INITIATIVES IN

MATHEMATICS AND SCIENCE EDUCATION
WITH GLOBAL IMPLICATIONS

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4.1 AN ACTIVITY TO ASSESS PRESERVICE ELEMENTARY TEACHERS’ PERCEPTIONS OF KNOWLEDGE NEEDS FOR MATHEMATICS AND SCIENCE INSTRUCTION

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A primary goal of teacher education programs is to help preservice teachers (PSTs) develop the necessary knowledge base to teach various content areas (Quebec Fuentes, Bloom, & Peace, in press). PSTs often possess faulty ideas about the types of knowledge required for classroom teaching which are informed by their own past experiences as students (Ball, 1988; Lortie, 1975). Specifically, in mathematics and science, misconceptions are common. Frequently, PSTs think of mathematics as a series of algorithms and science as a collection of facts and believe a teacher’s job is to transfer this knowledge to their students (Borko, Eisenhart, Brown, Underhill, Jones, & Agard, 1992; Kilpatrick, Swafford, & Findell, 2001; National Research Council, 2000). Ball and colleagues (Ball, Thames, & Phelps, 2008; Hill & Ball, 2009) delineate distinct knowledge domains necessary for effective mathematics teaching through the Mathematical Knowledge for Teaching framework and Magnusson, Krajcik, and Borko (1999) do the same for science. The framework, Pedagogical Content Knowledge for Science Teaching, developed by Magnusson et al. is based on the premise that teachers’ beliefs about the content impacts classroom instruction and students’ learning. This chapter presents the Preservice Elementary Teachers’ Science and Mathematics Activity (PETSMA) which is designed to address two particular types of knowledge that are critical to both mathematics and science teaching: factual/procedural knowledge and conceptual knowledge.

The PETSMA

The PETSMA (see Appendix) was constructed by building upon questions found in K-6 state-approved mathematics and science textbooks (Baptiste, Daniel, Hackett, Moyer, Stryker, & Vasquez, 2000; Biggs, Daniel, Feather, Snyder, & Zike, 2002; Charles et al., 2009; Lappan, Friel, Fey, & Phillips, 2009). Each grade level was represented with two mathematics questions and two science questions. For each grade level and subject area, the first question represented factual/procedural knowledge, and the second question represented the underlying concepts of the content that was included in the corresponding factual/procedural question. After each question in the PETSMA, there is an associated set of Likert-style questions that queries the PSTs about their confidence in answering the question and their confidence in their future ability to teach the content related to the question.

The PETSMA in Use

The PETSMA was used with a cohort of preservice elementary teachers on two separate occasions, once at the beginning and once at the end of the PSTs’ mathematics and science methods courses. The results of the two implementations, as reported in
Quebec Fuentes, Bloom, and Peace (in press) and Peace (2012), are summarized:

- PSTs were more confident in answering factual/procedural and conceptual questions in mathematics than in science.
- PSTs were more confident in teaching mathematics than science for both factual/procedural and conceptual knowledge.
- PSTs were more confident in answering factual/procedural and conceptual questions in mathematics than in teaching the related content.
- PSTs were more confident in answering questions and teaching the content related to the factual/procedural knowledge than the conceptual knowledge in mathematics.
- Preservice teachers were more confident in teaching the content related to the factual/procedural and conceptual questions in science than in answering the questions.
- PSTs were more confident in answering questions and teaching the content related to the factual/procedural knowledge than the conceptual knowledge in science.
- For factual/procedural and conceptual questions, the PSTs' confidence decreased as the grade level increased (with the exception of the sixth grade fact-based question) for both answering the questions and teaching the related content.

Follow-up discussions provided information about the PSTs' views of the natures of mathematics and science, previous experiences in school that influenced their views, and ideas about the preparation needed to teach mathematics and science.

