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Enhancing Mathematics Learning in Content Courses for K-8 Teachers: Promoting Growth Mindset, Challenging Unproductive Beliefs, and Addressing Mathematics Anxiety

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Abstract

In this essay, we describe some challenges that mathematics teacher educators may face when teaching content courses for future elementary and middle school teachers. We summarize research that suggests students in content courses may have fixed mindsets, unproductive beliefs, and mathematics anxiety that can interfere with their ability to learn mathematics content. We suggest possible interventions to address these affective issues, including student-centered instruction, valuing mistakes, process praise, self-directed learning, and activities that inspire student reflection related to his or her own mathematical understandings.

Introduction

Mathematics content courses are an opportunity for future elementary and middle school teachers to engage deeply with mathematical content and improve their understanding so they will be comfortable and effective in helping children learn mathematics in the future. Instructors of content courses are tasked with supporting these individuals, so they become more knowledgeable and confident in mathematics. Curricula designed for these courses aid in this task, and frequently emphasize problem solving, multiple solution methods, a variety of representations, justification of procedures (including why standard algorithms work) and require significant student explanation and discussion (e.g. Beckmann, 2017; Sowder, Sowder, & Nickerson, 2016). Such curriculum activities will help future teachers learn how to meet the Common Core State Practice Standards (CCSSI, 2010), which require that all students in grades K-12 learn mathematics through problem-solving, reasoning, justification, and understanding multiple representations.

However, some preservice elementary teachers (PSTs), may have affective predispositions that make it difficult for them to learn in a content course. By affective dispositions, we mean students' attitudes and/or feelings toward mathematics. For instance, many PSTs believe that they have already learned all the mathematics they need in order to successfully teach elementary school before they even set foot in a content course (Thanheiser, Philipp, Fasteen, Strand, & Mills, 2013). Such individuals may not realize that a deeper understanding of mathematics is required to be an effective teacher (Pair, 2016, Thanheiser et al., 2013). Additionally, PSTs often have high levels of anxiety (Hembree, 1990; Cady & Rearden, 2007; ***Beilock et al., 2010). PSTs*** with high anxiety typically report that in their prior experiences learning mathematics in school they relied on memorization in order to quickly complete procedures and arrive at correct answers (Johnson, 2019). Such students may doubt their ability to complete problem-solving tasks and grow their mathematical intelligence.

Instructors of mathematics content courses need to provide future teachers with opportunities to engage in learning activities that provide PSTs with a deeper understanding of the mathematics so that they may one day become confident teachers. But in order to do so effectively, instructors may need to address specific issues. This paper will detail how mindset, beliefs, and anxiety affect PSTs' learning in mathematics content courses, and offer recommendations for instructors to support positive change for future teachers in these areas.

Mindset

Powerful research conducted by Carol Dweck and others has addressed how beliefs about one's own intelligence have a significant influence on one's ability to learn (Dweck, 2006a; Mueller & Dweck, 1998). In contrast to a person with a fixed mindset, who believes their intelligence is fixed and cannot grow, those with a growth mindset believe that their intelligence can grow through effort. Research has shown that students who possess a growth mindset are more successful in learning. Dweck (2006b) wrote,

> In a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work—brains and talent are just the starting point. This view creates a love of learning and a resilience that is essential for great accomplishment. (para. 3)

Students who embrace growth mindsets learn more and view challenges and failures as opportunities to improve their learning and skills (Dweck, 2006a). Thus, students who have a growth mindset will learn more from their content courses than students who do not. Unfortunately, PSTs, along with most US students, believe that there exists a "math brain" and that only people born with mathematical ability can succeed in mathematics (Barlow & Reddish, 2016; Boaler, 2013). Fixed mindsets may prevent preservice teachers from achieving success in mathematics courses in college.

Students must become aware that they have a fixed mindset if they are to transform to a growth mindset, and have a willingness to accept that they are capable of gaining a deeper understanding of mathematics through a content course. Researchers have found that if students are made aware of the concept of growth mindset, they can change their attitudes and aptitudes towards learning, for the better (Boaler, 2016). To promote growth mindset, the instructor can engage students in tasks which allow them to productively struggle (NCTM, 2014), and provide praise for effort and process while valuing mistakes (Dweck, 2006a).

