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PRE-SERVICE ELEMENTARY SCHOOL TEACHERS' PERCEPTION OF THEMSELVES AS LEARNERS OF MATHEMATICS AND SCIENCE

Diana L. Moss, Ph.D.; Rachel Wilson, Ph.D.; and Danielle Divis

Abstract

This study investigated how prospective elementary teachers view themselves as learners of mathematics and science during their last year in a teacher preparation program at an American university. Using drawing and reflections as the method for collecting data, prospective teachers were prompted to draw themselves and reflect on learning mathematics and draw themselves and reflect on learning science prior to and after their mathematics and science methods courses. Drawings ($n = 147$) were coded according to the presence or absence of several themes including physical objects, teachers, students, and environment. The drawings and reflections indicated that the experience of participating in mathematics and science methods courses taught from a social constructivist perspective positively impacted prospective teachers' conceptions of themselves as learners and in ways consistent with current research-based pedagogies. The research study described here proposes that prospective teachers' learning experiences in mathematics and science methods classes might impact how they will teach mathematics and science in their future elementary classrooms.

Keywords: prospective elementary teachers, mathematics education, science education, pre-service teacher identity

Pre-service elementary teachers (PSETs) enter their methods courses with beliefs about learning mathematics and science based on prior education and life experiences (Hsu, Reis, & Monarrez, 2017). These beliefs can affect how pre-service teachers view themselves as learners as well as how they navigate the process of becoming a teacher (Lortie, 1975). The *becoming a teacher* process is influenced by the “experience of schools and teaching that [PSETs] bring with them to teacher preparation courses” (Beltman et al., 2015). Teacher educators are challenged to navigate PSETs' beliefs and prior experiences to prepare them to become effective classroom teachers.

Using drawings and written descriptions, this study investigated how PSETs view themselves as learners of mathematics and science during their last year in a teacher preparation program. Specifically, how do PSETs' perspectives on learning change after taking methods courses in mathematics and science?

Literature Review

Social Constructivism Learning and Environment

The constructivist learning theory supports teaching mathematics and science through inquiry where learning is student-centered, rather than lecture-based (Fosnot, 1996). A shared intention in mathematics and science teacher educa-

tion is to prepare PSETs to teach from a social constructivist (Vygotsky, 1978) perspective (National Research Council [NRC], 2007). In the theory of social constructivism, the central tenet is that learners construct their own understanding by participating in meaningful shared discourse. Although Vygotsky (1978) used speech as the primary mediation tool upon which to focus his studies, he noted other mediation tools such as symbols, algebraic systems, art, drawing, writing, and diagrams (Brooks, 2009). Brooks (2009) theorizes that “drawing might contribute to the formulation of thinking and meaning” (p. 2).

Further, learners are limited in what they can learn independently, and more can be learned with assistance from teachers and collaboration with others (Carlile & Jordan, 2005). In an environment conducive to learning mathematics and science, the teacher plays a vital role. The teacher not only needs to use interesting and engaging problems, but also encourage discussion and provide representations of multiple methods, support conceptual understanding, and encourage critical thinking (Davis et al., 2006; Picone-Zocchia & Martin-Kniep, 2008). Social constructivism accounts for the interactive communications that occur between teaching and learning, where teachers and students are “active meaning makers who continually give contextually based meanings to each other’s words and actions as they interact” (Cobb, 1988, p. 88). Moreover, the NRC (2001) contended that students must develop a “productive disposition” toward mathematics and believe that they are capable of learning and using mathematics (p. 131). Teachers that have a productive disposition are confident doers of mathematics and science who? encourage and support their students. Students who are learning in a positive environment should feel comfortable expressing their learning approaches and engaging in problem solving. Moreover, the teaching of mathematics and science should not focus entirely on the content but should consider the interactions that occur between teachers, students, and content as well (Cohen & Ball, 1999; Davis et al., 2006; Windschitl, 1999). These valuable interactions set the stage for productive thinking and learning.

Teacher Professional Identity Construction

A common challenge in both mathematics and science education is developing new teachers’ professional identities in line with research regarding mathematics and science thinking, teaching, and learning. Lave and Wenger (1991) and Wenger (1999) approached identity research from a sociocultural perspective where they framed? identity as dynamic (being reformed over time based on experience and personal meaning-making) and formed in communities with social and historical influences. In this perspective, identity links? to learning because “learning is conceptualized as the *process of becoming* a certain kind of person in relation to mathematical activity” (Langer-Osuna & Esmonde, 2017, p. 637). Researchers have suggested that new teachers tend to teach mathematics and science the way that they have been taught (Avraamidou, 2014a; Clift & Brady, 2005; Eick & Reed, 2002; NCTM, 2014; Zeichner & Tabachnick, 1981). Moreover, Avraamidou (2014b) and Luehmann (2007) have argued that by examining the identity work of teachers, we, teacher educators, can examine teacher learning and the factors that affect the development of teacher identity related to teaching science. By using an identity framework in research with pre-service and beginning teachers, researchers recognize that content-specific learning experiences within teacher education programs and in their previous schooling impact teacher beliefs about and emotions related to teaching that content (Wilson & Kittleson, 2012; Carrier et al., 2017; Timoštšuk & Ugaste, 2010).

PSETs’ Epistemological Beliefs

PSETs’ professional identity embodies and is embodied by their epistemological beliefs. Although content impacts learning in mathematics and science, the experiences that occur in the classroom also shape and influence the learning that takes place (NCTM, 2014; NRC, 2012). These experiences that occur in teacher education courses play an essential role

in integrating beliefs and theory (Huang et al., 2021). For instance, negative experiences in mathematics classrooms influence PSETs' perceptions of the subject, and sometimes cause negative feelings or anxiety toward learning and teaching mathematics. Mathematics anxiety is persistent among pre-service teachers (Bekdemir, 2010; Gresham, 2007; Hembree, 1990). Bekdemir's (2010) study found that PSETs' negative experiences in learning mathematics not only cause anxiety towards mathematics, but the anxiety towards mathematics increases as the grade levels progress. Studies have also found that anxiety towards mathematics is caused by teachers' behaviors and approaches to teaching mathematics (Andrew, 2004; Bekdemir, 2010; Frank, 1990; Hadfield & McNeil, 1994; Harper & Daane, 1998; Hembree, 1990; Jackson & Leffingwell, 1999; Perry, 2004). These prior mathematics experiences influence PSETs' beliefs about learning in their methods courses. Thus, a cycle of mathematics anxiety is present where the educators' anxiety impacts the students' anxiety (Vinson, 2001). This occurs because anxiety can impact teachers' abilities to teach mathematics with confidence (Akersson, 2017). Further, teachers cannot be expected to generate enthusiasm and excitement for a subject for which they have fear and anxiety. If the cycle of math phobia is to be broken, it must be broken in the teacher education institution (Mihalko, 1978, p. 36).

