Alabama Journal of Mathematics
37 (2013)

Developing Elementary Preservice Teachers' Initial Conceptions of Common Practices in Science and Mathematics Teaching

Kimberly Nunes-Bufford
West Forest Elementary School

Megan Burton
Auburn University

Charles Eick
Auburn University

This qualitative study investigated the developing conceptions of common teaching methods for mathematics and science among elementary preservice teachers when using the learning cycle as a framework for coursework. The use of tools for conceptual development, processes for meaningful learning, and common pedagogical approaches were explored using pre- and post-survey data and weekly blog entries. The study took place during a summer science and mathematics methods course sequence. Results indicated many of the participants initially thought science and mathematics should be approached in very different ways. Eventually, eighty-two percent of preservice teachers recognized commonalities in teaching approaches, including use of inquiry within a learning cycle framework.

STEM education focuses on students seeing connections between and applications for the fields of Science, Technology, Engineering, and Mathematics. This aligns with the science and mathematics standards documents, which include being able to ask, find, and determine answers based on evidence (Ball & Forzani, 2011; NGACBP, 2010; NRC, 2012). The Common Core State Standards for Mathematics require the implementation of the Mathematical Practices (NGACBP, 2010) which parallel the Scientific and Engineering Practices advocated in the new Science Frameworks (NRC, 2012) (See Table 1).

These similar practices in mathematics and science call for similar approaches in teaching both disciplines. These include: (1) use of tools for concept development that include devices for measuring, calculating, and analyzing numbers and manipulatives/materials for concept formation; (2) use of processes that include problem solving, investigation, reasoning and proof, communication, connections, and representations; and (3) inquiry-based pedagogical approaches that focus on learning by doing to seek answers and solutions to problems (Goodnough & Nolan, 2008; Justi & van Driel, 2005).

Efforts have been made in preservice teacher methods courses to prepare reform minded teachers of science and mathematics (McGinnis et al., 2002; Plonczak, 2010). Elementary teacher development programs have designed mathematics content classes that teach through reform methods that stress problem solving and reasoning (Cooney & Wiegel, 2003; Stuart & Thurlow, 2000; Thames, 2006) and created courses that fostered connections between science and mathematics content (McGinnis et al., 2002). Teacher educators also worked on the development of methods courses that integrated mathematics and science content and used common instructional strategies (Beeth & McNeal, 1999; Lonning & DeFranco, 1994; Stuessy, 1993). For example, Lonning and DeFranco (1994), attempted to develop an integrated science and mathematics content course, but found that inherently neither science nor mathematics disciplines were given full treatment. They determined that approaching science and mathematics with a common pedagogy of hands-on instruction, cooperative learning, and alternative assessments provided a better treatment and example of the disciplines to preservice teachers.

Despite reform efforts, U.S. elementary preservice teachers continue to emphasize repetition and memorization with little attention to understanding in mathematics (Hiebert et al., 2005). Many initially teach from a traditional approach because they perceive mathematics teaching as a focus on procedural knowledge (H. Hill & Ball, 2009; Ma, 2010), lacking a true model and understanding of the reform approach. Preservice elementary science teachers are more likely to adopt a reform approach, like in science, because of longstanding models that support conceptual development through a hands-on and process oriented approach to science education (Atkin & Karplus, 1962; NRC, 1996). Because a majority of elementary teachers in the United States will be teaching both mathematics and science, understanding standards-based reform teaching in both areas should be essential to elementary teacher preparation programs.

Approaching teacher development from a perspective of a common teaching model in mathematics and science teaching could help elementary preservice teachers begin to understand and envision teaching using standards based strategies in both areas. This study investigated the conceptions preservice elementary teachers held at the beginning and end of an experience that used a common teaching framework and embedded practices for science and mathematics methods courses. It explored how they relate, understand, and begin to use these common teaching practices (i.e., tools for conceptual development, processes for meaningful learning,

Table 1
Alignment of new mathematical practices with scientific and engineering practices

Standards for Mathematical Practice	**Scientific and Engineering Practices**
Make sense of problems and persevere in solving them.	Asking questions and defining problems.
Reason abstractly and quantitatively.	Analyzing and interpreting data.
Construct viable arguments and critique the reasoning of others.	Constructing explanations and designing solutions. Engaging in argument from evidence.
Model with mathematics	Developing and using models.
Use appropriate tools strategically.	Planning and carrying out investigations.
Attend to precision. Look for and make use of structure.	Using mathematics and computational thinking.
Look for and express regularity in repeated reasoning.	Obtaining, evaluating, and communicating information.

and inquiry-based approaches) in both courses. This differs from many previous studies that focused on teaching science and mathematics content using an integrated approach that modeled pedagogy, but did not provide a similar learning and teaching framework for the two subjects (Pang & Good, 2000).

The science and mathematics methods courses utilized a learning cycle framework for planning and teaching (Atkin & Karplus, 1962). In a learning cycle approach, new concepts are first explored through concrete experiences before abstract ideas are formulated and applied to new situations. For this study the learning cycle offered a way to create common language when incorporating similar teaching methods of using tools for conceptual development (Chick, 2007; L. Hill, 1997), discourse (Heywood, 2007; Williams & Baxter, 1996), inquiry-based practices (Morrison, 2008; Manouchehri, 1997; NRC, 2012), and reflection on learning (Ambrose, 2004).