Beliefs

PSTs within mathematics content courses have "dominant cultural beliefs" (NCTM, 2014, p. 6) of mathematics and its teaching and learning which create a lens through which they may view course activities differently than instructors intend (Ambrose, 2004). For instance, some PSTs believe that elementary school teaching will be relatively straightforward, and they downplay the importance of their own content knowledge (Ambrose, 2004; Thanheiser et al., 2013). That is, they believe they already understand the mathematics they need to teach elementary school and do not need to learn anything new in a content course (Thanheiser et al., 2013). Furthermore, PSTs may believe in other myths related to mathematics: that ***mathematics*** is not creative, or that a person has to be born with mathematical talent to succeed in mathematics (Barlow & Reddish, 2006).

Ernest (1989) described the social, cultural, and psychological aspects that influence a teacher's practice, many of which apply to PSTs as well. Especially relevant to an instructor of a content course are preservice teachers' conceptions of the nature of mathematics. Professional organizations such as the National Council of Teachers of Mathematics (NCTM) have promoted the view that mathematics is a dynamic, ever-changing human enterprise (NCTM, 1989; NCTM, 2014). NCTM contrasts the dynamic view (Ernest, 1989) with the view that mathematics is a static unchanging body of knowledge. According to NCTM (2014), the static view is an unproductive mathematical belief that is dominant within US culture. This view is closely related to what Ernest (1989) termed the instrumentalist view, the belief that mathematics is a collection of arbitrary unrelated rules and skills. If a preservice teacher holds an instrumentalist view, which is strongly held by many preservice teachers (Shilling-Traina & Stylianides, 2013), then they may not value open-ended problem solving or see the importance of multiple solution methods (Ernest, 1989). Such PSTs may have previously been successful in calculation-based mathematics courses, and they may question the value of the learning activities they are asked to engage in within a content course (Pair, 2016). As Thanheiser and colleagues (2013) noted, "A challenge for those of us teaching mathematics to PSTs is to change the beliefs that PSTs hold about what mathematics they need to know and how they need to know it" (p. 138).

Although beliefs are relatively stable and take significant time to be influenced (Cooney, Shealy, & Arvold 1998; Swars, Hart, Smith, Smith, & Tolar, 2007), there are some practices instructors of mathematics content courses can implement in order to promote positive beliefs about mathematics. Some of these include having PSTs discuss and reflect on their own understandings of why standard mathematical procedures work (Thanheiser et al., 2013) or having PSTs keep a mathematical autobiography (Stuart and Thurlow, 2000).

Anxiety

The beliefs that PSTs have regarding mathematics can sometimes lead to mathematics anxiety (Barlow & Reddish, 2006). Mathematics anxiety specifically refers to the stress and tension that can interfere with mathematical reasoning and computation (Wigfield & Meece, 1988). Research has documented a negative relationship between anxiety and mathematics performance in a wide range of student populations from the elementary (Ramirez, Gunderson, Levine & Beilock, 2013) to the undergraduate level (Hembree, 1990). Students with higher levels of anxiety tend to express lower levels of mathematics efficacy and more negative views of mathematics (Ashcraft, Krause, & Hopko, 2007; Ashcraft & Moore, 2009). Research has reported a prevalence of mathematics anxiety within preservice teachers (Cady & Rearden, 2007; Beilock et al., 2010). In a 2007 examination of K-8 preservice teachers' beliefs about mathematics, Cady and Rearden (2007) found that close to 70% of the sample expressed elevated levels of mathematics anxiety compared to other subjects. In another study, elementary education candidates expressed the highest level of mathematics anxiety of all college majors (Beilock et al., 2010). These anxieties may be the result of negative experiences in prior mathematics classrooms, in which they were required to rely heavily on speed, correctness, and competition (Johnson, 2019).