Studies have found that PSETs' prior learning experiences in science influence their beliefs toward the subject content, their ability to learn the subject, and their views about how to teach it to students (Carrier et al, 2017; Cavallo et al., 2002; Hsu et al., 2017; Kazempour, 2008, 2013). When PSETs describe their beliefs towards science learning as negative or neutral, these beliefs are associated with experiences of learning science through passive means, including lectures, worksheets, textbooks, and/or lack of collaborative learning (Hsu et al, 2017; Kazempour, 2008; Mensah, 2011). These negative beliefs, as a result of their own learning experiences, have been linked by researchers as influences on PSETs' beginning teaching identities (Carrier et al., 2017), their ideas about how to teach science (Hsu et al., 2017), and how often they are willing to teach science (Cavallo et al., 2002). When methods courses include an element of reflection for PSETs about their prior learning experiences in science, along with models of inquiry-based teaching and collaborative learning, PSETs with previously negative learning experiences were able to make significant improvements in their beliefs toward the subject (Kazempour, 2008) and include research-based practices as a part of their beginning teaching identity (Mensah, 2011).

Therefore, our study seeks to determine how PSETs' learning experiences in their mathematics and science methods courses impact their perceptions of learning mathematics and science, and in turn, how this might influence how they teach mathematics and science to their future students.

Theoretical Framework

Narrative Identity

Narrative identities are stories from students and teachers that help them make sense of their learning experiences. Sfard and Prusak (2005) argue that identities are a "collection of stories told about persons" and that these stories are influenced by participation in different contexts. However, narrative identity can focus on "stories told about the self" (Langer-Osuna, 2017) and complements positioning theories where participation in social practices is linked to individual formation of identities (Lave & Wenger, 1991). Sfard and Prusak's (2005) definition of narrative identities differs from Wenger's (1999) theory in that Wenger focused on experiences rather than stories. For example, research (Bartholomew et al., 2011; Rodd & Bartholomew, 2006; Solomon, 2007) indicated that "students' stories about mathematics tend to focus on how they develop a sense of belonging or exclusion" (Langer-Osuna, 2017). Teachers' narrative identities demonstrate how their own learning experiences relate to their approaches to teaching mathematics and science (Adams, 2013; Mensah, 2011; Rivera Maulucci, 2013; Williams, 2011). It is unclear from the research if and how teacher and stu-

dent identities relate to each other (Langer-Osuna, 2017). Narrative approaches to studying identity can provide a lens into how PSETs envision themselves as teachers of mathematics and science. We propose that drawing used in conjunction with written explanation can be a narrative approach that serves to analyze the stories of many individuals, “enabling analysis of patterns of experiences and stories” (Langer-Osuna & Esmonde, 2017, p. 641). PSETs’ drawings in mathematics and science methods courses can be used to study their identities and beliefs about learning mathematics and science.

Drawings are most often used in the elementary setting to observe children’s thoughts and emotions towards different content areas. Limited research exists on using drawings to explore the images and experiences that pre-service teachers associate with mathematics (Burton, 2012; Lee & Zeppelin, 2014; Rule & Harrell, 2006). Research has explored the drawings of PSETs and their perspectives on science teaching (Katz et al., 2010; Mensah, 2011; Mensah & Fleshman, 2017), but not necessarily as a way to document the science learning experiences of PSETs. Others (Akerson, 2017; Burton, 2012) have used drawings to investigate pre-service teachers’ internship experiences. Drawings have also been used as a form of narrative writing for second- and third-grade students (Caldwell & Moore, 1991) and can be particularly useful in regulating emotions (Drake & Winner, 2013). Rule and Harrell (2006) recommend that drawings be included in mathematics methods courses to connect pre-service teachers to their unconscious images of mathematics and to help shift their emotions towards mathematics to a more positive mindset.

A Framework for the Scholarship of Teaching and Learning

PSETs’ drawings completed before and after methods courses can be used as evidence of student learning to ensure that the learning goal of the methods courses are being met. In the scholarship of teaching and learning, student learning should be based on the teacher’s teaching philosophy (Stipek et al., 2001). The following figure offers a model that connects our (Teacher Educators’) teaching philosophy with the learning goal for PSETs, teaching activity for PSETs in methods courses, and evidence of PSETs’ learning.

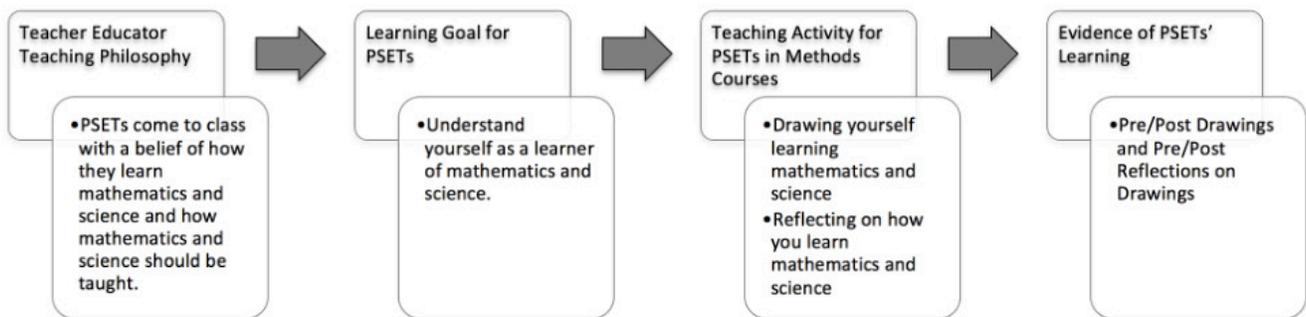


Figure 1. A model that connects our (Teacher Educators’) teaching philosophy, learning goal for PSETs, teaching activity for PSETs in method courses, and evidence of PSETs’ learning.

A major learning goal in our methods courses is for PSETs to understand themselves as learners of mathematics and science. This means that we want the PSETs to reflect on how they learned mathematics and science in their pasts and compare and contrast these teaching approaches to instructional practices that they hope to develop. We encourage them to revise and challenge their assumptions about learning and teaching mathematics and science. Based on this framework, this study aims to examine PSETs’ perceptions of themselves as learners of mathematics and science by analyzing PSETs’ stories through pre- and post-drawings as well as descriptions of their drawings.

Methods

Context

The context for the study was an undergraduate elementary education program at a regional comprehensive master's university in the southeastern United States. We, a mathematics teacher educator and a science teacher educator, each were teaching a methods course in the program: a) the first of two mathematics methods courses taken in the third year of the program, and b) the only science methods course taken in the fourth year of the program. The program, and the College, have social constructivism as a core philosophy. Therefore, classes are structured where teacher candidates participate as “students” in model activities, develop their pedagogical content knowledge, and analyze, deconstruct, and discuss activities in light of pedagogical strategies and content topics (Luehmann, 2007). This course structure is meant to address the possible scenario that PSETs might not have experienced such social constructivist learning environments and to encourage their confidence within this philosophy of teaching and learning. A course goal that is central to both the mathematics and the science methods courses is for PSETs to reflect on how they learned mathematics and science in their prior school experiences. We encourage them to compare and contrast the kinds of instructions that they experienced to the approaches to teaching in our methods courses. Thus, learning to pay attention to their own learning experiences will help PSETs articulate, challenge, and revise their assumptions about teaching and learning mathematics and science.