The research questions of this study were: (1) How do preservice teachers conceptions of tools for conceptual development, processes for meaningful learning, and pedagogical approaches for science and mathematics change for each subject at the beginning and end of the methods courses? (2) What connections between common educational practices in mathematics and science do preservice teachers make at the end of the methods course sequence?

Learning Cycle Framework for Science and Mathematics

A complex framework of generalizations, ideas, and relationships composes the content of mathematics (Molina et al., 1997) and the nature of science (NOS) (Akerson & Donnelly, 2008). Conceptual learning is essential to develop the skills to make generalizations, understand ideas, and examine relationships (Molina et al., 1997). Learning mathematics and science for conceptual understanding, as articulated in standards, is founded on the idea that learning is an active process (NGACBP, 2010; NRC, 2012; Tal et al., 2001). The learning cycle reflects a natural form of active learning (Lawson et al., 1989; Schmidt, 2008). The five phase learning cycle used in this study is also known as the 5E Model. The phases are: engagement, exploration, explanation, elaboration, and evaluation (Bybee, 1997). Although the learning cycle has its roots in the science field (Bybee, 1997; Atkin & Karplus, 1962), the tenets align closely with the Mathematical Standards found in the Common Core State Standards-Mathematics (NGACBP, 2010). Elements of the learning cycle can be seen in mathematics in models of teaching such as: Complex Instruction (Boaler, 2008), Cognitively Guided Instruction (Carpenter et al., 1999) , and Problem-Based Instruction (Delisle, 1997). For example in problem based instruction in mathematics, students connect to the material before being challenged to explore content through a problem, explain their solutions, and build on previous problems for new knowledge (Delisle, 1997).

Marek (2008) described using the learning cycle to explore the relationship among the diameter, radius, and circumference of a circle. This exploration involved measuring various circles, recording the results, determining relationships based on the results, determining measurements of other known objects based on given information, and reading about previous work on circumference by famous mathematicians. Using tools strategically, finding patterns and structure, and solving problems to develop a deep understanding of the concepts are core to the mathematics standards (NGACBP, 2010) and align with the exploration, explanation, and elaboration phases of the learning cycle (Bybee, 1997). The exploration and explanation phases align with the mathematical practice of constructing and critiquing viable arguments. This is an element often missing in the mathematics classrooms of the United States (L. Hill, 1997; Ma, 2010).

In this study the use of the learning cycle across the science and mathematics courses provided a common framework for student learning in science and mathematics, and for the planning and teaching of lessons within which common practices were embedded. Our bias in the use of the learning cycle from science was to portray to the students how much standards-based mathematics teaching was like standards-based science teaching; trying to build upon what we believe to be greater acceptance of inquiry approaches in science teaching. The learning cycle was not originally designed for mathematics education, but was easily applied to it. Also, we viewed the knowing and doing of mathematics, and the intent of effective, standards-based mathematics teaching, as a tool-based and process-oriented endeavor much like science.

Methods

Context of the Study

Participants were undergraduate elementary preservice teachers (22 of 25 total) enrolled in the summer science and mathematics methods courses. There were twenty-one Caucasian females and one African-American female. Participants were a cohort of students who completed four semesters of courses together at this large southeastern university. The principal researcher, also the mathematics methods instructor, collaborated with the science methods course professor. Participants completed the science course during the first five weeks and the mathematics course during the second five weeks of the summer semester. By sequencing the mathematics methods course after the science methods course, the researchers drew upon participants immediate prior knowledge of science pedagogy in the mathematics course. At the end of the mathematics course, participants shared their conceptions of how the model, tools, and processes used in teaching mathematics relates to teaching science. The purpose of using a similar framework and explicitly showing the connections between reform-oriented teaching in science and mathematics was to increase the likelihood that teachers would embrace this approach, seeing its impact in both areas.

Participants attended class or a field experience every day for ten weeks. Ten days in each course was spent in field experiences. In both classes, preservice teachers participated in hands-on investigations, discussions, and readings that explicitly connected to the 5E Model of the learning cycle (Chick, 2007; Heywood, 2007). The learning cycle was used as the common pedagogical framework for planning and teaching lessons in both courses. Students then took on the role of a teacher in planning and peer teaching in class, and examining the pedagogy of their teaching episodes using the learning cycle framework. In both the science and math courses research-based curricula that utilized inquiry and followed a learning cycle were used for these peer teachings. Preservice teachers also taught two mathematics and two science lessons, using the learning cycle, to elementary age students through field experiences at local summer camps.

