Prospective Elementary Teachers Explain & Model a Chemical Reaction

PURPOSE

The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) emphasize student engagement with the science and engineering practices to discover disciplinary core ideas and apply those ideas to generate new design solutions. However, teachers often lack the content knowledge and pedagogy to engage elementary students in constructing explanations and developing models. In our view, prospective elementary teachers (PETs) must engage in the science and engineering practices as learners of science before immersing them in the study of pedagogies to prepare them to plan and implement science instruction.

One way to enhance students' scientific literacy competence is by facilitating model-based inquiry (MBI) (Schwarz & White, 2005; Schwarz, 2009; Windschitl, Thompson, Braaten, & Stroupe, 2012) instruction. Teachers possessing modeling and representational competence and knowledge of *epistemology of science* (Russ, 2014) may carry out MBI with fidelity motivating students' participation to construct written, oral, and visual (i.e., model) explanations and representations of phenomena that reveal *epistemologies for science* (Russ 2014) and conceptual understanding. We propose situating MBI in a physical science course for teachers where prospective elementary teachers are learners of science in a practice-centered environment. The experience of learning science via an evidence-based practices approach before enrolling in teacher education programs can impact how prospective teachers think about and enact science instruction. We focus on prior collegiate science experiences because they shape how prospective teachers view teaching and enact pedagogical practices (Beijaard & Verloop, 1996).

CONCEPTUAL FRAMEWORK

Suppose prospective elementary teachers engage in MBI as learners of science before participating in pedagogical discussions in science education methods courses. In that case, they can better connect the experience to the instructional practices. The experience should prompt cognitive disequilibrium (Piaget, 1971) due to a lack of cohesion between prior and current science experiences. Introducing prospective elementary teachers to new ways of teaching science without addressing the problem of previous experience will not cause teachers to reflect and reconsider their practice (Birman et al., 2000; Loughran, 2013). The study seeks to add science experiences that disrupt the uniformity of prior collective experiences to motivate shifts in thinking about enacting science instruction (Verloop, 1992).

Prospective elementary teachers participate in coherent content storylines that build upon existing ideas through sensemaking events positioning students as co-constructors of knowledge. The goal is to authentically utilize the science practices to solve a problem—explain why the phenomenon occurs. Unfortunately, the notion that science investigations are for practicing process skills or confirming known outcomes (Lehrer & Schauble, 2015) still prevails. Manz et al. (2020) propose a framework for positioning the practice of "planning and carrying out investigations" within a suite of practices to extend its usefulness and align with the work of scientists. MBI encourages the use of a collection of science practices organically. In this way, the practices are taken up as scientists would engage with them.

This study is the first phase of a three-phase extensive study that seeks coherency of practice across the science content, science education methods, and STEAM methods courses for elementary teachers at a mid-sized state university in the southeastern United States.

To guide our research design, we developed an overarching research question—How are PETs modeling and explaining a phenomenon when engaged in the practices for the first time?—supported by three sub-questions:

1. In what ways are PETs representing the phenomenon in a scientific model?
2. How are PETs explaining the phenomenon with the CER framework?
3. To what extent are PETs communicating their understanding via visual and written descriptions?

RESEARCH DESIGN

Study Context

All prospective elementary teachers (PETs) in the state enroll in two science content courses for educators before admission to the teacher education program. The study focuses on the physical science content course. The physical science or life science content courses are the prospective elementary teachers' first experience with an integrated (science + pedagogy) course.

The physical science content course is structured around collaborative investigations and sensemaking experiences. Students initially make observations and inferences (Finson, 2010) about a scientific phenomenon. They draw what they see in the phenomenon, ask questions, and write about their observations. Next, they draw what they cannot see (inferences) using their imaginations to describe and illustrate the cause(s) of the phenomenon. This is the *observation and inferences model*. Then students form small groups to develop an investigation to generate data to help them answer an investigative question. When collaborative discussions occur, they reveal prior knowledge framing investigations. PETs were presented with both guided and open-ended opportunities to engage in initial explorations of the phenomenon. Further, collaborating on data analysis facilitated the construction of an explanation supported by evidence and scientific reasoning negotiated from multiple perspectives. Diversity of perspective increases the quantity and, thus, the quality of explanations. Ideas are analyzed and synthesized to form a consensus view resulting from a process that results from the *diversity bonus* (Page, 2019).