We exposed PSETs to discipline-specific practices (e.g., science: scientific and engineering practices and science process skills; math: e.g., the standards for mathematical practices (CCSSM, 2010). Additionally, in facilitating model activities for PSETs to highlight research-based pedagogical strategies, we use general and discipline-specific materials while students work in cooperative-learning groups. In both courses, students complete a field experience internship in a local public school. In the mathematics methods course, PSETs complete the internship at the end of the course and are responsible for conducting a diagnostic interview with three students. The purpose of the diagnostic interview is to assess what the students know and can do rather than report what they cannot do. In the science course, PSETs are responsible for creating and implementing a 3-day 5E unit in their internship classroom. In this internship experience, PSETs have a chance to teach using strategies they experienced as students in the science methods course and to see how elementary students respond to such teaching practices.

Participants

Participants in the study are all elementary education majors, therefore, they are all pre-service elementary teachers (PSETs). At the time of data collection, PSETs enrolled in each of the teacher educators' courses were asked by an outside visitor if their drawings and written descriptions from two class activities during the semester could be collected for research. The outside instructor kept the signed consent forms in their office until the end of the semester. In this way, the instructors did not know who had agreed to participate until after final grades were turned in. Seventy-two students from three sections of the mathematics methods course consented to participate, while 75 students from four sections of the science methods course consented to participate.

Data Collection

On the first day of class, PSETs were given the first prompt: “Draw yourself learning math” or “Draw yourself learning

science” and asked to “Explain your drawing below” in written text. This style of prompt is similar to that used in other studies investigating PSETs identities related to science teaching (Katz et al., 2010). On the last day of class, students were asked to repeat the prompt. They did not have their initial response available to them when they completed their final prompt.

Data Analysis

Drawings and written descriptions were collected from all PSETs enrolled in the mathematics and science methods courses. At the end of the semester, only those PSETs that provided consent for their classwork to be used for research were used in the data analysis. First, the student work was de-identified and labeled with numbers to keep track of matching initial and final course drawings and written descriptions and to keep PSETs’ participation confidential. All names used in the findings section (below) are pseudonyms. We chose a subset of science ($n = 16$) and mathematics ($n = 16$) drawings and written descriptions to develop emergent codes and categories (Charmaz, 2008). Though we allowed the codes and categories to emerge from the data, as teacher educators, we focused on labeling ideas within the drawings with words or phrases that are pertinent to evidence-based teaching strategies. For example, when students included pencils and paper in their drawings, instead of labeling them individually, we coded them as generic classroom materials, whereas when students included math manipulatives or hand lenses, we coded these as materials for hands-on learning. Emergent codes and categories for each set of drawings were compared across content courses and a shared coding scheme for drawings and written descriptions was developed. All initial science and mathematics drawings and written descriptions were then coded with the shared coding scheme. Elements in drawing and writing were coded as present (1) or absent (0). Results for each PSETs’ initial and final work were recorded in a spreadsheet, which was then exported to SPSS for analysis to compare the results of the presence/absence of elements in the initial vs. final drawings and written descriptions. Once in SPSS, we performed a McNemar test (Siegal & Castellan, 1988), assuming course activities are a “treatment,” to determine if there were significant changes across PSETs’ work between their initial and final drawings and written descriptions. All codes for the drawings are included in Appendix A and all codes for the written descriptions are included in Appendix B. The codes that showed significance, $p < .05$, for both mathematics and science drawings and written descriptions are reported and discussed in the following section.

Findings

Drawing Results

Analysis of the pre/post mathematics and science drawings data resulted in a significant difference, $p < .05$, in the proportion of eight categories in pre- and post- methods courses. Table 1 indicates the categories, descriptions, and significant quantitative results for the categories found in the drawings. The presence of these categories in the pre/post drawings will be described with illustrative examples.

Table 1. Drawing coding categories, descriptions, and significant results.

Drawing Category Name	Drawing Category Description	Pre/Post Significant Results for Mathematics ($n = 72$) and Science Drawings ($n = 75$)
Increase in Teaching Students as a Component of Learning	Drawing clearly includes a teacher with student(s)	Math: $p = .039$ Science: $p = .004$
Decrease in Board/Lecture	Drawing includes a board or teacher at the board	Math: $p = .026$ Science: $p = .009$
Increase in Materials for Hands-on Teaching	Drawing contains mathematics manipulative or science materials	Math: $p < .001$ Science: $p = .018$
Increase in Students Working Together	Drawing depicts two or more students working together	Math: $p = .039$ Science: $p < .001$
Decrease in Uncertainty of Student(s)	Drawing contains question marks, straight face, sad face, text that indicates uncertainty	Math: $p < .001$ Science: $p = .019$
Increase in Positive Expression	Drawing contains student(s) with happy face	Math: $p = .005$ Science: $p = .026$
Decrease Negative Expression	Drawing contains student(s) with unahppy face	Math: $p < .001$ Science: $p = .008$
Increase in Inclusion of Recent Content	Drawing depicts content recently learned in college methods course	Math: $p < .001$ Science: $p = .001$

Written Descriptions

The pre/post writing data resulted in three significant categories. Analysis of the pre/post mathematics and science written descriptions data resulted in a significant difference, $p < .05$, in the proportion of three categories pre- and post- methods courses. Table 2 indicates the categories, descriptions, and significant quantitative results for the categories found in the writing. Examples of the writing that show these themes will be provided.

Table 2. Writing coding categories, descriptions, and results.

Written Description Themes	Theme Description	Pre/Post Results for Mathematics ($n = 72$) and Science Written Descriptions ($n = 75$)
Increase in Collaboration	Writing contains examples of working together with other students, discussions, inclusion of hands-on materials, etc.	Mathematics: $p = .031$ Science: $p = .004$
Decrease in Negative Emotions	Writing describes negative feelings about learning mathematics or science (e.g., giving up, frustration, irritation, sadness, boredom).	Math: $p < .001$ Science: $p < .001$
Increase in Subject-Specific Practices	Writing includes specific pedagogies or practices learned in math/science methods courses (Math: Problem Solving/ Science: 5E)	Math: $p = .003$ Science: $p < .001$

Increase in Teaching Students as a Component of Learning

PSETs' drawings of learning mathematics and science showed a significant increase in the presence of a teacher. For example, a pre-drawing could contain a student at a desk with no teacher present and a post-drawing could contain a teacher helping a student at a desk. In math, eight PSETs did not include a teacher before the methods class but included a teacher after the methods class. Figure 2 is an example of a pre-post mathematics drawing. This PSET depicted a student sitting at a desk alone before completing the math methods course and depicted a student at a desk with a teacher after completing the mathematics methods course.