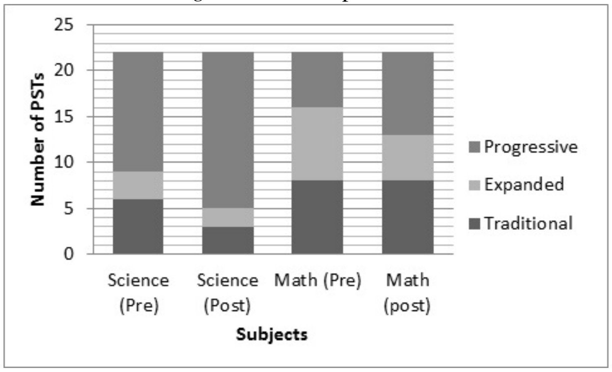
Data Collection

Methods of data collection in this multiple case design (Merriam, 1998) included an open-ended pre-survey, open-ended post-survey, and weekly blogs. The pre-survey was administered on the first day of the science class (See Appendix A) and the post-survey was administered on the last day of the math class (See Appendix B). Questions on the pre-survey and post-survey were designed to examine participants conceptions of tools and processes for learning, pedagogical approaches, and commonalties in approaches to mathematics and science. Tools included science and mathematical devices (such as measuring aides or calculators) and manipulatives (such as geoboards or fraction tiles). Participants also completed weekly blogs concerning science and mathematics teaching (See Appendix C for blog topics), including reflection on their implemented lessons in the field. The blogs allowed the researcher to examine changes in thinking that occurred throughout the semester, rather than simply at the beginning and end points that were measured through the pre- and post- survey. The study examined not only the changing conceptions in science and mathematics, but also sought to determine if what was learned in science first was being applied to thinking about mathematics teaching.

Data Analysis

The constant comparative method (Glaser & Strauss, 1967) was used to find conceptions of mathematics and science teaching that emerged from the varying data sources. Coding for category construction occurred with each data source. Keeping in mind the research questions, the researcher created main categories that would "reflect the purpose of the research" (Merriam, 1998, p. 183) and its questions. These main categories included conceptions of tools, processes, pedagogical approaches, and similarities in teaching science and mathematics. Pieces of information that related to the research questions were coded based on words or phrases from the participants, conclusions from the researcher, or connections to existing research (Glaser & Strauss, 1967; Merriam, 1998). Codes were placed in a chart for each participant in chronological order under each main category (e.g., conceptions of tools) where they fit with data sources noted. Codes were then collapsed for similarities. Next, the researcher examined data across the participant cases to make further generalizations. These generalizations across the cases for all main categories (except common approaches) were organized into three thematic categories (traditional, expanded, and progressive) that followed a continuum from simple to more complex thinking about practice. Traditional responses were those that mirrored traditional mathematics and science instruction in which instruction and lesson design focused on teacher centered rote or procedural learning. Participants with expanded responses expressed that students were involved in science and mathematics learning beyond the traditional view, but were vague in their articulation of their science and mathematics teaching. Responses in the progressive category articulated teaching that focused on concept development including students reasoning and making connections in each subject area. Participants with views in each of these three thematic categories for science and mathematics were enumerated at the beginning and end of the study using the pre-survey and post-survey. The process of transition was explored in greater depth through the blog entries. In studying developmental thinking on common approaches to teaching between science and mathematics, pre and post-surveys were analyzed for differences on the related questions. These differences were again enumerated based on numbers of participants who held them.

Figure 1. Conception of Tools



Findings

Conceptions of Tools

Traditional view. Six participants initially held a traditional view of tools in science, with three expanding their views during the semester, as indicated in Figure 1. They saw tools in science activities as a means of measuring or performing calculations. They did not see tools a means to foster conceptual understanding: "Concrete tools help students learn to physically answer the problem using objects. You use concrete tools while doing experiments" (Person 9, Post-survey).

Participants more readily accepted tools in science than in math. Although preservice teachers talked about using tools for hands-on learning in mathematics, eight participants were merely using tools to reinforce procedures. Their conceptions of tools were limited to computation tasks. Those with a traditional view of tools in mathematics were focused on students using tools to determine the right answer:

> I agree that using money is an excellent way to present materials during a math lesson. I also agree that students do need a teacher who will practice problems in repetition because most kids will learn better if the concept is drilled into them. (Person 16, Blog 9)

Even though the math methods class focused on using tools within the learning cycle approach, the eight preservice teachers with traditional views of tools rigidly held onto those views.

Expanded view. Three preservice teachers had an expanded view of tools in science at the beginning of the methods courses (See Figure 1). They recognized tools in science for more than measurement tasks, but they did not see the full potential of tools. They were vague in their articulation of the role of tools. "By having students use hands-on tools in experiments themselves, they are acting like scientists" (Person 9, Post-survey).

Eight participants with an expanded view of tools in math saw tools for more than just computation but in limited ways. They viewed tools as visual models for teaching primary concepts:

> Using play money because it makes counting money a lot easier when they can actually see it. Children are going to need to count money in real life situations so it is important that they know what it looks like. (Person 17, Blog 8).

Progressive view. Initially thirteen participants expressed using tools for hands-on, conceptual learning in science (See Figure 1). By the end of the semester 17 out of the 22 participants articulated how tools in science should be used to develop concepts. The field experiences provided preservice teachers with opportunities to use tools to teach science:

> I taught a lesson on how much water is on Earth. They were able to use concrete materials to pour beans into a gallon container to see how many pints are in a gallon and so on. They made a measurement book to see it for themselves. (Person 5, Post-survey)

Initially six participants held a progressive view of tools for teaching math. They believed that tools could help students understand concepts. When they followed standards based lessons, they saw the success in learning that could happen with the use of tools, such as the use of cards to teach fractions in the following case:

> When they placed their fraction, I had them place it where they thought it would go and tell me what percent it was. Rather than just having a sheet with equivalent fractions and percents for them to look at and learn, they actually had a chance to place actual cards in a place where it should go and strategize with their fractions of how to block others and what fractions they might have. (Person 4, Blog 10)

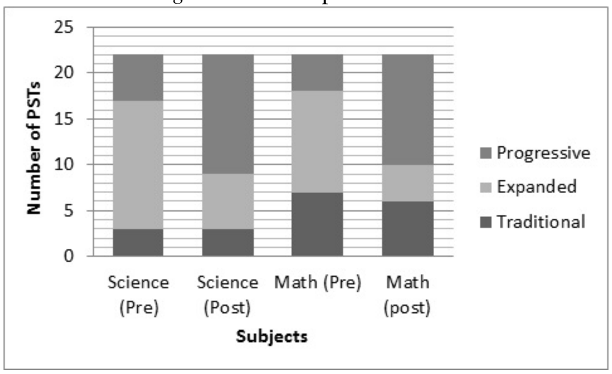
Nine of the 22 participants at semesters end recognized and articulated that tools in math could be used to explore and understand a concept. They described tools in terms of helping build student knowledge: "Students can use geoboards to help their understanding of polygons. These experiences are very important for students to create their own knowledge" (Person 7, Post-survey).

Conceptions of Processes

Traditional View. At the beginning of the semester a majority of the students had limited conceptions of processes for learning science and mathematics, as indicated in Figure 2.

Those with a traditional view articulated processes in teacher-directed and controlled lessons: "Teachers first need to inform the students about the content. Teachers need to make sure they teach the basics of the experiment and make sure students fully understand what they are about to do before they begin" (Person 16, Week 4). Students were in passive roles with teachers giving all of the information. Preservice teachers viewed science and math activities as 'inquiry'

Figure 2. Conception of Processes



if they included hands-on materials. Three participants began and retained the traditional notions about processes in science. Only one mathematics participant changed thinking to an expanded view by semester's end.

Expanded View. Fourteen of the 22 participants initially held an expanded view of processes in science (See Figure 2). They recognized the importance of students experiencing science, but did not articulate processes beyond the level of observation. In a lesson on the Laws of Motion a teacher responded, "These children were able to see what the laws were by creating things that dealt with it and learning first hand" (Person 5, Week 5).

Eleven preservice teachers initially held expanded views of processes in mathematics. They often focused on how students were enjoying the lesson rather than how the lesson promoted student reasoning. They wanted their students to go beyond the method in which the teacher modeled and students practiced problems. They would have students make observations or complete a task and then they would tell the students the mathematics behind the lesson:

> Once we explained not all people may have the same tool for measuring, as they used, you could see their minds thinking about how to measure a belt with a tool all people could use. We explained that for measuring length you need to use a ruler or a tape measure. The students had fun with this activity and they went away learning something. (Person 1, Week 8)

Progressive View. Initially five preservice teachers for science and four preservice teachers for mathematics held progressive views of processes (See Figure 2): "Math and science are more hands-on subjects. Students obtain meaningful understanding when they actually do experience hands-on" (Person 20, Pre-survey). These teachers had more cohesive understanding of processes in science and mathematics teaching. They believed that students should reason for themselves about concepts and relate that knowledge to other areas. Data sources indicated they were able to articulate processes in relation to lessons they had taught. They wrote of students reasoning, discussing their observations or findings with each other, or experiencing the concept, as in a science engineering lesson: "I thought it was so interesting to see what these kids could design and everything they used to create their designs, and the reasoning they had behind their creations" (Person 6, Week 5). By the end of the semester 13 of the 22 participants for science and 12 of the participants for math held progressive views of processes.

Conceptions of Pedagogical Approaches

Traditional View. Initially, seven participants in science and eight participants in math held traditional views about approaches for teaching, as indicated in Figure 3. Preservice teachers with this view believed that teachers should demonstrate or tell the information. Several of these participants liked the idea of hands-on activities but still tried to incorporate it into traditional instruction where explanation preceded it:

> I think that hands-on is always a good way to go, but I also think theres a time for explaining most likely before the hands-on activity. Students need instruction and explaining or they will just look at hands-on activities as play time. (Person 17, Week 4)

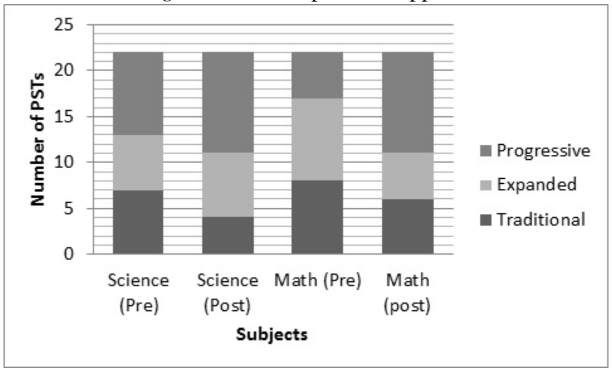
A number of the participants viewed hands-on activities as fun-time for the students and to be used for special occasions or good behavior. Difficulty with discipline during activities was also an issue for these participants: Four of the seven for science and six of the eight for mathematics maintained their view of traditional approaches.

