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Teaching Mathematics: Multiple Perspectives among Teacher Candidates during a STEM Field Experience

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In the present study, the researcher examined teacher candidates' perceptions of teaching elementary mathematics during summer science, technology, engineering, and mathematics experiences for rising third through fifth graders. Teacher candidates enrolled in mathematics and science pedagogy courses for summer term observed and taught elementary students for three weeks during the term. Data from three of the teacher candidates were analyzed using Interpretive Phenomenological Analysis to explore their perceptions of learning and teaching mathematics in their roles as teacher, student, and an observer during the summer STEM field experience. Teacher candidates encountered multiple changing perceptions related to teaching mathematics through the STEM field experience. This research presents insights from teacher candidates about the perceptions of the role of mathematics, the role of teaching mathematics, and the role of learning mathematics during STEM experiences. It illuminates the complexities of teaching in a multidisciplinary classroom. Teacher educators can use this insight as they seek to support teacher candidates as mathematics educators and also to prepare them to be interdisciplinary teachers.

***Keywords*:** mathematics, STEM, field experience, teacher education, elementary

Effective elementary mathematics instruction involves engaging students in sense-making, communication, connecting representations and mathematical ideas, problem-solving, and reasoning (Bass, 2011). Research has shown that when students are communicating and problem-solving in authentic ways, they are more engaged in mathematical learning (Niess, 2005). Science, technology, engineering, and mathematics (STEM) education is one way to provide authentic real-world engagement with mathematics content (National Research Council [NRC], 2011; Tran, 2018).

Preparing teacher candidates (TC) to apply instructional strategies such as STEM problem-based instruction within their future classrooms can be challenging because of the opposition they often see in the field (LeCornu & Ewing, 2008). In addition, research has shown that many TCs have years of experiences in which mathematics was taught ineffectively and without authentic context (Shoffner, 2008). These experiences often include mimicking, rather than conceptual understanding. In order to effectively plan and implement authentic and engaging instruction, TCs need experiences teaching and learning in this type of environment (McGee, Wang, & Polly, 2013). Learning experiences of TCs are maximized when coursework and field experiences are connected in meaningful ways so that TCs can make direct connections and apply the theories they learn in courses with the realities they see in the classroom (Abell, 2006; Weld & French, 2001).

Theoretical Framework

STEM Education

Over twenty years ago, the National Science Foundation (NSF) introduced the acronym STEM to communicate about the subject areas of science, technology, engineering, and mathematics (Sanders, 2009). This convergence of the four disciplines into one acronym was necessary because the four areas are closely tied and all are vital in today's world (Vasquez, Sneider, & Comer, 2013). It has been argued that recruiting more STEM professionals is critical for the success of the United States (U.S.) economy and its innovation (National Academy of Science, 2007). Problem-solving, adaptability, complex communication, self-management, and social skills are all interconnected elements of STEM education (NRC, 2011).

Sometimes, STEM has referred to the four distinct fields of study. However, within the field of education, it more commonly refers to a more interdisciplinary approach (English, 2016; Madden, Beyer, & O'Brien, 2016). Educators in STEM face a challenge regarding how to effectively integrate the disciplines while also maintaining the integrity of each subject. There are STEM education centers with a focus on instructional strategies such as project-based learning and exploring solutions to real-world problems that are intended to aid educators in addressing these STEM-related instructional challenges (Acara, Tertemizb, & Tasdemirc, 2018). For the purposes of this study, we draw upon a definition Shaughnessy provided in 2013:

> STEM education refers to solving problems that draw on concepts and procedures from mathematics and science while incorporating the teamwork and design methodology of engineering and using appropriate technology. (p. 324)

STEM education allows students to explore, create, analyze, discover, and draw conclusions, which are important in everyday lives (Tran, 2018). Individuals within professional education organizations have been advocating for the improvement of connections across STEM disciplines (National Science Teachers Association [NSTA], 2003; National Council of Teachers of

Mathematics [NCTM], 2000). This call for improved interdisciplinary STEM education is supported by research that has indicated that STEM experiences increase students' science and mathematics achievement levels (Becker & Park, 2011; Judson, 2014). However, single-subject instruction remains predominant in U.S. schools (Barrow, 2006). Moreover, some have concerns that many STEM programs do not genuinely integrate disciplines and instead focus on science or engineering content without providing substantial mathematical learning (An, 2017; Shaughnessy, 2013).