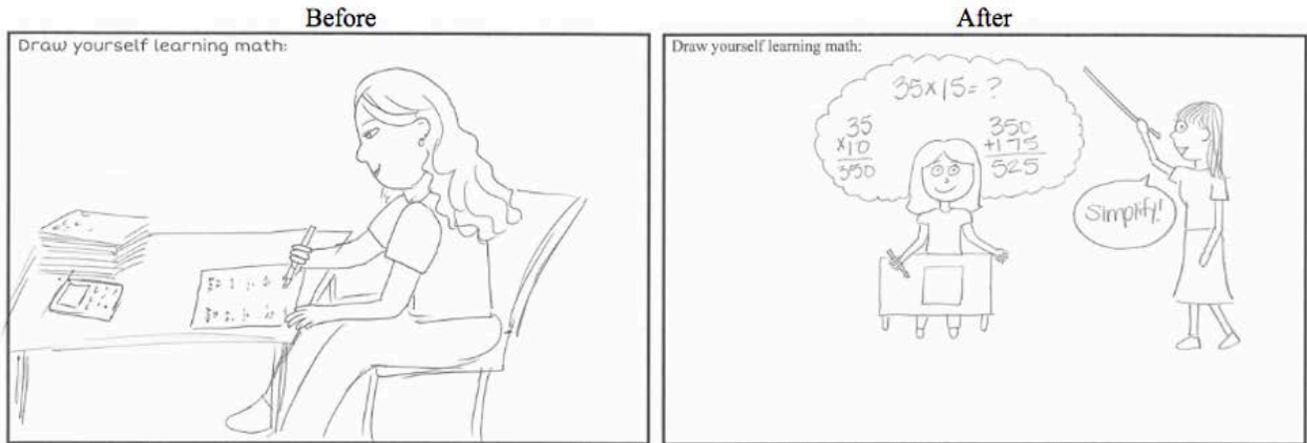


Figure 2. An example of an Increase of Teaching Students as a Component of Learning in Math.

In science, nine drawings that did not contain a teacher in the pre-drawing included a teacher in the post-drawing. Figure 3 is an example of a pre-post science drawing. The PSET included a student alone in the pre-drawing and a group of students with a teacher in the post-drawing.

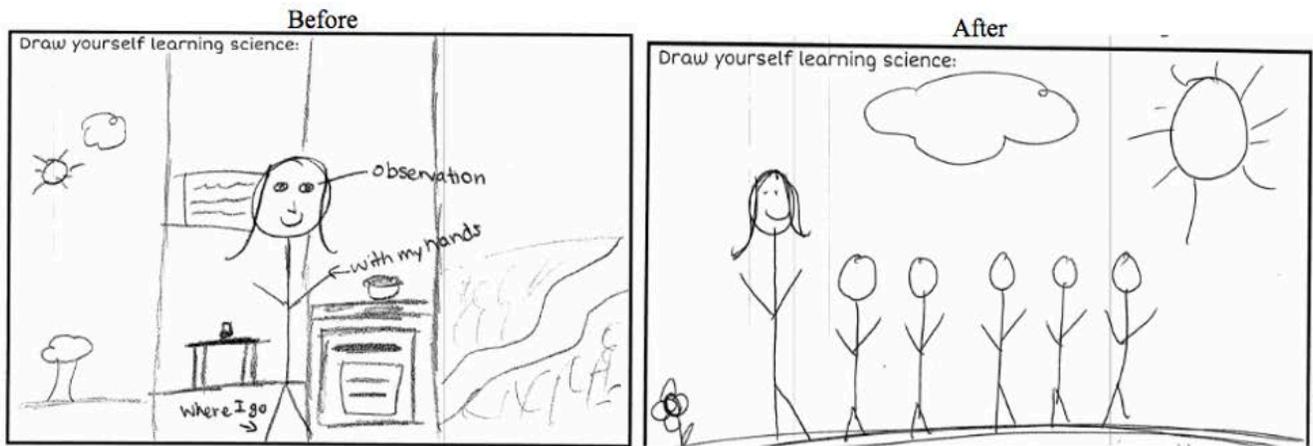


Figure 3. An example of an Increase of Teaching Students as a Component of Learning in Science.

Decrease in Board/Lecture and Increase in Materials for Hands-on Teaching

The PSETs' drawings indicated a decrease in lecture-based teaching and an increase in materials for hands-on teaching. In mathematics and science, many PSETs included a board or a teacher at the board in the pre-drawing and, in the post-drawings, included mathematics manipulatives or science materials without a board. In math, 21 PSETs did not include a board after taking the mathematics methods course, and, in science, 22 PSETs did not include a board after taking the science methods course. Figure 4 shows a pre mathematics drawing where the teacher is at the board and students are sitting in rows at desks that are facing the board, a lecture-based teaching setting. Although three PSETs included manipulatives in both their pre and post-drawings, 18 PSETs that did not have manipulatives in their pre-drawing added manipulatives to their post-drawings. The post-drawing shows hands using mathematics manipulatives that include base-ten blocks, counters, fraction circles, and connecting cubes, a reform-based teaching setting.

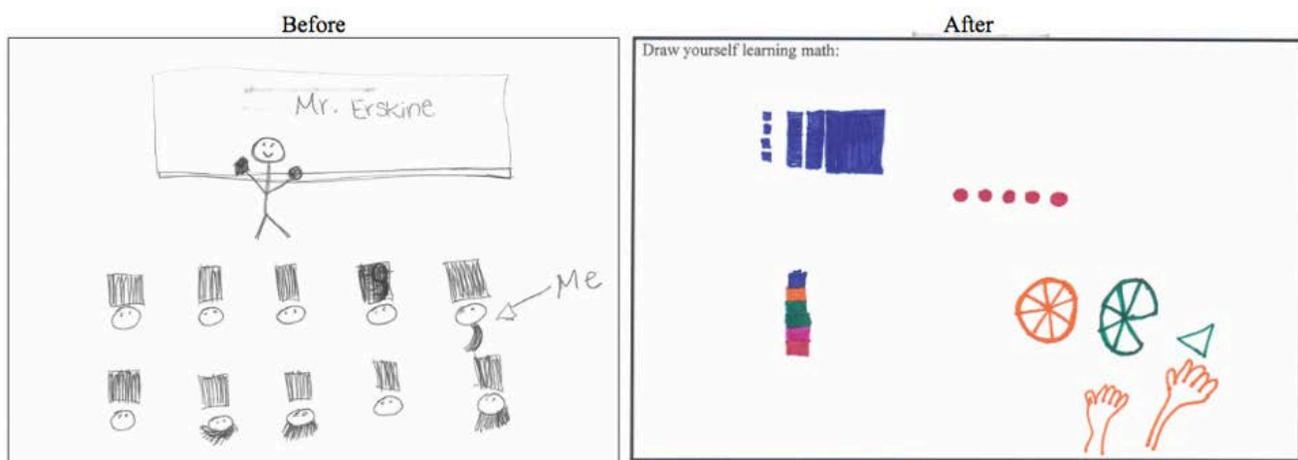


Figure 4. An example of a Decrease in Board/Lecture and an Increase in Materials for Hands-on Teaching in Math.

The PSETs' science drawings also showed a decrease in lecture and an increase in science materials, similar to the mathematics drawings. Eighteen PSETs included science materials in their pre and post-drawings, but 28 students that did not have science materials in their pre-drawings, added science materials to their post-drawings. Figure 5 shows a PSETs' pre and post science drawing.