After engaging in peer-to-peer discourse about the investigation(s), each prospective elementary teacher composed an *exhibition model* to represent their current understanding of the phenomenon. They drew models to represent inferences and generate written explanations with the aid of the Claims-Evidence-Reasoning (CER) framework (McNeill & Krajcik, 2011) and sentence frames (Windschitl & Thompson, 2013; Fulton, 2017). The course prepares prospective elementary teachers to construct claims based on evidence collected from investigations (McNeill & Krajcik, 2011). Next, the exhibition models hang on the wall for a pending Gallery Walk. The prospective elementary teachers walked around the room to observe, compare, and contrast all models for conceptual and representational features. Facilitated by the instructor, future elementary teachers engage in a class discussion to identify the perspectives presented in the exhibition models. Talk Moves (Michaels & O'Connor, 2012) are central here. The instructor elicits students' ideas without confirming or rejecting the accuracy.

The next step focused on considering other data or different interpretations of data and determining how best to represent the phenomenon as a model. The prospective elementary teachers formed *provisional models* to express their understanding of the phenomenon based on the data they and others generated through investigation(s) and reasoning from the evidence. The provisional model included both visual and written components.

The physical science instructor has an appointment within the College of Education, a Ph.D. in Science Education, and two degrees in engineering. Before returning to graduate school, the instructor taught high school physics and was previously an engineer.

Methods and Data Collection

Each PET created a set of models (observation and inference, exhibition, and provisional) and explanations for five phenomena presented across a semester. The set included three models and explanations. The first iteration revealed PET's prior experience and understanding of the scientific concepts involved in the phenomenon. They recorded observations and created inferences to explain why they believed the phenomenon occurred. Next, they worked in groups to plan an investigation that could produce evidence to support a scientific explanation. The models were presented to the class anonymously in a Gallery Walk. PETs reviewed each model and compared and contrasted the explanations and representations. As a whole class, and in a face-to-face setting, the instructor facilitated a discussion about the similarities and differences. When someone disagreed with another group's explanation, PETs felt comfortable disagreeing and explaining why. After listening to other interpretations, they produced a final but tentative, provisional model of the phenomenon.

We analyzed the data set (models and explanations) for the first phenomenon in a set of five presented by PETs in the physical science content course. They witnessed three bottles with balloons filled with varying amounts of baking soda being poured into the same amount of vinegar. The 'mixture' fizzed and inflated the balloons to different sizes. They were provided with the question, "Why do the balloons inflate to different sizes?"

The university's IRB office approved the study, and participants consented. Seven PETs completed three iterative models and explanations to describe why and if varying amounts of baking soda caused three balloons to inflate to different sizes. The following section describes how we analyzed the visual (in models) and written (explanations) data.

Data Analysis

Each PET's data set was read before rigorous coding commenced to gain a sense of all the data. An initial reading of the data included holistic coding (Saldaña, 2015) in reporting the researchers' initial impressions. We applied holistic coding to assign labels to large chunks of data to summarize the ideas. Descriptive, pattern, and versus coding occurred during the second coding round. Themes emerged across data to answer the research questions. Thematic analysis (Braun & Clark, 2006) best describes how the data was analyzed.

Due to length considerations, we condense the findings in the space below.

FINDINGS

Research Question 1: In what ways do PETs represent the phenomenon in a scientific model?

Four of the seven PETs were consistent in utilizing the "before," "during," and "after" form of representation. The other three chose not to represent the "during" component. The level of detail varied for initial observations of the phenomenon. PETs were directed to draw what cannot be seen in inference models. For most, this involved labeling what they could not see. For example, Figure 1 shows how PET 6 labeled the gas in the bottles, and Figure 2 illustrates (by PET 2) that the distance between particles is different for gases and liquids. Three PETs labeled the process a "chemical reaction" or indicated that a transformation occurred.

Moving from inference to exhibition and finally to the provisional model, PETs became more detailed or simplified in their representations. Those with detail (PET 6, 19, & 21) involved written and symbolic representations. Simplified provisional models had measurements of what could be seen depicted on scale drawings of the bottles and balloons. Five of six provisional models included measurements for the initial amount of baking soda used in the investigation.