Expanded View. Six participants initially held expanded views for teaching science and nine participants for teaching mathematics (See Figure 3). In science, they believed that students should be involved in a combination of experiments, centers, observation, and research: "Having learning centers for children to learn or review different science centers" (Person 10, Pre-Survey). In mathematics, they believed that the approach should focus on real-life mathematics and centers: "Real-life projects have value in everyday life like counting money. Role play like grocery store" (Person 14, Presurvey). Their descriptions included more than the teacher delivering knowledge, but not yet approaching learning for conceptual understanding.

Progressive View. At the beginning of the semester, nine participants in science and five in mathematics believed science and mathematics should be taught with a hands-on approach (See Figure 2). They talked in general terms about using learning centers, nature, and hands-on activities to develop understanding. Their teaching experiences in the field applied their conceptions and expanded their notions of teaching science and mathematics:

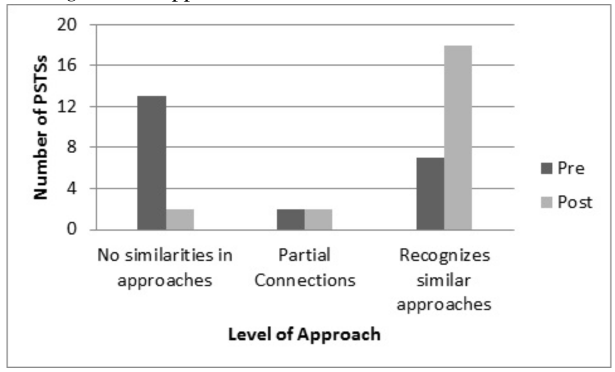
> During the lesson I elaborated on shelter as the basic need and had the students build their own shelter. I followed the 5Es teaching model. I

Figure 3. Conception of Approaches



ht

Figure 4. Approaches Between Science and Mathematics



> also provided the students with a very hands-on approach to learning by having them create their own shelter. By having them create their own shelter, they were able to make personal connections to what they were learning. (Person 19, Post-survey)

Eleven participants believed that science and mathematics should be taught with a hands-on, learning cycle approach by the end of the semester. These participants felt they benefited from the learning cycle approach in understanding what they were teaching. One student commented that the learning cycle was just as important in teaching math as in teaching science for students to develop their own understanding:

> The learning cycle, I feel, is a method of teaching that needs to be incorporated into mathematics. This is true because math, much like science, is easier to retain knowledge when there are activities that allow students to create knowledge. (Person 6, Week 6)

Common Approaches Between Science and Mathematics

Initially most of the preservice teachers thought of mathematics and science as being approached in different ways, as indicated in Figure 4. Thirteen preservice teachers initially indicated that there were no commonalties between teaching science and mathematics. They indicated that science was for teaching plants and animals and mathematics was for teaching numbers: "Math deals with numbers, geometry, fractions, etc. Science deals with animals, plants, biology, etc" (Person 22, Pre-survey).

Two participants indicated partial connections initially between teaching science and mathematics. They saw that they had connections but should be approached differently: "Math and science both use critical thinking. Math and science are different in that science has more experimentation and math has more number problem solving" (Person 11, Pre-survey). Two preservice teachers commented at the end of the semester that both science and mathematics is hands-on, but they described mathematics as finding the right answer.

Seven participants indicated that there were commonalties between science and mathematics teaching at the beginning of the semester. They indicated that science and mathematics both used hands-on learning: "Math and science also provide hands-on activities for learning. Science and math are similar in that we use each subject everyday" (Person 8, Pre-survey).

None of the participants mentioned or indicated any conception similar to the learning cycle on their pre-survey. Eighteen out of 22 participants at the end of the methods classes did recognize the learning cycle could be used for both science and mathematics. They recognized the important role of concrete experiences in science and mathematics lessons. A typical statement was, "I now see how closely teaching mathematics and science can be related. I noticed that they both have an importance of using hands-on or concrete experiences to help the understanding of the lesson" (Person 7, Post-survey). They recognized that students need to develop concepts. Some referred to their blogs as the source that helped them realize the learning cycle could be used for both subjects: "I was able to see similarities in math and science because some of the posts were the same such as dealing with the 5Es, concrete materials, hands-on activities and assessment in both math and science" (Person 16 Post-survey). Only two preservice teachers at the end of the semester viewed math and science as being separate subjects to be taught differently.

Discussion and Implications

Preservice teachers, in this study as well as in previous studies, consider science a subject in which students are supposed to be "doing" something (Gee et al., 1996). In this study students wrote about hands-on activities or experiments. It is unclear what is meant by experiments, but their intent is clear that students are involved with concrete materials. For mathematics, it was different. Even though the math methods class focused on using tools and developing processes within the learning cycle approach, a few of the preservice teachers continued to try to conform to their primarily traditional experiences in mathematics. The Mathematical Practices in the Common Core of State Standards tell us that students should be "doing" in mathematics as well in order to reason and make sense of the concepts (NGACBP, 2010). Preservice teachers instrumental view of mathematics perhaps interferes in the way they understand and embrace the learning cycle as a teaching method in mathematics.