Research has suggested that elementary students often receive poor instruction and lack of meaningful experiences in STEM because their teachers lack meaningful STEM experiences (DiFrancesca, Lee, & McIntyre, 2014; Parry, 2011). Teacher's content knowledge directly impacts the instruction they provide to their students (DePiper, Frank, Griffin, & Choi, 2014). To teach students using integrative-STEM approaches requires knowledge of multiple content areas, knowledge of how to teach the various disciplines effectively, and knowledge of ways to integrate the disciplines effectively. Understanding the connections across content areas and utilizing these for learning experiences involves a different type of knowledge of pedagogy and content (An, 2017). Therefore, it is critical that teachers have positive STEM experiences that prepare them with the content knowledge and pedagogy they will need to be effective in STEM classrooms (Nadelson & Seifert, 2013; Nadelson, Seifert, Moll, & Coats, 2012).

Preparing Teachers for STEM Classrooms

Although there is a dearth of research on the positive impact of STEM education on students, there is very little research concerning the STEM preparation of elementary TCs (Brown, 2012). However, when TCs are given the opportunity to experience STEM content as both a student and a teacher, research has indicated that they are more confident and competent in their ability to implement STEM content in their own future classrooms (Berlin & White, 2012; Murphy & Mancini-Samuelson, 2012). In most teacher education programs, teachers are still prepared through methods courses that focus on single, isolated subjects (Labaree, 2008). In order to prepare TCs for effective interdisciplinary teaching, they need guided experiences that allow them to explore various teaching strategies (An, 2017; Park & Oliver, 2008).

"Teaching is not merely a cognitive or technical procedure, but a complex personal, social, and often elusive set of embedded processes and practices that concern the whole person" (Olsen, 2008, p. 5). Thus, TCs need experiences and mentorship in interdisciplinary teaching to help them develop their ability to teach multiple subject areas effectively within one lesson (An, 2017). For elementary mathematics TCs, this involves trying new ideas, engaging in inquiry-based teaching, and learning from errors within a collaborative, supportive community (Belliveau, 2007).

Seminal research has indicated that teaching practices are shaped by teacher knowledge (Ball, Thames, & Phelps, 2008) and beliefs (Pajares, 1992). Scholars have suggested that sometimes lack of knowledge about the content or student thinking can hinder teachers from acting on their beliefs about teaching and learning (Empson & Junk, 2004). What teachers notice in the classroom setting influences what they are able to utilize as learning opportunities (Sherin, Jacobs, & Philipp, 2011). Evidence has shown that novice teachers and TCs tend to focus on themselves, whereas more experienced teachers tend to attend to students (Cohen & Ball, 2001). Supporting TCs' development of the ability to observe, interpret, and effectively respond to student thinking during lessons involves identifying and implementing productive mathematics learning practices both in coursework and fieldwork (Amador, Weston, Estapa, Kosko, & De Araujo, 2016; Cohen & Ball, 2001).

This study is grounded in the belief that elementary TCs need early STEM inquiry-based field experiences, in which they focus on students as mathematics learners, take teaching risks, and reflect upon the practice of teaching to meet the needs of all learners in order to successfully continue this type of instruction in their own classroom (Aguirre et al., 2013).

The Contextual Background

Faculty at a mid-sized southeastern university in the U.S. established a three-week elementary STEM field experience to provide summer teaching experiences for TCs enrolled in mathematics, science, and reading methods courses. This was the first teaching field experience for these TCs. Prior to this semester, the TCs examined lesson planning, assessment, professionalism, individual reading instruction and worked with individual students.