Teachers have the opportunity to deter students' anxiety, but unfortunately teachers often perpetuate a negative cycle due to their own anxieties (Beilock et al., 2010). Teachers with higher mathematical anxiety often have lower expectations of their students (Mizala, ***Martínez,***

& Martínez, 2015) and use more traditional, drill and practice-focused, methods of teaching (Trujillo & Hadfield, 1999). We believe that teacher preparation programs, specifically mathematics content and methods courses, are vital and promising spaces to promote more positive experiences for PSTs to decrease anxiety and improve impacts on future generations of students. This is especially important for female students as Beilock and colleagues (2010) found that female students of female teachers with high mathematics anxiety experienced an increase in their mathematics anxiety even more than male students.

So what can content instructors do to address the anxiety of future teachers? Researchers have found that mathematics anxiety can be reduced for students if they grow in their understanding of mathematics, and mathematics content courses within a teacher education program are an avenue to promote this development (Buckley et al., 2016). As their mathematical skills and knowledge improve and grow, they become more confident and comfortable doing mathematics. But as noted earlier in the paper, students must have a growth mindset and be free of unproductive beliefs if they are to grow in their mathematical knowledge. The classroom recommendations described in the next section, which aim to promote growth mindset, challenge unproductive beliefs, and enhance mathematics learning, may also help to alleviate mathematics anxiety for students.

Research-Supported Interventions

The research suggests that preservice teachers have unique mindsets, beliefs, and anxiety that may diminish the intended learning outcomes of a mathematics content course (Barlow & Reddish, 2006; Thanheiser et al., 2013). Growth and change in these areas take time; but there are activities and practices that an instructor of a mathematics content course can implement to promote growth mindset, challenge unproductive mathematical beliefs, and address mathematics anxiety (Ambrose, Clement, Philipp, & Chauvot, 2004; Cooney, Shealy, & Arvold, 1998; Swars et al., 2007). Some practices suggested by research that we will now discuss include student centered learning, valuing mistakes, process praise, self-directed learning, and reflective activities.

Student Centered Learning

An elementary teacher must have a deep conceptual understanding of the material that is taught to young mathematics learners (Ma, 2010), should believe that mathematical intelligence can grow (Dweck, 2006a), have positive beliefs about mathematics that she will pass on to students (Barlow & Reddish, 2006), and must be free of mathematics anxiety (Beilock et al., 2010). The National Council of Teachers of Mathematics (NCTM) has long supported teachers in implementing teaching practices that promote positive mindset and beliefs about mathematics (NCTM, 1989, 1991, 2000, 2014). The research-informed teaching principles recommended by NCTM for K-12 teachers can also be useful in teaching undergraduate mathematics content courses for preservice elementary teachers. For instance, NCTM (2014) recommends instructors engage their students in meaningful learning through student-centered individual and collaborative activities in order to promote mathematical sense-making through reasoning, justification, and problem-solving. These suggestions are informed by decades of research-driven investigations into reform-based teaching in the classroom. By engaging in such activities, PSTs may come to believe that mathematics is a problem-solving activity and is about communication and making connections (Boaler, 2016**). Instructors must engage PSTs by implementing**

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tasks that promote reasoning and problem solving, facilitating meaningful mathematical discourse, posing purposeful questions, and supporting productive struggle while eliciting student thinking (NCTM, 2014). Using these methods, instructors can model effective teaching strategies that future teachers can emulate in their own classrooms. Implementing student-centered instruction may seem overwhelming to a new instructor of a mathematics content course. Resources such as NCTM's (2014) Principles to Actions or Jo Boaler's (2016) Mathematical Mindsets are good starting points for learning more about student centered learning. We now go into detail regarding the value of one important student-centered activity: valuing mistakes in the classroom.

