to explain real-life phenomena that they choose to investigate further. This approach naturally helps faculty mentors pay more attention and recruit PSTs with diverse backgrounds and interests. The importance of student differences in undergraduate research is articulated by Taraban and Logue in the following statement, “There is a need for more attention to student differences as they apply to research participation, including academic ability, gender, and college level, and to the academic resources and practices that more inclusively and effectively involve students in research” (2012, p. 499).

Moreover, most teachers and teacher candidates have had limited exposure to mathematical modeling (Anhalt & Cortez, 2016). Prior research strongly emphasized the significance of including modeling tasks in teacher education. Anhalt and Cortez (2016) found that PSTs who participated in a mathematical modeling module that was integrated into their content pedagogy course broadened and deepened PSTs’ understanding of mathematical modeling and were better prepared to integrate mathematical modeling into their future classroom instruction. The researchers who focused on modeling emphasized that “… a pressing need exists in mathematics teacher education for increased learning opportunities about mathematical modeling that will benefit both teachers and their future students” (Aguirre, Anhalt, Cortez, Turner, & Simic-Muller, 2019, p. 8). In particular, mathematics teacher preparation programs should incorporate the practice of mathematical modeling throughout a PST’s course of study (AMTE, 2017). Furthermore, modeling tasks also provide PSTs with opportunities to understand the necessity of developing culturally responsive and social justice-oriented mathematics pedagogies (Aguirre et al., 2019).

Research Questions

Informed by the literature, we aimed to explore PSTs’ growth as a result of engaging in undergraduate research alongside faculty mentors (authors). The following research questions guided our research design and data analysis:

1) How did PSTs analyze their own teaching and identify their own growth as a teacher following the implementation of their MEAs?
2) How did PSTs analyze their undergraduate research experience and identify their own growth as a researcher and as a teacher following the analysis of data collected during their MEA implementations?

Methodology

We provided PSTs with undergraduate research experiences through a collaborative project that focused on MEAs. In this project, several faculty mentors hired volunteer undergraduate students and guided them through the development and implementation of MEAs. The authors of this paper collaborated on mentoring several PSTs in a systematic way for three academic years that finally resulted in a mentorship model that could be used specifically for PSTs.

Design of Mentorship Experience

The mentoring cycle for developing and implementing MEAs includes the following phases: (1) task development, (2) rehearsal, (3) implementation, (4) reflection, (5) analysis, and (6) dissemination (see Figure 1). When mentoring undergraduate research projects, it is important to consider the PSTs' backgrounds. Their progress in their teacher preparation program, previous coursework (particularly methods courses), and the extent of their prior interactions with mathematics education faculty all inform the level of support needed during the mentoring cycle.

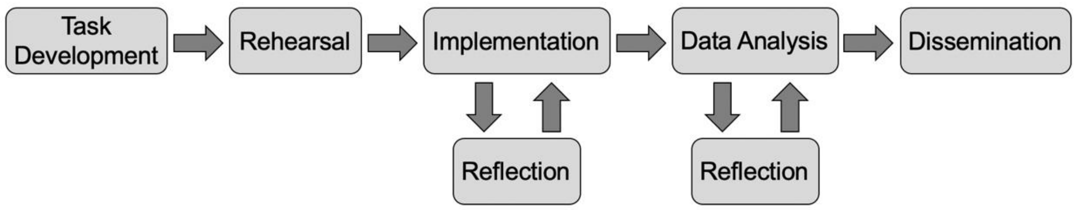

Figure 1. Mentoring Cycle

During the *task development* phase, we meet periodically with our PSTs to research and develop the modeling task. The initial context for the modeling task is guided by the PSTs' areas of interest (e.g., music, dance, cultural artifacts). We then provide PSTs with literature related to mathematical modeling as well as literature relevant to their selected contexts to allow them to conduct a literature review without having formal training in academic research. After PSTs review related literature and refine the purpose of their modeling task, we meet with our PSTs to help them further elaborate their intended outcomes for students during the task. This helps the PSTs articulate clear learning goals for the task, design the task sequence, and create questions to guide discussions as well as assess and advance students' thinking. During the *task development* phase, PSTs write a formal lesson plan aligned with a recommended instructional sequence: notice and wonder, introduction to the modeling task/problem statement, mathematical analysis of related artifacts, creating a mathematical model, and application of model to develop a new artifact. Depending on where PSTs are in their teacher preparation program, the sophistication of the lesson plans may vary. Examples of PSTs' projects included mathematical analysis of different artifacts (e.g., snowflakes, African cultural masks, dance moves), creating physical models for musical melodies, and choosing the best bank option.