Description of Elementary Students in STEM Field Experience

Approximately 150 rising third- through fifth-grade students attended the camp in which the TCs received STEM field experience. Over 50% of the elementary students received scholarships based on financial need and teacher recommendation. Students came from six different school districts and possessed diverse academic needs, cultural backgrounds, and learning styles. Students from high-needs schools attended alongside students from schools in which resources were plentiful. The population of the camp was approximately 60% African American, 20% Asian, 15% Caucasian, and 5% other nationality representations. Students were randomly divided into two classes for each grade. Students attended camp Monday through Friday from 8 a.m. to 12 p.m.

STEM Field Experience

Prior to the STEM field experience, the instructors in the courses modeled interdisciplinary collaboration in planning, observing, and debriefing through a three-day workshop that prepared the 24 TCs to serve as lead teachers in the content. The TCs participated in three weeks of full-time methods coursework in addition to the three-day professional development workshop (PDW) that was centered on the STEM Camp. The methods courses explored the discipline-specific pedagogical content knowledge and both interdisciplinary learning and planning. They experienced project-based STEM education during the PDW as they learned. These experiences helped build knowledge that informed their planning and implementation of STEM curriculum.

The faculty predetermined the overarching weekly STEM Camp themes and more explicit foci for each grade. This allowed faculty to provide the three-day PDW, a skeleton of ideas and instructional focus for each of the teacher teams, and order appropriate materials. The PDW allowed TCs to explicitly explore and experience a small portion of the content and instructional style that they would be teaching each week. On day one, the focus was on structures, on day two it was on robotics, and the final day was focused on forces in motion.

During the PDW, TCs explored and participated in major projects they would be teaching. For example, third-grade teachers used the engineering design process to make and race doodlebots. Doodlebots are robots made of batteries, a cup, wire, erasers, a motor, and markers. They move and draw as they move. Circuits, weight, measurement, time, and data analysis are explored in this process. The TCs researched models online, charted their data using a graphing program, and made movies of this experience. They also worked in teaching pairs to make concept maps about materials, questions, roadblocks, and content that would help in their planning. The TCs were provided a template for planning, an outline for the week, and a template for each lesson. During the PDW, TCs were provided with essential questions for their week, essential content that must be included during the week for each subject area, a list of materials, and a list of possible activities that could be utilized to teach the content around the theme for that week.

The first week of the camp was focused on robotics, the second week was focused on structures, and the third week was focused on forces in motion. Each grade level's theme had a slightly different focus and essential question. For example, week three was focused on forces in motion, so the rising third graders explored automobiles, the fourth graders explored amusement park rides, and the fifth graders explored rockets. The third-grade students explored Newton's Laws through automobiles. They utilized engineering principles as they built and tested various cars, such as balloon cars that moved when the air of a balloon attached to the car was released and propelled the car forward. They also tested various angles of roads and various surfaces. They used mathematics to purchase materials for cars they built and to measure time, angles, and distance in various races and tests. They also collected and displayed data based on their tests of cars. They utilized technology to record and chart the speed of vehicles and to research various aspects of the content they were learning. One essential question they explored during this unit was the following: Where do force and motion show up in our daily lives?

The purpose of the STEM field experience was to provide authentic meaningful experiences for TCs that connect to coursework. Teams of six TCs were assigned to a classroom. The TCs in each class were subdivided into three groups of two teachers. Each group of two teachers was assigned a week to plan, a week to teach, and a week to observe peers and elementary students. Two TCs worked collaboratively to plan and implement a STEM unit for each week. During the weeks of planning and teaching, teams worked to utilize theories and concepts explored in methods coursework to bring concepts to life through the lessons they planned and implemented. They also received the supportive guidance of course instructors that served as their supervisors and mentors during this time.

The team of TCs that were observing utilized observational protocols for elementary students and their TC peers to capture experiences during each lesson. They would focus half the time on observing elementary student thinking and half the time on teacher practices. This allowed TCs to learn from various perspectives. When observing elementary students, they were asked to observe engagement, connection to the content, peer interactions, and evidence of student thinking. When observing peers, they focused on organization and management of the learning environment, the use of engaging instructional strategies for all learners, assessment of learning, content knowledge, instructional scaffolding, and technological knowledge.