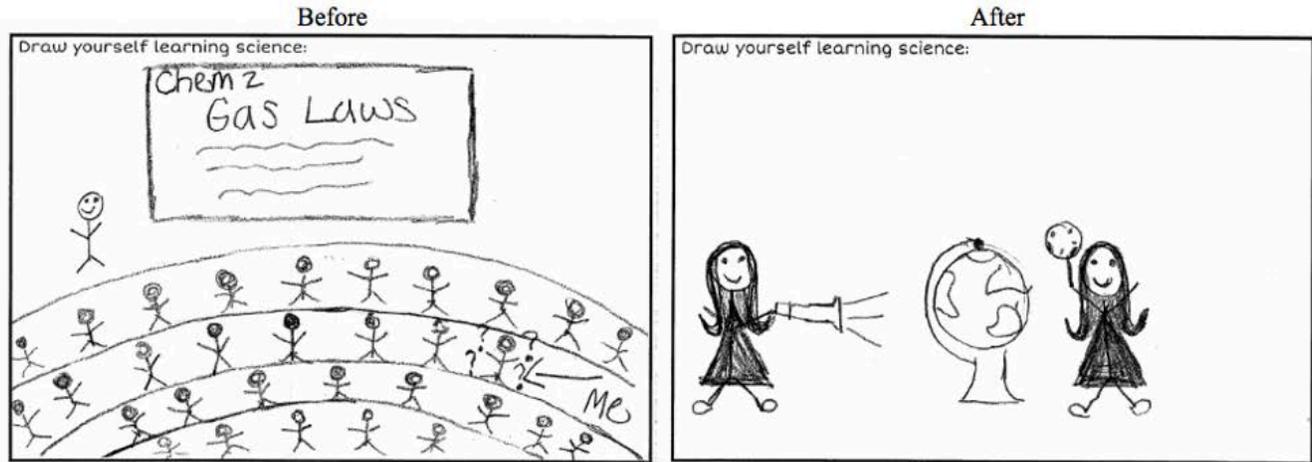
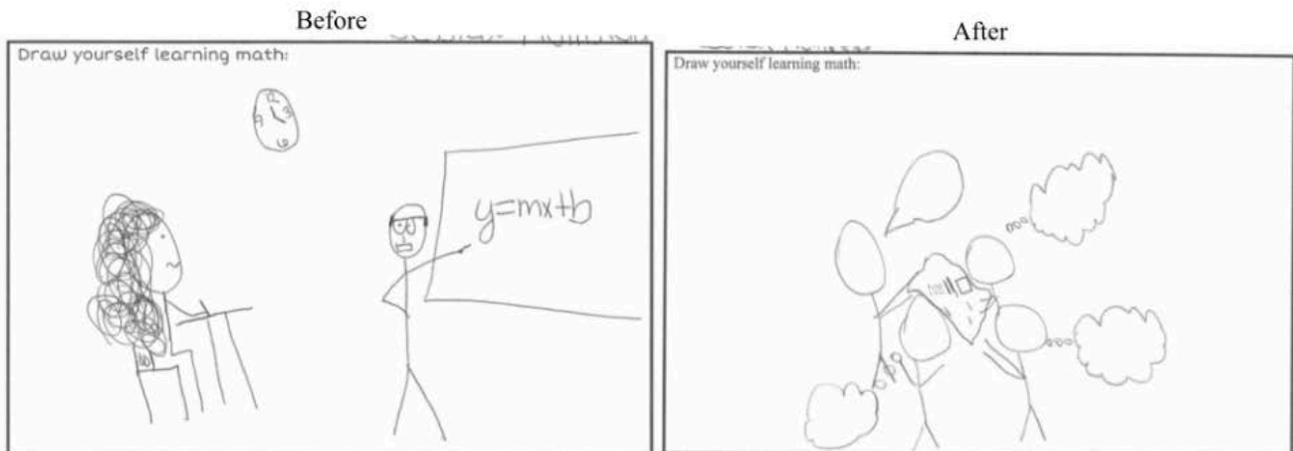


Figure 5. An example of pre/post science drawing that show a decrease in board/lecture and an increase in materials for hands-on teaching.

Increase in Students Working Together

We found that the PSETs' pre-drawings contained individuals, whereas the post-drawings contained groups of people working together. The groups of students collaborating were often depicted as having discussions, indicated with speaking bubbles. In the mathematics drawings, 10 PSETs that did not include students working together in their pre-drawing showed students working together in their post-drawing. Twenty-two PSETs that did not depict students working together in the science pre-drawing drew students working together in the science post-drawing. Figure 6 shows an example of Julia's pre mathematics and Astrid's pre science drawing with an individual and Julia's post mathematics and Astrid's post science drawing with a group of students.



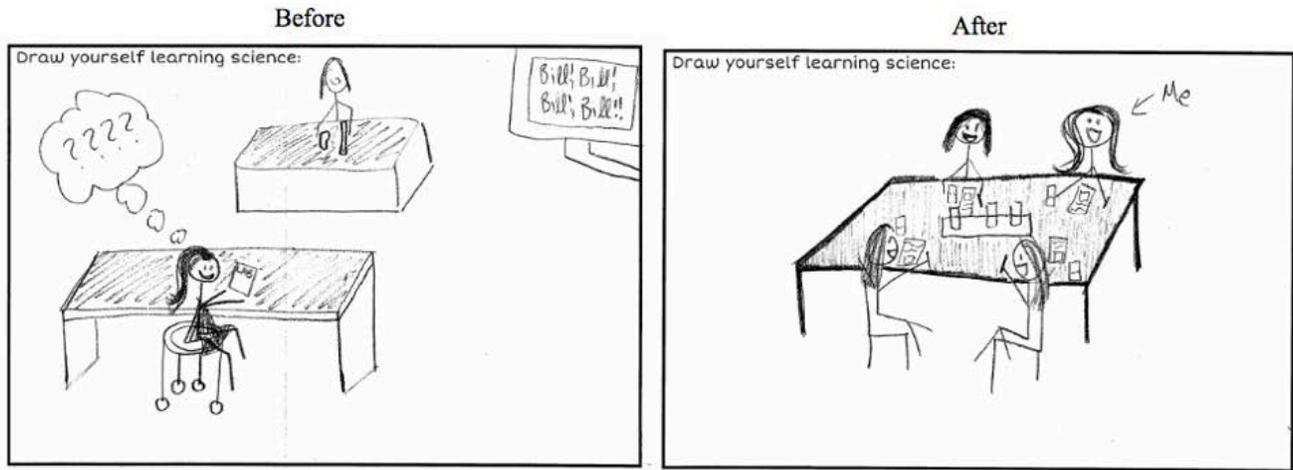


Figure 6. An example of pre/post drawings that show an increase of both students working together in mathematics (top) and science (bottom).