Once a modeling task is developed, we transition to the *rehearsing* phase where we consider how the task would be implemented in a classroom setting. The PSTs consider how they will introduce the task, how they will manage the task, and how they will support students' learning of the mathematics related to the task by planning rich questions and anticipating students' responses. The PSTs also consider what data need to be collected from students in order to identify what learning has occurred. During this phase, the PSTs lead informal rehearsals of the task in mock classroom settings (typically with their classmates, friends, and/or family members acting as students) and utilize feedback from these rehearsals to revise and refine the task itself. Depending on the extent of revisions, PSTs may have a second rehearsal for additional feedback.

Once the modeling task is finalized, we proceed to the *implementation* phase and the PSTs implement the task with the intended audience. We utilize our relationships with local community partners to identify opportunities for the PSTs to implement the task with children in either a classroom setting as a guest teacher or a non-classroom setting. We also provide PSTs with opportunities as a guest instructor in classes offered to education majors at our university. We deliberately choose classes where students are expected to prepare an MEA-like task as part of their course requirements. This experience is mutually beneficial to the PSTs and the students. The PSTs receive professional feedback from their peers related to teaching and classroom experiences while the students are able to observe a peer teaching and conducting research. During this phase, PSTs also collect data that could provide evidence of students' thinking and learning. Data mostly consist of student-constructed models (drawings or pictures), students' written work, and written records of whole-class discussions.

After implementing the task, we transition to the *reflection* and *analysis* phases. PSTs participate in the *reflection* phase twice: once after the *implementation* phase and again after the *analysis* phase. During the first *reflection* phase, we meet with the PSTs for a debrief, focusing on what went well with the task and what revisions could be made to further improve the task. Later, the PSTs write a post-implementation reflection and consider how implementing their modeling task supports their growth as a teacher. The reflection includes: (1) a detailed narrative description of what happened during the lesson including question-answer discourse and a description of in-the-moment lesson revisions, (2) a description of student learning with evidence, and (3) a critical reflection of the lesson including what went well and what could be improved.

Following this, we then proceed to the *analysis* phase where we work with the PSTs to analyze the student data collected during task implementation. For the first round of analysis, we interpret the collected data separate from the PSTs. For the second round of data analysis, we compare our analysis with the PSTs' analysis in order to come to a consensus of what could be inferred from the data. After the *analysis* phase, the PSTs engage with the *reflection* phase again. This time, the purpose of the written reflection is to consider how analyzing student learning data supports their growth as a teacher and a researcher. The prompts include: (1) PSTs' takeaways from the analysis of student work, (2) lesson modifications informed by their analysis of student learning, and (3) areas of focus for future data analysis experiences. Note that some PSTs had the opportunity to implement their tasks more than once which created another opportunity for the implementation-analysis-reflection phases.

The final phase of the mentoring cycle is *dissemination*. The culminating activity of the mentoring cycle is for the PSTs to present their research. For most of our PSTs, this is their first research experience. Part of that experience is sharing their findings with a larger audience. We suggest venues for dissemination (e.g., regional conferences, state conferences) and, with our guidance, the PSTs prepare a conference proposal. For accepted proposals, we then work with the PSTs to develop and rehearse their presentation. We also work with our PSTs to write and revise an article that can be submitted to practitioner journals for publication consideration.

Participants

This on-going project is being implemented in a large public university in the Mid-Atlantic region of the United States which offers undergraduate programs in elementary education and secondary education. Participants are recruited by course instructors based on their interest in undergraduate research opportunities, mathematical modeling, and/or their submitted coursework (e.g., final projects, lesson plans) that could be extended to a potential research project after the course is completed. Participants who are approached with the opportunity to participate in the mentoring cycle are able to decline without any penalty and those who choose to participate are compensated (either with hourly pay or credit hours) for their research work.

Thus far, eight PSTs have participated in the mentoring cycle. Working as co-mentors, we have successfully completed one full cycle with two PSTs who worked collaboratively on a single research project and are in the *dissemination* phase with another PST. The first author previously mentored one PST who completed the *rehearsal* phase and is currently mentoring two PSTs who are working independently on individual research projects. Both of these PSTs are in the *dissemination* phase. The second author is currently mentoring two PSTs who are working collaboratively and are in the *rehearsal* phase. While data were collected from the eight PSTs who participated in the mentoring cycle, we chose to focus on the three most recent PSTs who are in the dissemination phase for our data analysis because of the consistency in data collection from these participants.