Each afternoon, faculty debriefed with TCs with vertical team meetings, sharing observation protocols, analyzing data, and discussing next steps. The TCs were also required to invest time in exploring pedagogical content in relation to their field experiences. TCs submitted weekly reflections, weekly and daily lesson plans with brief reflections about the lesson plans, observations of themselves, peers, and elementary students, and a case study.

The purpose of the current article is to share reflections and perceptions concerning teaching mathematics in a STEM field experience by TCs. Analyzing the TC perceptions in this experience through various lenses sheds insight onto their perception of mathematics in STEM education, their own professional identities as mathematics educators, and their views on teaching mathematics. The article is framed around the following research question: How do various roles and experiences impact the perspectives TCs have during a STEM field experience?

Research Methods

Participants

In this study, the researcher examined three TCs from the context mentioned above: Bree, Jose, and Anna. They taught a class for children entering fifth grade in the upcoming school year. The TCs were enrolled in the mathematics pedagogy course at the time of the STEM field experience. They observed students, observed peers, and planned and implemented lessons in order to grow as professionals and to give authentic context to what they learned during their coursework. All three TCs were 20-21 years old and identified as Caucasian. Two identified themselves as female and one as male. All were engaging in their first whole-class teaching experience. They were selected for analysis in the present study because they were in the same classroom and their data would reflect the same lessons and students, from different perspectives. Out of the six candidates randomly placed in that classroom, the researcher randomly selected one candidate teaching each week to analyze.

Data Collection

Data on TC perceptions related to teaching mathematics were collected using multiple sources of data in order to gain a holistic view of perceptions of teaching, students, and mathematics within a STEM program. In addition, the sources provided insight into the changes that occurred in individual TCs throughout the three-week experience through lesson plans, reflections on their own teaching, observations and case studies of students observed, and observations of peers.

The lesson plans that were collected for analysis were those in which TCs highlighted areas where mathematics was taught and used a different color to identify where mathematics was utilized as a tool. TCs were told that mathematics as a tool was found in contexts in which the student understood the mathematical content and time was not spent exploring the mathematics, but instead was used to understand science, technology, or engineering concept. Mathematics being taught in a STEM lesson, on the other hand, was considered as contexts in which students might use the science, engineering, or technology concept to engage or create authentic meaning, but would be given the space and intentionality in the plan for exploring and discussing the mathematical content utilizing the process standards (NCTM, 2000). In addition, TCs wrote a reflection about teaching mathematics at the end of the week. They identified instances in which they utilized effective strategies and teaching practices and areas in which they struggled. They also shared how this influenced their ideas about STEM education and teaching elementary mathematics.

In addition, the TCs also observed students when they were not teaching. They observed students in various contexts, but for this study, only observations in which mathematics was mentioned were analyzed. They also created a case study for two students utilizing work samples, observations, and interviews. They used this data to write a reflection about the experience. This included a description of the student as a mathematics learner, the observed strengths of the student, and suggestions for future instruction to support deeper mathematical development.

TCs observed their peers, identified effective teaching practices, and provided at least two suggestions for improving the lesson in the future. They then shared their feedback with their peers in afternoon debriefing sessions. This provided opportunities for professional conversations about teaching practices. These observation notes were collected as data for this study.

Data Analysis

Data were examined through Interpretative Phenomenological Analysis (IPA). This form of analysis is used to explore how participants make sense of their world (Pietkiewicz & Smith, 2012). Implicit within this type of analysis is the recognition that meanings are attached to experiences and participants cannot be analyzed without recognizing this connection. In IPA, the researcher attempts to understand "what it is like to stand in the shoes of the subject (although recognizing this can never be completely possible)" (Pietkiewicz & Smith, 2012, translation of pg. 362). Participant perspectives are examined through a critical lens of questions that challenge their thinking. Critical questions such as the ones below guided TCs' observations of peers, observations of students, and reflections on their own experiences:

> 1. What mathematical ideas does the student conceptually understand? What mathematical ideas does the student struggle to demonstrate? What evidence do you have? What would your next steps be?
> 2. What was a challenging part of implementing this lesson for you? What would you do differently next time and why?
> 3. What is something specific that changed your perspective today? Why?