**Recommendations for Use of the PETSMA**

The PETSMA is not intended to be a measure of PSTs’ content knowledge. Rather, the PETSMA is meant to introduce PSTs to the unique knowledge needs for teaching mathematics and science. Therefore, the PETSMA is most informative when used in conjunction with a follow-up, whole-class discussion. The substance of the discussion provides insight about the PSTs’ perspectives concerning teaching and learning mathematics and science. For instance, one of the aforementioned findings, which indicated that the PSTs were more confident in teaching the content related to the questions in science than in answering the questions, seems curious. However, during the whole-class discussion, the PSTs explained that, in preparing to teach a science lesson, they were confident in their ability to research the relevant content. They did not necessarily need to remember the facts and terms at all times.

When implementing the PETSMA, allow about 30 minutes for the PSTs to answer all of the questions. As previously discussed, remind the PSTs that the PETSMA is not meant to assess their content knowledge and it is anticipated that they might not remember some of the content necessary to answer the questions. Stress that answering the content and Likert-style questions will serve as the foundation for a whole-class
discussion. Some prompts that can be used to guide the discussion after the PSTs complete the PETSMA follow:

- Describe your initial reactions to the PETSMA.
- Which questions were and were not challenging for you to answer? Why?
- Compare the two questions for each subject/grade level with respect to the content of each question, your confidence in answering each question, and your confidence in teaching the content related to each question.
- Compare the mathematics and science questions with respect to your confidence in answering each question and your confidence in teaching the content related to each question.

The PETSMA can be used at any point during a teacher preparation program. However, using the PETSMA at the beginning of a mathematics or science methods course can inform teacher educators about PSTs’ perceptions of the knowledge needs for teaching mathematics and science which in turn can support the development of the course.

The PETSMA can be modified in several ways. Although the comparison of mathematics and science questions offers additional insights about the PSTs’ views of each discipline, the mathematics or science questions could be separated and used independently. The PETSMA was originally designed for use with preservice teachers, but it can also be used with inservice teachers. The general structure of the PETSMA can be used for other grade levels and subject areas such as secondary earth science, biology, algebra, or geometry. Regardless of the population of teachers or subject area, a PETSMA-like activity which includes parallel pairs of factual/procedural and conceptual questions followed by Likert-style questions will open discussions about teacher knowledge. Participants will be exposed to the two subdomains of teacher knowledge, and teacher educators will learn participants’ perceptions about the knowledge necessary for teaching.

References


Preservice Elementary Teachers’ Mathematics and Science Activity

(PETSMA)

Instructions: On each of the following pages, you will find two mathematics questions and two science questions representing Kindergarten through sixth grade. After each question, you will find an associated set of two teacher questions asking your opinions on your ability to answer the questions and your ability to teach the content related to the question. Please answer all questions to the best of your ability.

Note: This is not a test of your content knowledge, but rather an opportunity for you to think about mathematics and science from the perspective of an elementary teacher.
Kindergarten Mathematics

1. Count the umbrellas and write the number.

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. How many circles are there below? How did you count the circles?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

Kindergarten Science

1. Draw a circle around the animals below that move by swimming.

   BUTTERFLY  FISH  HORSE  WHALE  TIGER  BIRD

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. Sort the animals above into two groups by writing their names into one of the two boxes below. Explain how you chose to sort them.

   Group 1

   Group 2

Explanation of how you sorted them:

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree
First Grade Mathematics

1. (Multiple Choice) About how many paper clips long is the key?

- a. 8
- b. 6
- c. 4
- d. 2

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. Adam measured the length of the shorter edge of this piece of paper with the paper clip (pictured above). He estimated that the length is about 7 paper clips. Julia also measured the length of the shorter edge of the paper. She used the key (pictured above) and estimated the length to be about 4 keys. Can Adam and Julia both be correct? Explain.