Data Collection and Analysis

The primary goals of this project are to understand how PSTs' participation in the mentoring cycle supports their growth as teachers and as researchers. To understand the PSTs' growth as teachers, we collected and analyzed their lesson plans and their post-implementation written reflections. For four of the eight PSTs, their *implementation* phase occurred during the pandemic which resulted in unique challenges related to teaching in a virtual setting and these challenges were captured in their post-implementation reflections. To understand the PSTs' growth as researchers, we collected and analyzed their post-analysis written reflections. Because the lesson plans of each PST had similar structures, we decided not to include those in this report. The data included in this report consist of two sets of reflections of the three most recent PSTs. All three PSTs implemented their modeling tasks in a virtual setting.

The collected data were analyzed using constant comparative analysis (Merriam, 1998). Both authors first analyzed the collected data separately to identify common themes for each reflection type. We coded the PSTs' reflections by considering their self-identified areas of growth as well as initial themes identified in their reflections. The authors then met to discuss their analysis and triangulate their findings. During this discussion, the authors refined and finalized the common themes that led to the key areas of growth.

Results and Discussion

Informed by Groth et al. (2020), the analysis of the PSTs' written reflections resulted in two areas of growth: growth as teacher and growth as researcher. The post-implementation reflections focused solely on their growth as teachers whereas their post-analysis reflections focused their growth as teachers and researchers.

Post-Implementation Reflections

In their post-implementation reflections, the PSTs were asked to think about how the lesson went and identify opportunities to improve their lesson and their teaching. All three PSTs identified incidences when their teacher actions impacted their students' learning and their students' experiences with the content. This allowed the PSTs to actively revise their lessons immediately following the *implementation* phase. The common themes identified across the PSTs' post-implementation reflections included: questioning and facilitating discussions, increasing student participation and engagement, identifying and extending student learning, task implementation and setup, and improving instructional practices.

Questioning and Facilitating Discussions

All three PSTs were able to identify moments of their lessons where they were able to effectively facilitate student discussions. The PSTs attributed their ability to facilitate discussions to their lesson planning and instructional strategies (e.g., Notice and Wonder task, use of breakout rooms for small group work). All three PSTs also discussed the importance of questioning in their lesson reflections. They were able to identify moments in their lesson where they asked effective questions to extend student thinking and to transition between instructional tasks. When considering how to revise their lesson for future implementations, the PSTs identified moments where their questioning could have been more effective and missed opportunities for follow-up questioning.

Increasing Student Participation and Engagement

All three PSTs discussed the importance of student engagement throughout their lesson. These PSTs implemented their modeling tasks in a virtual setting and when planning their lessons, they identified technology tools (e.g., Google Jamboards [Google Workspace, n.d.]) and features of the virtual platform (e.g., breakout rooms) that could encourage student engagement. However, they recognized that maintaining student engagement throughout the lesson was still difficult.

All three PSTs recognized the teacher's role in encouraging and maintaining student engagement. For example, one PST said, "The teacher needs to come up with a way to enhance the participation of the students and make sure that the students are answering the teacher questions." Some of the suggested revisions to increase student engagement for future implementations included providing more clarity in their task set-up, prompting students to participate in whole group discussions, and encouraging more student-to-student discourse.

Identifying and Extending Student Learning

The PSTs were able to identify instances of student learning during their lesson implementations as well as offered ideas for extending student learning in future implementations. They referenced the importance of aligning their instructional tasks with their stated learning goals and objectives. They spoke about making connections between the students' thinking (whether shared through discussions or in their written work) and the learning goals for the lesson. As one PST stated,

> I need to always ask myself: What's the most important thing students have to do or know? I need to make sure that the objective is met by the end of the lesson and that all students met the learning goals that I have prepared.

They also spoke about utilizing students' prior knowledge and providing opportunities for extension tasks.