Additional questions were occasionally added because of IPA's dynamic nature (Smith & Osborn, 2008). The researcher was fully immersed in the data to gain evidence of the participants' sense of the situation being studied and to document how the participants made sense of the experience. The situation being studied was the TCs' perceptions related to teaching and learning mathematics within a STEM field experience.

Initially, data were read multiple times. First, they were read by data type, such as examining case studies. Next, they were read based on groups, such as data from the week each participant was a teacher. The third way data were analyzed was by week. For example, all the data from week one were read together. Finally, the data from each individual were read together to form a coherent understanding of the participant. During each reading, extensive notes on comments, language use, and context were taken, following guidelines of IPA. The notes taken in phase one were analyzed for emergent themes that were grounded in specific experiences or specific participants. Codes were tagged based on week, participant, role, and any other important note that would help in the third and fourth phase of analysis. For example, one code was TLC1ao (teacher lack of confidence week 1 Anna observer). This was a code comprised of a group of tags: the theme of teacher confidence that was tagged as confidence or lack of confidence in addition to the tag for week, participant, and role.

After themes were identified, they were grouped into clusters. For example, teacher confidence was grouped into teacher identity along with perceived content knowledge and other themes. Finally, a narrative account of the study was provided that highlighted examples of themes within the identified clusters.

Results

The IPA process involves the researcher "stepping into the shoes of the participant" in order to better understand the participant and the situation (Pietkiewicz & Smith, 2012, translation of pg. 362). It includes narration of the findings and examples of clusters. The results section, when using IPA, is the story that emerges from the data and specific examples that support the story. In the present study, several clusters emerged from the data. Most participants found one area of mathematical teaching and learning to be central in the journey. Although each was very different, it was interesting to see how the TCs' views of mathematics and their mathematical identities influenced their perceptions of teaching and learning mathematics through a STEM field experience.

Bree

Two clusters that associated with Bree were a productive struggle and seeing mathematics as a tool for STEM learning or STEM learning as a tool to teach mathematics. During the three weeks, Bree's journey with the concept of productive struggle included re-envisioning the teaching and learning of mathematics. Her journey began with thinking about mathematics as a tool for other areas of STEM (e.g. using computation of money to buy materials). She struggled to consider how to teach mathematics not already mastered. During the PDW and planning phase, she was questioned about scaffolding students who did not already know the content, and she would say things like, "their peers will help them and I will be there". As the STEM Camp continued, she began to hint that STEM could promote mathematical learning, but she struggled to articulate how this could be executed. She taught during the final week, and her lesson plan reflections noted that space and planning were needed to support mathematics during STEM instruction. This did not appear in her initial observations and case study, which both focused on mathematics only as a tool.

Bree wrestled with the notion of productive struggle in mathematics throughout the three weeks. Initially, she reflected the difficulty in knowing when and how to help students. She saw her role as making mathematics fun and easy in STEM. She observed students struggling with concepts and felt the teacher should step in and demonstrate to the student how to do the mathematics. However, when she taught, which was the final week, she reflected on the impact of letting students build on what they know when the answer is not immediately obvious. In her final reflection, she shared:

> I used to think teaching was standing up front and making it easy for the kids to understand. Even though we talked about it in class, when I first saw students struggling, I remembered being a student and feeling I was dumb because I could not just do it. I now understand that my job is to get students to do the work of learning and it is different than I thought. However, it is important to make sure the rest of the class understands the power of productive struggle and doesn't think the fastest finisher is the smartest. It is all about relationships and how you think of mathematics.

Her experiences in the STEM Camp brought the material learned in the methods courses to light. In Bree's reflection, she noted:

> When I first heard the term productive struggle in class, it didn't make any sense to me. I thought the word "struggle" in itself is a teacher's role to minimize... When given the chance to work through it on their own, they realized how much they knew and what they could do, but the teacher watched from afar to ensure they weren't left without tools to solve it.