Valuing Mistakes in the Classroom. Neuroscience researchers have found that the brain is like any other muscle in the body, the more it is used the more it grows (Boaler, 2016). Boaler discussed how recent research related to neuroplasticity suggests that our brains are most active when we make mistakes, and that valuing mistakes in the mathematics classroom can promote a growth mindset and enhance mathematics learning (Lischka, Gerstenschlager, Stephens, Barlow, & Strayer, 2018). Rather than focus solely on correct answers, an instructor of a mathematics content course can draw attention to interesting mistakes. During class discussions, an instructor may ask "Who had an interesting mistake and how did you learn from it?" This allow students to understand that mistakes are part of the process of doing mathematics. At the beginning of the semester, an instructor can tell PSTs how important inspecting mistakes are to one's learning of mathematics. We believe that such a discussion early in the semester can also be used to promote the notion of a growth mindset and encourage PSTs to believe in their own potential to develop their mathematical understandings.

In student-centered classrooms, student work is often on display, and mistakes are often out in the open for inspection (Lischka et al., 2018). Preservice teachers are often uncomfortable sharing their work for fear of making a mistake. Thanheiser and Jansen (2016) found that allowing PSTs to label their work on a spectrum of being an in progress rough draft to a complete solution can allow PSTs to feel more comfortable expressing their thinking and having their mistakes identified by their peers. Such a learning environment will make students feel more comfortable and may gradually lead to a reduction in mathematics anxiety for affected students.

Process Praise

PSTs develop ideas about their own potential from the subtle and not so subtle messages they receive from instructors. These messages include the expectations the teacher sets for students, how they value learning from mistakes, and the words they use to provide feedback. These may all influence students' mindsets and success (Mueller & Dweck, 1998). Boaler (2016) and Dweck (2006a) suggest that process praise promotes more lasting confidence and motivation than intelligence praise or outcome praise. That is, instead of praising PSTs' intelligence or talent, instructors should praise PSTs for "what they accomplished through practice, study, persistence, and good strategies" (Dweck, 2006a, p. 177). Praise should not only be for obtaining correct answers, but also for students' efforts while in the process of doing mathematics in the classroom (Kamins & Dweck, 1999). For example, an instructor may praise students for their persistence in solving a problem, or their creative approaches to mathematical problem-solving. Therefore, Instructors should provide students with challenging tasks that allow them to engage in the problem-solving process. Without tasks that are more than mere exercises in manipulation of symbols (i.e. solve $4x + 4 = y$) students will not have the opportunity to engage in authentic mathematics. There will be no processes to praise, since there are only limited paths to finding a solution. Instead, we can introduce students to questions that have multiple solution paths such as the border problem (see figure 1). Borrowed from Boaler (2016), an instructor can ask students to briefly look at the number of tiles around the border of a square and work out how many squares are in the border without counting them.

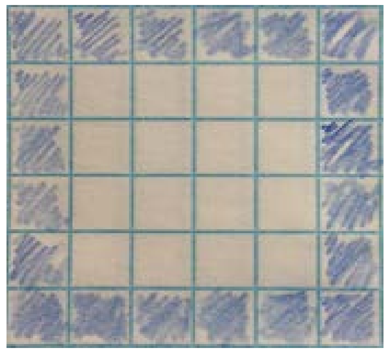

Figure 1: Border Problem

Boaler (2016) found that the students' different ways of seeing were a resource for engaging discussions and allowed teachers to praise students' process of thinking about real mathematics in unique ways. Additionally, the development of different algebraic generalizations, allowed students to then recognize that these algebraic expressions were equivalent. When students see patterns growing in different ways they become engaged in the mathematics (Boaler, 2016). See Figure 2 for some possible ways that students might see the number of squares in the border. Student observations can be used to generate equivalent formulas for the general square with n sides: $(n + n) + [(n - 2) + (n - 2)] = 4(n - 2) + 4$.