We also found that PSETs' description of their drawings included an increase in collaboration. For example, one PSET, Julia, described her pre-drawing as, "I am sitting in a desk taking notes as the teacher writes important information on the board." She writes about her post-drawing by saying, "In groups, my classmates and I discuss how we think about mathematics and we use manipulatives to help us figure it out." Astrid writes, "I picture sitting at a black lab table watching my teacher demonstrate something. In this picture I have to write a lab report and I have no idea what I'm doing" as she describes her pre-drawing. For her post-drawing, she says, "I am working in a group with a lot of hands-on materials. We are writing down our observations about what we notice."

Decrease in Uncertainty of Students

The mathematics and science pre-drawings depicted students as unsure, and the post-drawings indicated confidence. Uncertainty was shown using a straight or sad face, question marks, or text indicating uncertainty. Confidence was shown with a happy face, exclamation points, or text indicating confidence. This category was seen across the mathematics and science drawings. Although 43 PSETs did not show uncertainty in the pre or post mathematics drawings, 23 PSETs showed uncertainty in their pre-drawings but did not show uncertainty in their post-drawings. In science, 56 PSETs did not depict uncertainty in their pre- or post-drawings, but 15 PSETs showed uncertainty in their pre-drawings, but not in their post-drawings. Figure 7 shows examples from mathematics and science.

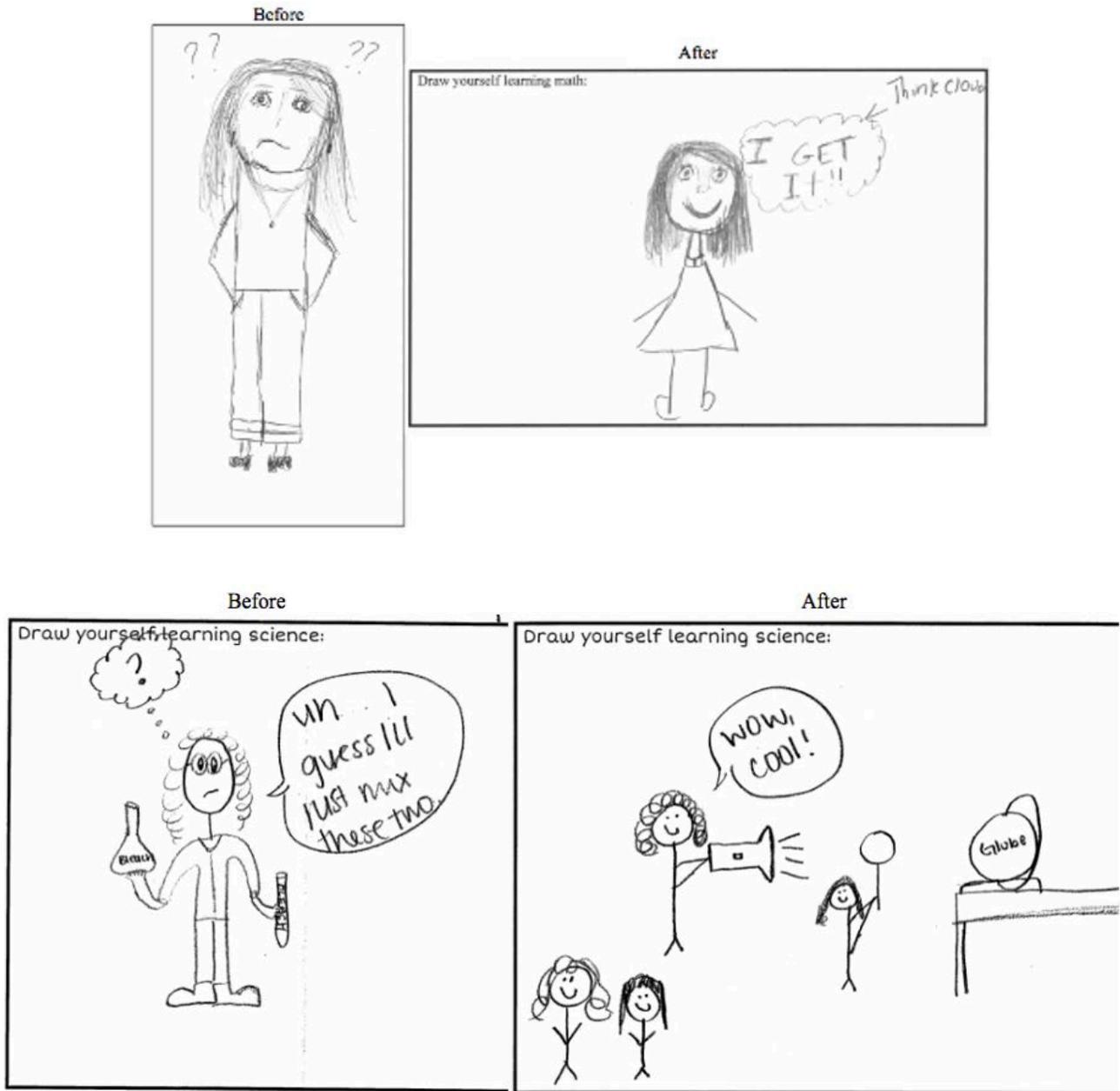


Figure 7. An example of pre/post drawings that show a decrease in uncertainty and an increase in confidence in mathematics (top) and science (bottom).

Increase in Positive Expression/Decrease in Negative Expression

The drawings showed that there was an increase in positive expressions and a decrease in negative expressions from before the mathematics and science methods classes and after the mathematics and science methods classes. A positive expression is indicated with the presence of a happy face and a negative expression is indicated with the presence of a frown. In both mathematics and science, the number of drawings with a positive expression increased from pre to post and the number of drawings with a negative expression decreased from pre to post. Sixteen PSETs depicted positive expressions in their pre- and post-drawings. However, 27 PSETs that did not show positive expressions in their pre-drawing drew

positive expressions in their post-drawing. The science drawings were similar with 34 PSETs showing positive expressions in their pre- and post-drawings, but 21 PSETs that did not have a positive expression in their pre-drawing added a positive expression to their post-drawing. In addition, 70 PSETs' pre- and post-drawings did not contain a negative expression, but two PSETs that had a negative expression before the mathematics course did not draw a negative expression after the mathematics course. Similarly, in science, 67 PSETs did not have a negative expression in their pre- or post-drawing, but 8 PSETs that had a negative expression before the science course, dropped the negative expression after the science course. Figure 8 shows an increase in a positive expression and a drop in a negative expression in math. The science drawings were very similar.