Task Implementation and Setup

All three PSTs recognized the necessity of task set-up in their lessons. They recognized that their instructional choices impact students' engagement with and participation during the task. The PSTs spoke about the lack of clarity in their directions for creating the mathematical model and how this may have influenced the nature of the models the students created. They also identified instances in their lessons where they could have checked in with their students to ensure that all of their students understood the task directions and how not understanding the task could impact student participation. The PSTs again spoke about opportunities to revise and improve their lesson plans for future implementations. Examples of lesson revisions included providing clear time cues during the Notice and Wonder task, using different instructional strategies (e.g., Gallery Walk), rewording questions and prompts, and planning for additional wait time throughout the lesson.

Benefits of Teaching Experience

All three PSTs spoke about how this experience supports their continued growth and development as teachers. Participating in this undergraduate research model provided the PSTs with an opportunity to plan and implement a lesson early in their teacher preparation program. They were able to practice using different instructional strategies, interpreting student thinking, incorporating technology, and reflecting on their teaching. As one PST described, "The only way you can get better at teaching is by consistently placing yourself into positions where you are able to lead and foster and [*sic*] environment for learning."

Post-Analysis Reflections

In their post-analysis reflections, the PSTs were asked to think about what they learned from the data analysis process, how their data analysis would inform lesson modifications, how engaging in data analysis supported their growth as a teacher and a researcher, and how this experience would inform future analysis of student work. Unlike the post-implementation reflections which approached the PSTs' lesson implementation atomistically (e.g., what went well, what would you change), the post-analysis reflections approached the PSTs' data analysis experience more holistically (e.g., what did you learn, how did you grow). This is why the nature of the themes differed between the post-implementation and post-analysis reflections. The common themes identified across the PSTs' post-analysis reflections included: analyzing student work, lesson effectiveness, and benefits of field experience.

Analyzing Student Work

All three PSTs shared that the data analysis process provided them with opportunities to analyze student thinking at a much deeper level than they had previously experienced. By analyzing students' work samples, the PSTs were able to better understand their students' mathematical reasoning processes and their prior knowledge related to the mathematical goals of their lessons. As one PST shared in her reflection,

> [Data analysis] allowed me to understand and reason behind each individual's comprehension with the idea of geometric attributes, qualities, and ideologies…The analysis of student's work also served as guidelines to what prior knowledge they had before the lesson and what information they were able to form throughout the study.

A similar sentiment was shared by another PST who wrote, "By going through and analyzing the data I collected, I was able to grow as a researcher by examining the student responses and see their thought process behind their answer."

In addition to analyzing individual student learning, the data collection and analysis process also made PSTs aware of learning trends across all students in their classes. For example, one PST explained,

> [Data analysis] taught me how to look for trends in the most common answers. How to group similar answers together to create new overall themes. It also taught me how to compare the growth in learning that students are experiencing.

Lesson Effectiveness

The PSTs also indicated that the data analysis process allowed them the opportunity to further reflect on their teaching. All three PSTs discussed the effectiveness of their lessons and opportunities for lesson revisions in their post-analysis reflections and these discussions were directly tied to evidence of student learning as revealed during the data analysis process. One PST explained, "You see first-hand what the students [*sic*] takeaways from the lesson were…Then as a teacher you know those methods are the most effective ways that your students learn." Another PST shared,

> I was able to see where students understood what was happening and what task needed to be completed, and I was also able to tell where students had confusion. By seeing these different parts, I could tell in the spots where students didn't quite pick up the concept of the question, I needed to go further into detail in my teaching.

In addition to reflecting on their implementations, all three PSTs included lesson revisions for future implementations that were informed by their data analysis. When discussing possible lesson revisions, one PST shared,

> After reviewing students' work, I felt that I could have explained and modeled what I was looking for before starting each task. I let students go off on their own, which for some students may have worked but as a collective whole was not an effective strategy concerning instruction. The more specific and explanatory I am as an instructor, the more successful my implementation will be.

Benefits of Field Experience

When reflecting on their data analysis experiences, all three PSTs mentioned the importance of practicing instruction and implementing lessons multiple times to support their professional growth. The data analysis process provided the PSTs with tools and strategies for systematically reflecting on their teaching and identifying opportunities for growth through practice, as described by one PST who stated,

> I can go back and use the data to compare which methods are the most effective to get students to learn and retain the information. I would also want to compare the analysis of student work from my first implementation to the second implementation… The more trials and more data you do you are able to reach more conclusive results. It's always good to compare all old results to new results to see what changed and what stayed the same. If any new themes emerged that weren't talked about before. Or if students show a deeper understanding of a theme that was once talked about before on a very basic level.