Lindgren and Bleicher (2005) drew similar conclusions when strong science students were reluctant to teach science using the learning cycle. However, students, who had negative science educational experiences, embraced the learning cycle approach. Half of the students who initially held a traditional view of tools in science moved towards the expanded or progressive viewpoint. Perhaps they could make this shift to because it still fit with the "doing" notion of science. There was very little change among preservice teachers who held traditional views of processes. They wanted students finding the right answer. However, inquiry-based teaching involves student exploration around a central idea, formulation of questions, investigations to answer the questions, and reflection of learned ideas based on evidence (Morrison, 2008; NRC, 2012).

There was a large shift in both math and science for those who originally held expanded views of processes that moved towards more progressive views. This supports the notion that once teachers begin to accept concepts of inquiry and the learning cycle, they are more likely to continue growing in this area. In this study, many of the preservice teachers were able to articulate teaching in terms of processes for understanding by the end of the semester. These processes developed over time as preservice teachers worked with children in the field. Stuart and Thurlow (2000) found that when preservice teachers used concrete experiences in math courses and with students in field placements, it set the stage for conceptual change due to bolstering self-confidence in teaching, gaining a sense of accomplishment, and deepening of mathematical understanding. Settlage (2000) found the same to be the case for science teaching. Reflection, in the form of weekly blogs, was also used as a tool in this conceptual change process by providing time for the preservice teachers to examine conflict in ideas and examine new ideas as they put them into practice (Heywood, 2007). . For elementary preservice teachers, conceptions of inquiry and the sciences processes may need to be explored more across methods and content classes to help them develop a clear understanding of how to fully utilize inquiry to support student understanding of processes and content.

Focusing on the learning cycle in mathematics and science helped many of the preservice teachers in this study to recognize the importance of an active learning environment across disciplines. A majority of the preservice teachers (18 of 22) recognized common approaches to teaching science and mathematics through the use of the learning cycle. They wanted their students to be engaged in learning through hands-on and inquiry approaches in science and mathematics, and this understanding could be viewed as fitting the beginning of the learning cycle. Explicitly teaching common tools, processes, and approaches via the learning cycle in both methods courses led to a more complex understanding and initial acceptance of reform-minded teaching in mathematics; though not to the extent as in science. For mathematics, this approach seemed to foster the most growth for students who began with expanded views and moved towards progressive views.

The preservice teachers partial understanding of the intent of tools, processes, and pedagogical approaches, such as the learning cycle can be expected with novice teachers learning how to teach (Marek et al., 2003; Settlage, 2000). As preservice teachers enter the field it is important to provide coaching and support of reform-based approaches, taking them from where they are and what they understand to deeper conceptions of teaching and learning in practice. Providing an approach, such as the learning cycle, can aide the understanding and implementation of reform strategies in the STEM fields, as well as seeing how these fields connect. In this study, most preservice teachers moved from seeing science and mathematics as completely separate content areas, to being able to provide concrete examples from field experiences that articulated common approaches of science and mathematics in the elementary classroom. Findings indicated that purposeful planning and design of science and mathematics methods courses can yield changes in the early development of thinking about the teaching of mathematics to be closer to accepted notions in science. Additional studies are needed to examine if and how preservice teachers articulate common approaches to mathematics and science beyond the methods classes.

References

Akerson, V., & Donnelly, L. (2008). Relationships among learner characteristics and preservice elementary teachers views of nature of science. *Journal of Elementary Science Education*, *20*(1), 45-58. Retrieved from `http://dx.doi.org/10.1007/BF03174702`

Ambrose, R. (2004). Initiating change in prospective elementary school teachers' orientations to mathematics teaching by building on beliefs. *Journal of Mathematics Teacher Education*, *7*(2), 91-119. Retrieved from `http://dx.doi.org/10.1023/B%3AJMTE.0000021879.74957.63`

Atkin, J., & Karplus, R. (1962). Rebuilding the science program. *The Science Teacher*, *29*(5), 45-51.

Ball, D. L., & Forzani, F. M. (2011). Building a common core for learning to teach: And connecting professional learning to practice. *American Educator*, *35*(2), 17–21. Retrieved from `http://www.aft.org/pdfs/americaneducator/summer2011/Mirel.pdf#page=12`

Beeth, M. E., & McNeal, B. (1999). *Co-teaching mathematics and science methods course.* (Retrieved from ERIC database. (ED443666))

Boaler, J. (2008). Promoting 'relational equity' and high mathematics achievement through an innovative mixedability approach. *British Educational Research Journal*, *34*(2), 167-194. Retrieved from `http://www.tandfonline.com/doi/abs/10.1080/01411920701532145`

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction.* Portsmouth, NH: Heinemann.

Chick, H. (2007). Teaching and learning by example. In J. Watson & K. Beswick (Eds.), *Mathematics: Essential research, essential practice* (p. 3-21). Adelaide, SA. (Proceedings of the 30th Annual Conference of the Mathematics Education Research Group of Australasia)

Cooney, T. J., & Wiegel, H. G. (2003). Examining the mathematics in mathematics teacher education. In A. Bishop, M. Clements, C. Keitel, J. Kilpatrick, & F. Leung (Eds.), *Second international handbook of mathematics education* (Vol. 10, p. 795-828). Springer Netherlands. Retrieved from http://dx.doi.org/10.1007/978-94-010-0273-8_26

Delisle, R. (1997). *How to use problem-based learning in the classroom.* ASCD.