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

First Grade Science

1. Name the four main parts of a tree.

   

   

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. Why should we try to save trees?
Second Grade Mathematics

1.

\[ 36 + 48 \]

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. To perform the subtraction below, you can “borrow” from the tens place of the top number. Why does this move not alter the answer?

\[ 32 - 17 \]

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

Second Grade Science

1. Draw a line to match each word with its meaning.

- heat
- find the size or amount of something
- temperature
- energy that can make things change
- measure
- how warm or cool something is
- fuels
- a tool to measure temperature
- thermometer
- things that give off heat when they burn

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. A man warms a marshmallow over a fire. How does the heat get from the fire to the marshmallow?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree
Third Grade Mathematics

1. Write two special names for this figure.

\[ \square \]

2. Is a square a rectangle? Why or why not?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree

B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

Third Grade Science

1. Use the following words to complete the sentences.
   
   Asteroid   Atmosphere   Comet   Corona   Fuel
   Planet   Solar System   Star   Sunspot   Telescope
   
   • A dark area on the Sun's surface is called a _______.
   • A small chunk of rock or metal that orbits the sun is a(n) ________.
   • A satellite of the Sun is called a ________.
   • Something burned to provide heat or power is a ________.
   • A tool that gathers light to make faraway objects appear larger, closer, and clearer is a ________.

2. What would be different about summer and winter if Earth's axis were straight up and down instead of tilted?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree

B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree
Fourth Grade Mathematics

1. For a through d, use the bar graph below.

<table>
<thead>
<tr>
<th>Math Test Scores</th>
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<tbody>
<tr>
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<tr>
<td></td>
</tr>
<tr>
<td>Average Score</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

- a. Which class has the highest average math test scores?
- b. Which two classes have the same average test scores?
- c. What is the average math test score for 4A?
- d. How many more points would 4A need to have the same average test scores as 4C?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. Explain why the graph below is misleading and how it should be changed so that it is less misleading.

<table>
<thead>
<tr>
<th>Top Game Scores</th>
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<tbody>
<tr>
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<td></td>
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<td>Top Game Scores</td>
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</table>

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

Fourth Grade Science

1. Use the following words to complete the sentences.

Cardiac Muscle  Cartilage  Fracture  Involuntary Muscle
Skeleton  Ligament  Marrow  Skeletal Muscle
Smooth Muscle  Sprain  Tendon  Voluntary Muscle

- A tough band of tissue that holds two bones together where they meet is a(n) ____________.
- The supporting frame that gives the body its shape and protects many organs is called the ____________.
- A muscle that is attached to a bone and allows movement is a(n) ____________.
- A strong band of tissue that connects a muscle to bone is a(n) ____________.
- A smooth muscle is classified as a(n) ____________.

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. How do muscles and bones work together to help you move?

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree
Fifth Grade Mathematics

1. A bag contains 13 purple marbles, 9 green marbles, 6 blue marbles, 5 yellow marbles, and 12 red marbles. What is the probability of pulling out a yellow marble?

Fifth Grade Science

1. Use the following words to complete the sentences.
   - Cambium
   - Chlorophyll
   - Chloroplast
   - Cortex
   - Epidermis
   - Fungus
   - Nonvascular
   - Phloem
   - Photosynthesis
   - Respiration
   - Root Cap
   - Xylem

   - The outer layer of a root is the _____________.
   - Water and minerals flow up through the _____________.
   - Foods flow down from the leaves through the _____________.
   - Water and minerals pass through the root's _____________ to the xylem.
   - A green pigment called _____________ allows plants to use the Sun's energy to make their own food.

2. A fair coin is tossed six times and for all six tosses the result was heads. What is the probability of the seventh tosses being heads? Explain your answer.

2. What is the difference between the way plants make food and the way plants use food?
Sixth Grade Mathematics

1. Find the value for N that makes the number sentence correct.

\[
\frac{2}{3} + \frac{3}{4} = N
\]

2. Why are common denominators necessary when adding fractions?

Sixth Grade Science

1. What causes a dropped coin to fall?
   a. Inertia
   b. Velocity
   c. Gravity
   d. Friction

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. The pirate ship below is sailing in the direction indicated and is moving at 50 miles per hour. A pirate who was sitting 100 feet above the boat on the top of the highest mast accidentally fell. Where would he most likely land?

A. Directly below where he fell (at the base of the mast)
B. Somewhere between the mast and the back of the ship
C. He would miss the boat entirely and land in the ocean

A. This question was easy for me to answer.
   Strongly Agree  Agree  Disagree  Strongly Disagree
B. This question will be easy for me to teach.
   Strongly Agree  Agree  Disagree  Strongly Disagree