According to this PST, implementing the same lesson multiple times provided her with the opportunity to better understand how her instruction directly impacts student learning as she was able to analyze multiple iterations of data collection. A similar sentiment was shared by another PST who wrote, "The more I can take from prior implementations, the more I will improve my instruction and research factors."

Conclusion

Participating in the mentorship model supported two main areas of growth for the PSTs: growth as teachers and growth as researchers. While it is difficult to distinguish between these areas of growth due to their interconnectedness, key ideas from their post-implementation and post-analysis reflections related to their growth as teachers and researchers are summarized below (see Table 1).

The PSTs who participated in this mentorship model identified core teaching practices (e.g., questioning, facilitating discussions) and they improved their knowledge of student thinking and reasoning. They were also able to analyze rich data and identify trends in student learning. The findings from this study affirm that engaging in undergraduate research provides PSTs with opportunities to improve their teaching practice as well as their understanding of research processes. By participating in this mentorship model, PSTs were able to: (1) strengthen and extend their mathematical content knowledge, (2) plan and implement rich mathematical tasks aligned with appropriate content standards, and (3) collect and analyze data to identify student thinking and to improve their practice. Our findings support that this mentorship model attends to multiple Standards for Preparing Teachers of Mathematics (AMTE, 2017) and supports the development of well-prepared teachers.

Table 1. Key Findings from PSTs' Reflections

PSTs' Growth as Teachers	PSTs' Growth as Researchers
Identifying student learning and opportunities for extending learning	Understanding individual student's learning progressions and thought processes
Understanding students' mathematical reasoning	Recognizing learning trends and common reasoning across students
Analyzing students' mathematical thinking	Comparing growth in learning
Valuing multiple implementations to improve/revise instruction	Valuing multiple implementations to improve/revise data collection
Improving task implementation	
Improving student participation and engagement	
Questioning and facilitating student discussions	

Undergraduate research experiences are mutually beneficial for PSTs and their faculty mentors. For the PSTs, conducting undergraduate research related to students' mathematical thinking and learning provides them with professional experiences beyond formal coursework. Additionally, it creates opportunities for PSTs to reflect on their own practice in a guided way with the support of a faculty mentor. Such unique and systematic interactions with a faculty mentor build on PSTs' habit of becoming reflective practitioners. For the faculty mentors, interacting with PSTs outside of typical coursework experiences provides them with opportunities to integrate their teaching and scholarship. Working closely with PSTs can help faculty become better teacher educators. Furthermore, mentoring undergraduate research can help faculty build on their scholarship into a particular direction, especially for faculty from universities with limited graduate research.

References

Aguilar Batista, J. J. (2017). *Modeling through model-eliciting activities: A comparison among students at different performance levels* [Unpublished doctoral dissertation]. The University of Texas at Austin.

Aguirre, J. M., Anhalt, C. O., Cortez, R., Turner, E. E., & Simic-Muller, K. (2019). Engaging Teachers in the Powerful Combination of Mathematical Modeling and Social Justice: The Flint Water Task. *Mathematics Teacher Educator*, *7*(2), 7-26.

Anhalt, C., & Cortez, R. (2016). Developing understanding of mathematical modeling in secondary teacher preparation. *Journal of Mathematics Teacher Education*, *19*(6), 523–545.

Association of Mathematics Teacher Educators (AMTE). (2017). *Standards for Preparing Teachers of Mathematics*. Retrieved from http://www.amte.net/standards

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 399–407.

Bauer, K. W., & Bennett, J. S. (2003). Alumni perceptions used to assess undergraduate research experience. *Journal of Higher Education*, *74*(2), 210–230.

Cai, J., Morris, A., Hohensee, C., Hwang, S., Robinson, V., & Hiebert, J. (2018). Reconceptualizing the roles of researchers and teachers to bring research closer to teaching. *Journal for Research in Mathematics Education*, *49*(5), 514–520.

Campbell, A., & Skoog, G. (2004). Preparing undergraduate women for science careers. *Journal of College Science Teaching*, *33*(5), 24–26.

Carmona, G., & Greenstein, S. (2010). Investigating the relationship between the problem and the solver: Who decides what math gets used? In R. Lesh, P. L. Galbraith, C. Haines, & A. Huford (Eds.), *Modeling students' mathematical modeling competencies: ICTMA 13* (pp. 245-254). Springer US.