Gee, C. J., et al. (1996). *Preservice elementary teachers: Their science content knowledge, pedagogical knowledge, and pedagogical content knowledge.* (Retrieved from ERIC database. (ED393702))

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Transaction Books.

Goodnough, K., & Nolan, B. (2008). Engaging elementary teachers pedagogical content knowledge: Adopting problem-based learning in the context of science teaching and learning. *Canadian Journal of Science, Mathematics and Technology Education*, *8*(3), 197-216. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/14926150802315130

Heywood, D. S. (2007). Problematizing science subject matter knowledge as a legitimate enterprise in primary teacher education. *Cambridge Journal of Education*, *37*(4), 519-542. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/03057640701705856

Hiebert, J., Stigler, J. W., Jacobs, J. K., Givvin, K. B., Garnier, H., Smith, M., ... Gallimore, R. (2005). Mathematics teaching in the united states today (and tomorrow): Results from the timss 1999 video study. *Educational Evaluation and Policy Analysis*, *27*(2), 111–132.

Hill, H., & Ball, D. L. (2009). The curiousand crucialcase of mathematical knowledge for teaching. *Phi Delta Kappan*, *91*(2), 68–71.

Hill, L. (1997). Just tell us the rule: Learning to teach elementary mathematics. *Journal of Teacher Education*, *48*(3), 211–221.

Justi, R., & van Driel, J. (2005). The development of science teachers' knowledge on models and modelling: promoting, characterizing, and understanding the process. *International Journal of Science Education*, *27*(5), 549-573. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/0950069042000323773

Lawson, A. E., et al. (1989). *A theory of instruction: Using the learning cycle to teach science concepts and thinking skills. NARST Monograph, number one, 1989.* Monograph. National Association for Research in Science Teaching. (Retrieved from ERIC database. (ED324204))

Lindgren, J., & Bleicher, R. E. (2005). Learning the learning cycle: The differential effect on elementary preservice teachers. *School Science and Mathematics*, *105*(2), 61–72. Retrieved from http://dx.doi.org/10.1111/j.1949-8594.2005.tb18038.x

Lonning, R. A., & DeFranco, T. C. (1994). Development and implementation of an integrated mathematics/science preservice elementary methods course. *School Science and Mathematics*, *94*(1), 18–25. Retrieved from http://dx.doi.org/10.1111/j.1949-8594.1994.tb12284.x

Ma, L. (2010). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Routledge.

Manouchehri, A. (1997). School mathematics reform: Implications for mathematics teacher preparation. *Journal of Teacher Education*, *48*(3), 197–209. Retrieved from http://dx.doi.org/10.1177/0022487197048003005

Marek, E. (2008). Why the learning cycle? *Journal of Elementary Science Education*, *20*(3), 63-69. Retrieved from http://dx.doi.org/10.1007/BF03174709

Marek, E., Laubach, T., & Pedersen, J. (2003). Preservice elementary school teachers' understandings of theory based science education. *Journal of Science Teacher Education*, *14*(3), 147-159. Retrieved from http://dx.doi.org/10.1023/A%3A1025918216347

McGinnis, J. R., Kramer, S., Shama, G., Graeber, A. O., Parker, C. A., & Watanabe, T. (2002). Undergraduates' attitudes and beliefs about subject matter and pedagogy measured periodically in a reform-based mathematics and science teacher preparation program. *Journal of Research in Science Teaching*, *39*(8), 713–737. Retrieved from http://dx.doi.org/10.1002/tea.10042

Merriam, S. B. (1998). *Qualitative research and case study applications in education. revised and expanded from "case study research in education"*. San Francisco, CA: Wiley & Sons.

Molina, D. D., Hull, S. H., & Schielack, J. F. (1997). *Guidelines for the mathematical preparation of prospective elementary teachers.* (Retrieved from ERIC database. (ED436370))

Morrison, J. (2008). Individual inquiry investigations in an elementary science methods course. *Journal of Science Teacher Education*, *19*(2), 117-134. Retrieved from http://dx.doi.org/10.1007/s10972-007-9086-z

National Governors Association Center for Best Practices, Council of Chief State School Officers [NGACBP]. (2010). *Common core state standards: Mathematics.* Washington, DC: National Governors Association Center for Best Practices, Council of Chief State School Officers. Retrieved from http://www.corestandards.org/Math

National Research Council [NRC] . (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas* (H. S. Helen Quinn & T. Keller, Eds.). The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=13165

National Research Council [NRC]. (1996). *National science education standards.* Washington, DC: The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=4962

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics*, *100*(2), 73–82. Retrieved from http://dx.doi.org/10.1111/j.1949-8594.2000.tb17239.x

Plonczak, I. (2010). Videoconferencing in math and science preservice elementary teachers field placements. *Journal of Science Teacher Education*, *21*(2), 241-254. Retrieved from http://dx.doi.org/10.1007/s10972-009-9166-3

Schmidt, L. (2008). How we don't learn. *Leadership*, *38*(2), 10-14.