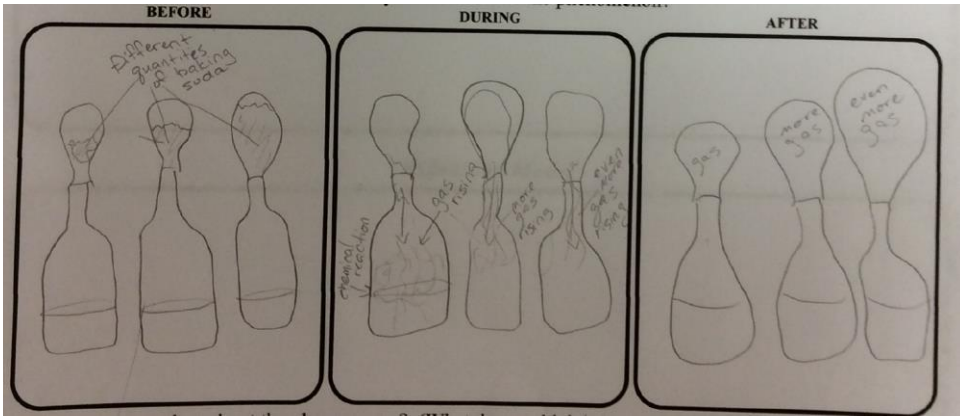


Figure 1. PET 6 inference model.

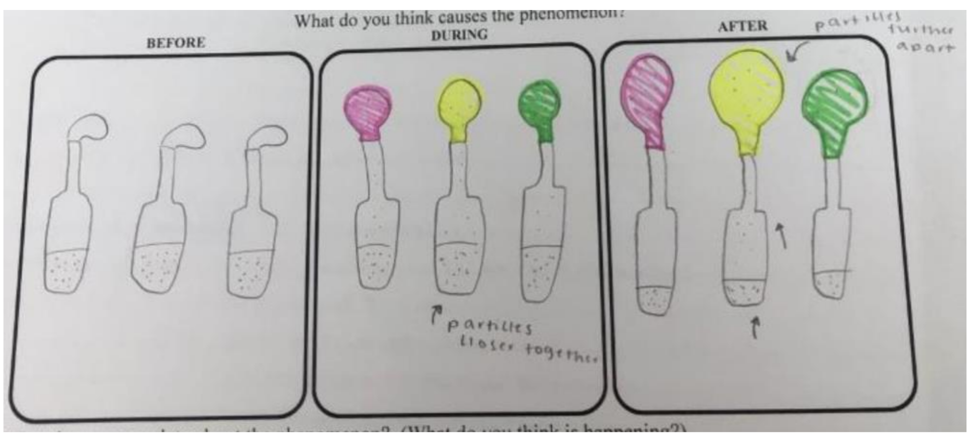


Figure 2. PET 2 inference model.

Research Question 2: How are PETs explaining the phenomenon with the CER framework?
Six of seven PETs could generate appropriate claims. PET 16 treated the claim as a hypothesis. The data she collected from her investigation indicated that baking soda differences led to equally inflated balloons. Her claim read, "I claim the more the baking soda used, the bigger the balloons will be." They don't align. She did not have evidence to support that claim, so her reasoning was stated as follows:

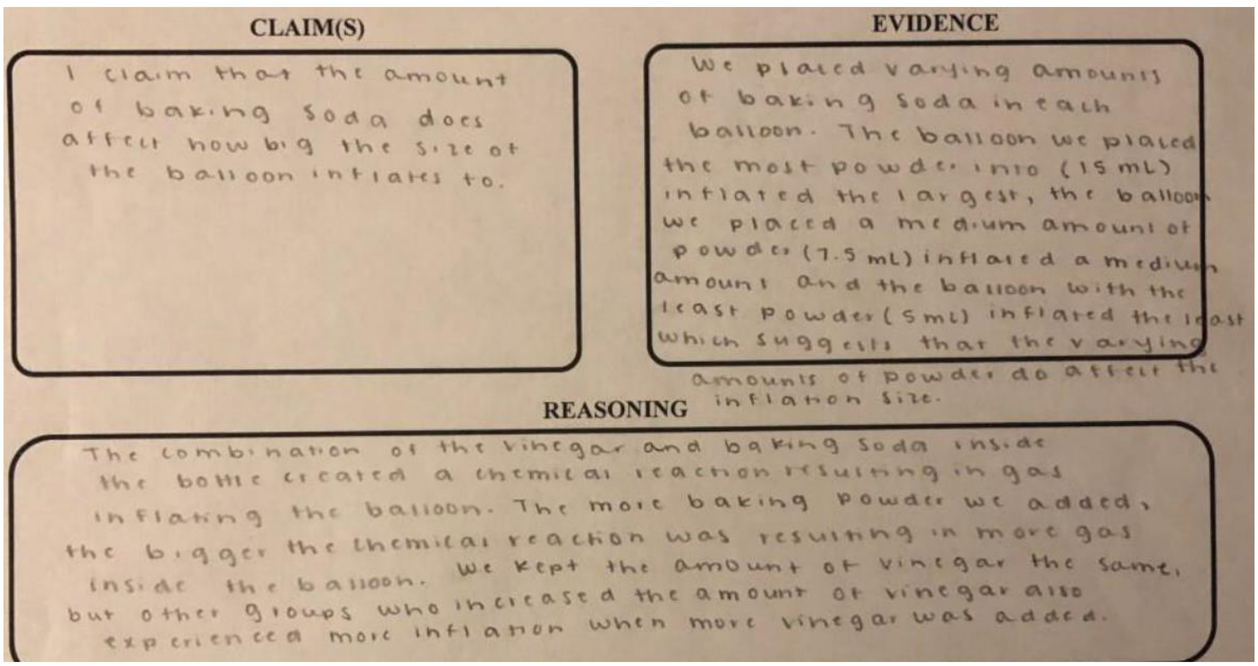
> My evidence doesn't support my claim. Even though we used different amounts of baking soda in each balloon, all the balloons turned out to be the same size. The amount of baking soda we used did not seem to change the size of the balloons. *PET 16*

For evidence, everyone but PET 16 described how the results of their investigation led to the conclusion that more baking soda caused the balloon to expand more. PETs had difficulty with the reasoning. Four restated the evidence and placed it in the reasoning section. The remaining two PETs focused on the fact that more baking soda added to vinegar caused a more significant chemical reaction. Figure 3 indicates more baking soda caused an increase in gas production.

Research Question 3: To what extent are PETs communicating their understanding via visual and written descriptions?

All PETs have written descriptions or labels on the models they developed. However, when symbols appear, they are not always labeled. For example, PET 4 labels the bubbles in the vinegar and the arrows to indicate that the gas is rising. PET 16 draws upward arrows and what appears to be compression waves at the bottom of the bottles. Neither are labeled.

PET 2 and 4 explain the chemical reaction in the CER framework; however, they do not refer to it in the model. Both PETs do not include the "during" representation; therefore, there is nowhere to label or discuss it on the model. The "before" and "after" drawings occur before and after the chemical reaction.



CLAIM(S)

I claim that the amount of baking soda does affect how big the size of the balloon inflates to.

EVIDENCE

We placed varying amounts of baking soda in each balloon. The balloon we placed the most powder into (15 mL) inflated the largest, the balloon we placed a medium amount of powder (7.5 mL) inflated a medium amount and the balloon with the least powder (5 mL) inflated the least which suggests that the varying amounts of powder do affect the inflation size.

REASONING

The combination of the vinegar and baking soda inside the bottle created a chemical reaction resulting in gas inflating the balloon. The more baking powder we added, the bigger the chemical reaction was resulting in more gas inside the balloon. We kept the amount of vinegar the same, but other groups who increased the amount of vinegar also experienced more inflation when more vinegar was added.

Figure 3. PET 2 provisional explanation.

SIGNIFICANCE

We examine prospective elementary teachers' first experience explaining and modeling phenomena in a science course. Prospective teachers develop four other models based on physical science concepts before the end of the physical science course for teachers. This first modeling experience gleans insights into their initial perspectives of modeling practice in the context of matter. Understanding how PETs conceptualize developing models and constructing scientific explanations informs the teacher educator community about how they initially engage in the science practices. By knowing what prospective elementary teachers understand, teacher educators can plan ways to support them in developing models and constructing explanations.

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