Consortium for Mathematics and its Applications (COMAP) & Society for Industrial and Applied Mathematics (SIAM). (2016). *Guidelines for assessment & instruction in mathematical modeling education*. Authors. http://www.comap.com/Free/GAIMME/

DeVore, S., & Munk, D. (2015). Undergraduate research in teacher education: A rationale for broader engagement. *CUR Quarterly*, *35*(4), 12–17.

Google Workspace. (n.d.). *Jamboard*. https://workspace.google.com/products/jamboard

Groth, R. E., Bergner, J. A., Austin, J. W., Burgess, C. R., & Holdai, V. (2020). Undergraduate Research in Mathematics Education: Using Qualitative Data About Children's Learning to Make Decisions About Teaching. *Mathematics Teacher Educator*, *8*(3), 134-151.

Hunter, A. B., Laursen, S. L., & Seymour, E. (2006). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, *91*(1), 36–74.

Hunter, A. B., Weston, T. J., Laursen, S. L., & Thiry, H. (2009). UR-SSA: Evaluating student gains from undergraduate research in science education. *Council on Undergraduate Research Quarterly*, *29*(3), 15-19.

Jahan, M. P., & Aly, S. J. (2018, June). *Engaging undergraduate students in hands-on research using undergraduate-specific small internal grants from the university* [Conference session]. 2018 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, Utah, United States. https://peer.asee.org/30400

Kardash, C. M. (2000). Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, *92*(1), 191–201.

Koellner-Clark, K., & Lesh, R. (2003). Whodunit? Exploring proportional reasoning through the footprint problem. *School Science and Mathematics*, *103*(2), 92-98. https://doi.org/10.1111/j.1949-8594.2003.tb18224

Lester, F. K., & Wiliam, D. (2002). On the purpose of mathematics education research: Making productive contributions to policy and practice. In L. D. English (Ed.), *Handbook of international research in mathematics education* (pp. 489– 506). Erlbaum.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, *3*(4), 270–277.

Lopatto, D. (2008). Exploring the benefits of undergraduate research: The SURE survey. In R. Taraban & R. L. Blanton (Eds.), *Creating effective undergraduate research programs in science* (pp. 112–132). Teachers College Press.

Madan, C. R., & Teitge, B. D. (2013). The benefits of undergraduate research: The student's perspective. *The*

Mentor: An Academic Advising Journal, 15. https://doi.org/10.26209/mj1561274

Manak, J. A., & Young, G. (2014). Incorporating undergraduate research into teacher education: Preparing thoughtful teachers through inquiry- based learning. *CUR Quarterly*, *35*(2), 35–38.

Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education*. Jossey Bass.

Mousoulides, N., Pittalis, M., Christou, C., & Sriraman, B. (2010). Tracing students' modeling processes in school. In R. Lesh, P. L. Galbraith, C. Haines, & A. Huford (Eds.), *Modeling students' mathematical modeling competencies: ICTMA 13* (pp. 119-129). Springer US.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Author.

National Governors Association Center for Best Practices and the Council of Chief State School Officers. (2010). *Common Core State Standards (Mathematics)*. Author.

Osborn, J. M., & Karukstis, K. K. (2009). The benefits of undergraduate research, scholarship, and creative activity. In M. Boyd & J. Wesemann (Eds.), *Broadening participation in undergraduate research: Fostering excellence and enhancing the impact* (pp. 41–53). Council on Undergraduate Research.

Silver, E. A. (2003). Border crossing: Relating research and practice in mathematics education. *Journal for Research in Mathematics Education*, *34*(3), 182–184.

Stohlmann, M., & Albarracin, L. (2016). What is known about elementary grades mathematical modelling. *Education Research International*, *2016*, 1-9. https://doi.org/10.1155/2016/5240683

Taraban R., & Logue, E. (2012) Academic Factors That Affect Undergraduate Research Experiences. *Journal of Educational Psychology, 104*(2), 499-514

Wentzel, T. J. (1997). What is undergraduate research? *CUR Quarterly*, *17*, 163.

Author Information

Melike Kara	Kimberly Corum
https://orcid.org/0000-0003-1237-0597	https://orcid.org/0000-0003-2472-5279
Towson University	Towson University
Department of Mathematics	Department of Mathematics
7800 York Road Towson, MD 21252	7800 York Road Towson, MD 21252
United States	United States
Contact e-mail: *mkara@towson.edu*	