Although Bree had initial difficulties with productive struggle, she was able to focus on mathematics within the STEM curriculum, in student observations, and in teacher reflections. She initially focused on mathematics as a tool for learning, rather than focusing on the learning process. This could be seen as a connection to her view of productive struggle. For example, in her lesson plan, she planned for students to use the protractor to measure angles during rocket testing. Data from her reflection, lesson plan, and peer observation of this lesson made it clear that she had her own form of productive struggle in recognizing that mathematics needed to be more than a tool in STEM education.

When she passed out the protractors, she realized students had not used them before and she had never pre-assessed prior understanding of measuring angles. She reflected that her first reaction was to put the protractor on the document camera and tell them what to do so they could move toward the "fun" experiment; however, she realized that doing so would minimize their potential learning opportunity. Therefore, she first asked them what they knew about angles. Next, she tasked them with predicting how different angles might affect the trajectory of the rocket. Then, she asked, "If one person had a rocket that went really far, how could the rocket be recreated to determine if the angle was the reason it went so far?". Students came up with various nonstandard units for angle measurements, such as cutting out paper to make the angles, etc. Then she introduced the protractor. Although this pushed back the lesson a day, she reflected that the students were interested in how to measure angles because they wanted to learn from the experiment. She noted that the struggle students experienced made the learning more powerful for them. She reflected that it was this moment in the lesson when she finally realized the need for productive struggle and reasoning.

She believed that if she showed the students how to use a protractor without the prior conversation, students would measure the angle but not understand what it meant. In addition, she noted the need to plan based on assessment data in the future. In her final reflection, she connected this interaction with the interactions she had in her student interviews, which occurred prior to her teaching. She noted that she had initially questioned students more for their responses, rather than to truly focus them and allow them to describe fully their thinking.

Jose

A cluster that emerged from Jose's data was mathematical content knowledge. He initially recognized the need for mathematical content knowledge in teaching and was confident in his abilities. Over the experience, however, he began to reflect on elements of teaching he had not originally considered. For example, he identified the need to know the content students should be learning. Although he had been introduced to the standards throughout the course, it was during this experience that he began to reflect on the importance of knowing the prior and future educational standards for students as well as truly understanding the meaning of each standard. His data also indicated that he struggled with identifying ways to make mathematics content accessible to students, knowing common ways student think about the content, and knowing specific ways to teach the content. He saw that all three areas were important in teaching and wanted to focus on improving his ability. In one reflection, he wrote:

> I really have to know my stuff. I have always been good at math and thought this would be easy, but it's not. I have a hard time understanding what they see in problems and where they are confused. I need to really study what we are learning in class about learning trajectories, misconceptions and so much more if I am going to be prepared for a lesson.

Through this experience, he recognized and more clearly articulated the complexity in teaching mathematics, especially when combined with other disciplines, such as those incorporated in a STEM camp. He noted in a student observation that students can show conceptual strengths, even when they get an answer wrong. When one student found an efficient way to do volume (multiplication), he reflected:

> I thought that this was neat because she was able to recognize that there was a simpler way to do the operation. She multiplied 4x3 wrong, but that was just a mistake, she corrected it immediately, and what impressed me was the concept

> and connection, not the multiplication facts. If students' answers are completely wrong, I ask them how they reached their conclusions and try to pinpoint where they made errors. However, it is good for students to see that everyone makes mistakes and that is a part of learning.

Jose also reflected several times that students might excel in one STEM discipline and struggle in another. For example, he noted students that some of the students excelled in mathematics but lacked knowledge of technology, due to their prior access and experiences with technology.

Anna

Anna was very concerned about her own confidence level and the emotions and feelings of the students in her class. She shared initially that she enjoyed worksheets in elementary school mathematics, but that once you "had to think" in the older grades, she was lost. She was nervous about teaching in a STEM environment because things were not as "structured and straight forward" as a traditional classroom. She had also been worried about not having a classroom teacher in the room if she needed help. In her peer observation, she noted the confidence of peers and shared that they seemed to enjoy teaching. In her own week of teaching, her nerves subsided some but were still present. Although her first day went well, she immediately expressed apprehension about day two:

> Day one went well, but we over planned for that day. I am nervous about this next day because I didn't have as much time to really think it through. I mean we planned, but day one was always what I focused on the most in the week.