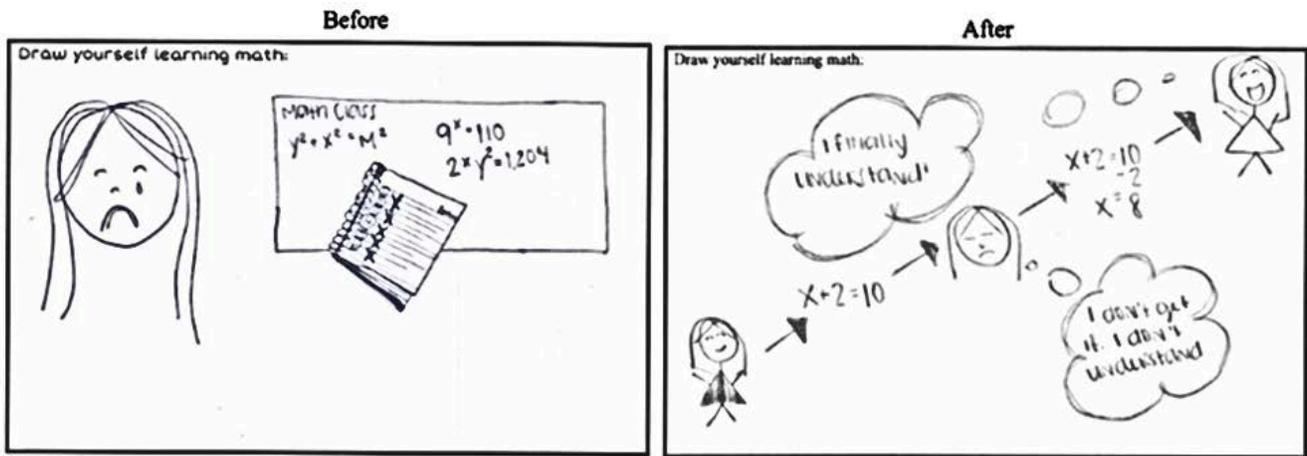


Figure 8. An example of pre/post drawings that show an increase in a positive expression and a decrease in a negative expression.

We also found that PSETs' descriptions of their drawings included a decrease in negative emotions. In math, Kathy described her pre-drawing as, "My drawing is a picture of me, very sad because I made a bad grade on a test. There are also a few complicated problems written on the whiteboard. Let's say math isn't my best subject." However, her post-drawing showed, "As I am introduced to a problem I am frustrated I don't understand, but that is a part of my process. I finally understand the equation and I am content. The cloud bubbles also represent not just what is written, but my thinking processes to get the new answer" (see Figure 8). Similarly, Tamara, a PSET in science wrote, "I have a bad relationship with science...it was almost as if I didn't try at it for so long that I gave up." Her post-drawing shows a definite change in negative emotions, and she described it as, "I still need to work on total content understanding, but I have gotten SO MUCH better with science, both in understanding and my feelings towards it. I feel like I understand major concepts and don't cry every time I see or hear a science question."

Increase of Inclusion of Recent Content

The pre-drawings in mathematics most often depicted the content area of algebra because this was the most recent mathematics class that students had taken. Post mathematics drawings contained the content area of numbers and operations because that was the focus of the methods course in which the drawings were collected. Figure 9 shows a pre-drawing that contains algebra and a post-drawing that contains numbers and operations. Twenty-one PSETs in mathematics that showed algebra or calculus in their pre-drawings did not include algebra or calculus from their post-drawings but included the recent content of numbers and operations. Twenty-five PSETs in science that did not have recent content in their pre-drawing added recent course activities to their post-drawing. The pre-drawing in science shows many different

content areas including chemistry and biology. The post-drawing shows the most recent content from the methods class (e.g., a recent course activity) (see Figure 10).

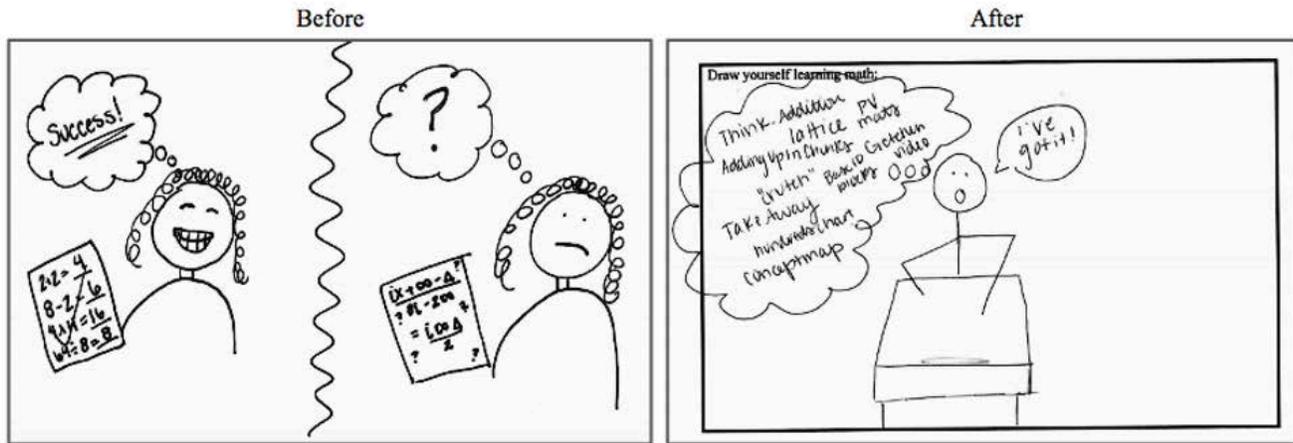


Figure 9. An example of pre/post mathematics drawings that show the most recent content.



Figure 10. An example of pre/post science drawings that show the most recent content.

Similar to the inclusion of most recent content in PSETs' drawings, PSETs' writing showed a significant increase in subject-specific practices. Jamie described her pre math drawing in Figure 9:

One of the many reasons I plan to become an elementary teacher is the lack of complex math classes required. My math background would consist of the typical honors high school courses with some AP calculus involved. If I were to define my feelings towards math, I would say that the effort is there, the lessons are usually retained with work and practice but the interest area is lacking beyond your basic, life-applicable math problem.

When writing about her post mathematics drawing, she remarked, "From this course, I have learned so many new ways to solve problems. Each way provides a different perspective and process to cater to what fits the student best."

A student in the science methods class, Hilary, commented on her pre-drawing (Figure 10), "I believe science should be hands-on and interactive. This is a picture of myself exploring the world around me." She remarked about her post

science drawing, and said, “This is a picture of me learning science through hands-on activities. The best way to learn science is to ask a question and explore activities to find evidence. Science is [a] way to help us understand the world around us.”

Discussion

Based on the results of this study, PSETs' experiences in constructivist content-focused methods courses with an internship component seemed to influence PSETs' perceptions of learning mathematics and science. In particular, PSETs significantly increased their positive emotions and/or decreased their negative emotions related to learning mathematics and science content in their drawings. There was also a decrease in PSETs' negative emotions in their written explanations. Katz et al. (2010) studied PSETs' drawings in science after a semester of after-school internship which used constructivist learning tenets in the design. They found an increase in the inclusion of positive expressions and/or a decrease in the inclusion of negative expressions in the PSETs' drawings (Katz et al., 2010). These findings also align with Akerson's (2016) results where PSETs' perceptions towards mathematics shifted from a negative toward a positive experience after completing a field experience where PSETs observed classroom settings where students were learning mathematics in a collaborative setting and engaged in discussion with each other. These findings have important implications for how enthusiastic PSETs feel about teaching these content areas, given that researchers have found links between PSETs' attitudes towards their content, their approaches to teaching the subject (Wilson & Kittleson, 2012; Hsu et al., 2017), and in the case of science, even how often they are willing to teach it (Cavallo et al., 2002).