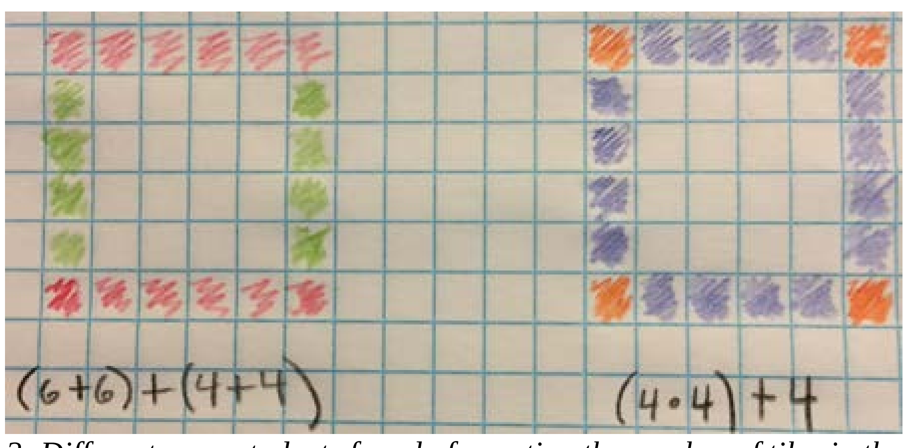

Figure 2: Different ways students found of counting the number of tiles in the border

Self-Directed Learning

Students' levels of perceived control over their ability to achieve academically is negatively correlated with levels of boredom and anxiety, better self-monitoring and better grades (Haynes, Perry, Stupnisky, Lia & Lia, 2009). Self-directed learning encourages students to attribute both their successes and their failures to factors they can control (e.g. degree of effort or quality of study strategies) rather than uncontrollable factors (e.g. bad luck, poor teaching) (Perry, Stupnisky, Hall, Chipperfield and Weiner, 2010). An instructor could provide students with a list of habits of self-management of learning (such as, "I know when and what kind of help I need" or "I accept mistakes and setbacks as part of the learning process") and have them write about which of those characteristics they are good at, which they struggle with, and how they might improve on these habits during the semester. Another way to encourage self-directed learning is to give students weekly quizzes, which are not collected or graded by the professor. According to research in cognitive science frequent quizzes allow students to recall concepts from their memories (Brown, Roediger & McDaniel, 2014). The solutions to the quiz are posted online for students to access after which they write a reflection on what concepts they understand and what concepts they are struggling to learn. Students need to write about how they will become proficient in these concepts before the exam (Costa & Kalick, 2008). It is this self-reflection that supports students' self-management of learning and helps students realize that their degree of effort and study habits are what ultimately leads to their success in learning the mathematics content.

Reflective Activities

PSTs with unproductive beliefs about mathematics need several opportunities for reflection on the mathematics throughout a teacher education program if they are to alter their beliefs (Ambrose et al., 2004; Cooney, Shealy, & Arvold, 1998). There are several activities an instructor of a content course can implement parallel to mathematics instruction that can provide opportunities for reflection. Stuart and Thurlow (2000) found having preservice teachers write a mathematical autobiography and then reflecting on their learning through mathematical journaling could cause a belief change for preservice teachers. Another activity that has been shown to be effective in challenging preservice teachers' beliefs are task-based student interviews. Thanheiser, Philipp, Fasteen, Strand, and Mills (2013) found that having a 15-minute interview in which PSTs are asked to solve 3-digit subtraction and addition problems and explain the process had the effect of causing PSTs to reflect that they have more to learn from their mathematics content courses.

In her study with PSTs, Ambrose (2004) found that belief change was possible if the teacher education candidates had intense experiences teaching mathematics to children. PSTs in Ambrose's (2004) study each individually taught a child the concept of fractions. Through the experience, these PSTs came to understand that teaching mathematics is more difficult than they previously imagined. They also appreciated multiple solution strategies in mathematics to a greater extent than they did previously, and recognized the importance of making connections among mathematical representations.

Conclusion

Preservice teachers are adults that come to the university classrooms with prior assumptions and knowledge about mathematical concepts that need to be challenged in order to transform their thinking (Cranton, 2006, Mezirow, 1991). A shift in mindset, beliefs, and anxiety is not a quick nor single event. On the contrary, future teachers need ongoing support to develop a growth mindset, revise their beliefs as needed, and reduce any anxiety. Beliefs are relatively stable and take significant time to be influenced (Cooney et al., 1998; Swars et al., 2007). We believe content courses can provide the initial disequilibrium needed to begin change that will continue throughout their teacher education program. Instructors can enhance the learning of future teachers by implementing strategies that allow mindset, beliefs, and anxiety to be frequently addressed.

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