Anna also showed concern for students' mathematical confidence. She wanted to plan things they could do and would have fun at, which was easy in STEM Camp, but she also wanted structure so that students would not "get out of control". She expressed that "everyone should be able to participate". As she reflected on students and peers, she was asset-based in her assessment of their performance and shared the positive notes, whether they were related to the content, motivation, social, or otherwise. However, when focusing on her own identity and practice as a teacher, she focused on her deficits and areas of struggle. For example, one lesson on geometric shapes for bridges had one point of confusion. Students became frustrated, but Anna was able to help them move past the frustration and effectively measure various aspects of the bridge to build it effectively. Anna reflected:

> I wasn't prepared to scaffold, so when they didn't know the answer to my question, they began to shut down and get frustrated. If I had planned better, they would have really enjoyed this. In the future, I need to plan scaffolding and also start where they are and build on what they know.

Anna’s lack of confidence in her ability to multi-task was evidenced when she noted that she needed, “more time to practice because there is so much going on all the time and so many details to be aware of in each moment”. She reflected that when she felt she improved in one area, she would notice a new area that needed attention. When questioned about the observations done by her peers and instructors, she noted that everyone gave her positive feedback and their suggestions were helpful. However, her focus remained on the areas of improvement in her own teaching, rather than on the students. Her teaching demonstrated an ability to create mathematical discourse and to adjust lessons when students needed additional support. Although her management and transitions were not smooth, they were appropriate for her level of experience in the program.

Each participant tended to have a cluster that was a focus for him or her during the experience. Moreover, each TC experienced change when this cluster was followed throughout their STEM camp experience.

Discussion

Bree experienced a profound change in her view of teaching through her recognition of productive struggle. Although she saw it in observations, it was during her role as teacher that this concept learned in coursework became a reality to her. She began to recognize the powerful impact of a teacher’s relationship with students. She shared that teachers need to know their students in order to know when students need to struggle and when they need assistance. This correlates with previous research in which it was found that TCs require experiences with strategies and pedagogy learned in coursework in order to more fully visualize their place in authentic classrooms (Abell, 2006).

Although Jose was initially confident in his mathematical content knowledge, the STEM camp experience allowed him to experience specific knowledge that elementary mathematics teachers need. He never explicitly identified the knowledge he referred to as mathematical content knowledge for teaching (MKT) elementary students (Ball et al., 2008), but he did share elements that are part of this specialized content knowledge. This includes being able to determine the content students should be learning, to understand ways to make that content accessible to students, to identify common ways student think about the content, and to apply specific approaches for teaching the content. This change occurred during both his role as an observer and a teacher. Through his recognition of the complex knowledge required of teachers, he was also able to assess student knowledge at a deeper level. He also reflected about a student strategy he had not expected, as evidenced by his statement, “This surprised me because I was not prepared for a student to have this kind of content knowledge”. Preparing TCs to focus on student mathematical thinking and reasoning is important in order to promote student learning (Aguirre et al., 2013). Another example of the MKT Jose noted that concerned scaffolding was, "Scaffolding is more than just assisting through questioning. I need to be intentional with problems presented to students in order to scaffold". This awareness of the demands of practice is critical for effectively teaching mathematics (Ball et al., 2008).

Anna's focus on confidence and emotions of her students was also reflected in comments she made about herself. She noted, "I worry about not knowing the answer, not understanding a student's strategy, or messing up in a way that hurts a student in math, the way I was hurt by teachers". This is an example of the challenges many TCs face in changing their perceptions and confidence about mathematics after negative experiences and ineffective teaching (Shoffner, 2008). While Anna's confidence remained a struggle, she found ways to push her own learning forward because of her desire to change a cycle of mathematics anxiety. Through teaching at the STEM camp, she recognized the potential in the students and herself but still appeared to require additional successful experiences and feedback in order to raise her own affect about teaching mathematics.

This analysis provides insights into TCs' views of teaching and learning mathematics during a STEM education field experience. It highlights areas that might be impacted by the experience. The differences in improved understanding or awareness that each TC gained from the various roles reiterate the importance of providing holistic STEM experiences for TCs.

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