Settlage, J. (2000). Understanding the learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Education*, *84*(1), 43–50. Retrieved from http://dx.doi.org/10.1002/(SICI)1098-237X(200001)84:1<43::AID-SCE4>3.0.CO;2-F

Stuart, C., & Thurlow, D. (2000). Making it their own: Preservice teachers' experiences, beliefs, and classroom practices. *Journal of Teacher Education*, *51*(2), 113-121. Retrieved from http://dx.doi.org/10.1177/002248710005100205

Stuessy, C. L. (1993). Concept to application: Development of an integrated mathematics/science methods course for preservice elementary teachers. *School Science and Mathematics*, *93*(2), 55–62. Retrieved from http://dx.doi.org/10.1111/j.1949-8594.1993.tb12195.x

Tal, R. T., Dori, Y. J., & Keiny, S. (2001). Assessing conceptual change of teachers involved in stes education and curriculum devleopment - the stems project approach. *International Journal of Science Education*, *23*(3), 247-262. Retrieved from http://dx.doi.org/10.1080/09500690175006650l

Thames, M. H. (2006). *Using math to teach math.* Berkeley, CA: Mathematical Sciences Research Institute.

Williams, S. R., & Baxter, J. A. (1996). Dilemmas of discourse-oriented teaching in one middle school mathematics classroom. *The Elementary School Journal*, *97*(1), pp. 21-38. Retrieved from http://www.jstor.org/stable/1001790

Appendix A
Pre-Survey

1. How is teaching math like teaching science? What is similar and what is different?
2. How would concrete tools/experiences play a role in a science lesson? Give examples.
3. How would concrete tools/experiences play a role in a math lesson? Give examples.
4. Name and describe a few teaching strategies or approaches used to teach science for meaningful understanding.
5. Name and describe a few teaching strategies or approaches used to teach math for meaningful experiences.

Appendix B
Post-Survey

1. How is teaching math like teaching science? What is similar and what is different?
2. How would concrete tools/experiences play a role in a science lesson? Give examples.
3. How would concrete tools/ experiences play a role in a math lesson? Give examples.
4. A. Name and describe a few teaching strategies or approaches used to teach science for meaningful understanding.
   B. Name and describe a few teaching strategies or approaches to teach math for meaningful understanding.
5. A. Think back to a science lesson that you taught this summer and briefly describe it.
   B. How do you think it met effective practice approaches to teaching? Explain.
6. A. Think back to a math lesson that you taught this summer and briefly describe it.
   B. How do you think it met effective practice approaches to teaching? Explain.
7. How has the blog helped you in your development of . . . A. Ideas about teaching science?
   B. Ideas about teaching math?
   C. Similarities between the teaching of math and science?

Appendix C
Weekly Blog Questions and Issues

Week 1: Why is following a Learning Cycle so important in teaching science? Wont more traditional approaches such as giving information first to students, such as in reading the textbook, completing worksheets, and writing notes/definitions work just as well? Explain.

Week 2: We have learned about inquiry and the associated process skills for teaching science through doing science. We have learned that the Learning Cycle for planning and teaching a series of lessons is best practice. So, how does the S-T-E-S piece fit into all of this? What really is it anyway? How does it work, and is it important in my science teaching?

Week 3: So, this week you had the chance to finally practice teach about either ecological or technological ideas to kids, and followed some portion of the Learning Cycle to do it! Also, assessment was on everyones mind. So, how did you assess your students attitudes, understanding, or performance in your lesson this week? Do you feel your assessment strongly aligned with your learning objective(s)? Was it authentic enough?

Week 4: This week we have been doing many hands-on activities in our FOSS Earth Materials kit curriculum. Are all hands-on activities equal? Is hands-on best no matter what you do, when you do it, or how you do it? Explain to me your thinking now about hands-on activities in science to best help student learning.

Week 5: Inventing and building and Newtons Laws of Motion can certainly seem to be unruly in the classroom, but is this O.K.? Taking kids outdoors to learn about science in nature also has its own planning and managing hurdles, but is it worth it? Even in doing the states science teaching in the classroom with kits, there is a level of uncertainty and messiness with kids and materials in motion, but it seems to work. How are you now feeling about these issues? Where do you begin personally in your future classroom?

Week 6: Think about the Learning Cycle. Explain how the Learning Cycle pertains to the teaching and learning of mathematics. Support with examples. Then respond to two other people's responses.

Week 7: So far in class we have discussed inquiry in mathematics, assessing mathematical understanding, developing number sense, and participating in tasks to develop our own mathematical knowledge. Think about all we have talked about, experienced for ourselves, and experienced with students. Explain which part of the Learning Cycle you find to be the most important in developing a true understanding of mathematics and why. Support with examples of your own experiences or mathematics field experiences.

Week 8: In class we have been learning about how to assess and different types of assessment. Think about one of your math teaching experiences this semester. How did you determine student understanding of the topic? Be specific. Support with examples. Based on your assessment what judgments and decisions will you have to make about teaching/learning? Would you teach the lesson differently if you taught it again? Be specific. Support with examples.

Week 9: We have used concrete materials in class and with students in lab. I want you to think about the role that concrete experience plays in learning. Think of an instance in which concrete experiences played a role in your own learning of mathematics. Describe that learning experience. Describe how you have used concrete experience in one teaching lesson this term.

Week 10: Think about the two consecutive lessons you taught this week. What growth did you see in your students' understanding of the topic? What role did concrete experience play in your lessons? How did you promote inquiry?