Additionally, we saw significant increases about content-related understanding. Content understanding is an important component in the development of a constructivist teaching identity, as this strategy of attending to student ideas requires higher-level knowledge of the teacher (Windschitl, 1999). In PSETs' drawings, from pre- to post- they increased the inclusion of recent content from the model constructivist activities used in class as well as decreased the uncertainty expressed about their content understanding. In their written explanations, PSETs showed an increase in discussion of subject-specific practices.

We agree with Langer-Osuna & Esmonde (2017) that as PSETs reflected and made sense of their experiences of learning mathematics and science through drawing and written descriptions, they told stories about their mathematical and scientific selves. Similar to Battey and Franke's (2008) findings that shifts existed in teacher identities based on stories before and after participating in professional development, we found that PSETs showed evidence of shifting identities based on drawings completed before and after engaging in methods courses.

Implications for Teaching

The results of this study provide implications for mathematics and science teacher educators, especially those that teach methods courses to PSETs. Providing model experiences related to reform-based teaching is what pre-service teachers expect (Timošćuk & Ugaste, 2010) and may be an important element in shifting their emotional responses to content-area teaching. After experiencing model constructivist mathematics or science teaching, PSETs increased their inclusion of elements associated with constructivist learning environments (materials for hands-on teaching and students working together) and decreased their inclusion of passive elements of learning (board/lecture) in their drawings as well as included an increase in written expressions of collaboration with peers as a component of learning.

While we saw significant increases in PSETs' inclusion of aspects of reform-based teaching practices in their post-drawings and explanations, we are only cautiously optimistic that this will result in the consistent use of these practices in their

classroom teaching. Research has found that new science teachers will often espouse the use of reform-based practices in their classrooms, but not implement these (Davis et al., 2006). Despite being exposed to constructivist ideas in university classes, teachers tend to use strategies based on their personal learning histories (Eick & Reed, 2002). In addition, if PSETs have had negative emotions about their learning of the subject, they may choose to plan more passive learning for their students to prevent them from struggling (Wilson & Kittleson, 2012). Finally, even science teacher enthusiasts, who have expressed positive experiences about learning and teaching science, struggle to consistently teach science because of constraints related to time, resource availability, and testing for other subjects (Bradbury & Wilson, 2020). Therefore, even though we see potential in using both modeling of reform-based teaching strategies and reflection on their perspectives of content-area learning throughout the semester, their experiences in the methods courses are only one small set of their learning experiences.

Limitations and Suggestions for Future Research

This study gave us a glimpse into how PSETs' identities related to learning mathematics and science develop in a social context like a classroom. Limitations exist connected to PSETs' abilities and willingness to draw themselves. Thus, the method of using drawings as evidence of learning could be paired with using narrative identities where PSETs reflect and make sense of their experiences of learning mathematics and science through telling stories (Langer-Osuna & Esmonde, 2017; Battey & Franke, 2008). In future studies, it would be beneficial to explore how PSETs' identities develop in other instructional settings, such as field experiences and online, asynchronous, and blended mathematics methods courses. Research should also be done to examine drawings before and after methods courses, as well as after student teaching, to locate possible shifts in instructional practice and for teacher educators to improve their courses. In addition, future studies should also address how PSETs' perceptions of themselves as learners of mathematics and science impact how they design and teach lessons to students. In future research, mathematics and science teacher educators could use pre- and post-course drawings of students learning along with drawings of students teaching to try to analyze connections between PSETs' ideas about learning and teaching elementary mathematics and science.

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Appendix A

All Codes for Drawings and p -values

Drawing Category Name for Mathematics and Science	Pre/Post Results for Mathematics ($n = 72$) and Science Drawings ($n = 75$)	
	Mathematics $p =$	Science $p =$
Books/papers	.359	.441
Computer/internet	1.000	.289
Drawing on paper/board	.375	1.000
Writing on paper/board	.690	.332
Symbols on paper/board	.250	1.000
Teaching students	.039	.004
Desk/table	1.000	.164
Board	.026	.009
Windows	1.000	.219
Mathematics Manipulatives/Science Materials	<.001	.018
Pencil	.481	.754
Ruler	1.000	.625
Calculator	.031	1.000
No person	1.000	1.000
Student alone	.700	.429
Teacher alone	1.000	1.000
With other students working separately	.289	.180
With other students working together	.039	<.001
With a teacher (unknown gender)	1.000	.064
With a teacher (known male)	1.000	1.000
With a teacher (known female)	.388	1.000
Parent/expert	.500	1.000
Teacher in front of class	.383	.064
Teacher off to the side	1.000	1.000
Teacher with a student	1.000	1.000
Student at the board	.238	1.000
Student at desk/table	.845	.441
Centers	1.000	.250
Indoors	1.000	1.000

Student thinking cloud: connections to content	<.001	.289
Student thinking cloud: ? or uncertainty	<.001	.019
Student speaking bubble: ? or uncertainty	.375	.453
Student positive expression	.005	.026
Student negative expression	<.001	.008
Student neutral or no expression	1.000	.201
Teacher positive expression	.629	.454
Teacher negative expression	.500	1.000
Teacher neutral or no expression	1.000	.289

Pre/Post Results for Mathematics ($n = 72$)

Drawing Category Name for Math	$p =$
Basic operations present	1.000
Algebra present	<.001
Geometry present	.625
Contrast between arithmetic and “other” mathematics content	.063

Pre/Post Results for Science ($n = 75$)

Drawing Category Name for Science	$p =$
Earth science	.001
Biology	.009
Physical science	.405
5E	.063

Appendix B

All Codes for Written Descriptions and p -values

Drawing Category Name for Mathematics and Science	Pre/Post Results for Mathematics ($n = 72$) and Science Drawings ($n = 75$)	
	Mathematics $p =$	Science $p =$
Hands-on	.002	.188
Text	1.000	.049
Media	1.000	.021
Writing	.092	.092
Collaboration	.031	.004
Lecture	.008	.070
Activity from class	1.000	.832
Positive	.230	.596
Negative	< .001	< .001
World outside	1.000	

Pre/Post Results for Mathematics ($n = 72$)

Writing Category Name for Math	$p =$
Problem solving	.003
Reasoning and proof	.039
Communication	.500
Connections	.063
Representations	.688
Numbers and operations	.549
Geometry	.500
Fractions	.250

Pre/Post Results for Mathematics ($n = 72$)

Writing Category Name for Math	$p =$
Problem solving	.003
Reasoning and proof	.039
Communication	.500
Connections	.063
Representations	.688
Numbers and operations	.549
Geometry	.500
Fractions	.250

Pre/Post Results for Science ($n = 75$)

Writing Category Name for Science	$p =$
5E	< .001
Experimenting	.571
Recording	.219
Observing	.804
Data collection	.375
Engaging in argument from evidence	.500
Asking questions	.031
Mathematical thinking	1.000
Inferring	.500
Measuring	1.000
Modeling	.125
Earth science	1.000
Life science	<.001
Physical science	.041