

Helping Pre-service Elementary Teachers Write Scientific Arguments and Understand Their Connection to the Common Core State Standards

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Scientific inquiry is important in elementary school science instruction. Inquiry includes asking questions, formulating hypotheses, designing experiments to identify causal variables and generate observations, keeping accurate records in order to interpret evidence, evaluating evidence, and developing arguments, models, and theories (NRC, 2007). Classroom discourse in science, such as writing, should include and support these elements of inquiry. Writing helps practicing scientists ask questions, solve problems, reflect on and propose explanations, collaborate with other scientists, and communicate and persuade others of their findings. Writing during school science instruction using tasks that model how practicing scientists write can aid students' learning about science and writing and help teachers connect hands-on science instruction to the Common Core State Standards for English Language Arts (CCSS).

Over the last three years, more than one hundred pre-service elementary teachers participated in a study in which I collected and examined their personal science writing and the writing they asked elementary students to complete as part of week-long science units conducted in a local urban elementary school. The teachers were senior undergraduate or graduate students enrolled in my one-semester science education pedagogy course where I taught them to use a pedagogical tool called "science notebooks" for their own learning of science concepts and development of scientific arguments, and in practice teaching sessions with their peers. I also encouraged though did not require them to have their elementary students use science notebooks. There are many variations of the pedagogical tool called "science notebooks" (e.g. Gilbert & Kotelman, 2005; Marcarelli, 2010; Norton-Meier, Hand, Hockenberry, & Wise, 2008), but generally they are used by science students of all ages to record prior knowledge, questions, data, scientific arguments and explanations, and reflections of learning to help make sense of science experiences and build understanding of science concepts. The benefits of using science notebooks are that they help students explain their reasoning through expository writing, help guide teacher instruction, enhance students' literacy skills, support differentiated learning, and help to foster teacher collaboration (Gilbert & Kotelman, 2005). Figure 1 shows an entry from a pre-service teacher's science notebook written during a lesson about force in which many of the main components of the science notebook are labeled with headings.

Figure 1 Pre-service teacher's science notebook entry for a lesson about force.

Feb 7 - Feb 14

Make it Move

Question - How many different ways can you move the ball?

Prediction - I think that there are multiple ways why - because right away I can think of at least 5 (throw, kick, roll, use hands + foot)

Claim
How many ways can you move the ball
 8 ways to move the ball

Evidence
How did you combine post-HS to get this number?
 • Throw
 • Blow
 • Roll
 • Move w/ feet
 • using hands + fingers
 • Bounce
 • Drop (use gravity)
 • Move w/ object

Reason - Why do you think there are this many ways?
 We found a lot of ways but many were very similar and we were able to make groups that use the same ~~objects~~ objects, ~~body~~ body parts, or force.

Reason
Force - applying pressure to an object to make it move by pushing and pulling - everything is either push or pull

Claim - 2 ways to move the ball

Evidence - From book and redone posts

Explore

Teacher explain

Theoretical Framework and Literature Review

A condensed version of Toulmin's (1958) argumentation structure served as the theoretical framework for the scientific arguments the pre-service teachers were taught to write. This structure includes three of Toulmin's categories: claims, data, and warrants (reasons). Claims are assertions or propositions that provide a general statement about what happened and require justification or substantiation from data (Sampson & Clark, 2008). As Driver, Newton, & Osborne (2000) explain, "Claims are seen to be grounded through the process of argument – relating the imaginative conjectures of scientists to the evidence available (p. 295), while evidence is the arbiter that scientists look to when competing theories arise. Both claims and evidence hold a central role in science learning as well.

Claims, evidence, and reasons were taught to the pre-service teachers because these form the core of argument construction and are the basis of scientific inquiry as described in national science education standards documents (e.g. NRC, 2000; NRC, 2007) and previous research (e.g. Zembal-Saul, 2009; Zembal-Saul et al., 2002; Ruiz-Primo, Li, Tsai, & Schneider, 2010). Yet, the development of these components is quite challenging for beginning elementary teachers, who often lack the pedagogical and science content knowledge and understanding about how science works that is helpful in formulating more extensive science arguments (Davis & Smithey, 2009; Driver et al., 2000). Previous research has also found that students and teachers at all levels have difficulty constructing arguments through talk and writing (Zeidler, 1997; Zembal-Saul et al., 2002; Zohar, 2004). Thus, Toulmin's abbreviated framework of claims, evidence, and reasons helped the pre-service teachers understand how to guide their elementary students and become aware of what constitutes an argument in science. In my science education pedagogy course, claims, evidence, and reasons were continually expected as the way of presenting findings from hands-on investigations in science.

The act of writing scientific arguments during science instruction makes students' thinking visible as they coordinate their claims, evidence, and reasons (Zembal-Saul, 2009). By writing these aspects of their argument, as in science notebooks, students learn how to use the language of science while making meaning of scientific concepts at the same time (Mortimer & Scott, 2003; Zembal-Saul, 2009). Writing helps students better understand content because they are manipulating new concepts in order to write about them (Applebee, 1984). This is because, according to Vygotsky (1934/1986), writing requires higher cognitive functions in order to: (a) convey one's written message to an imaginary or absent person without the expression and intonation of oral speech, and (b) make a conscious effort to portray meaning using alphabetic symbols, sound structures, and sentence sequences so that the situation is explained fully and intelligibly to a reader (including to students themselves when they look back on their writing later). This process is often called writing-to-learn (Fulwiler, 1987; Gere, 1985; Zinsser, 1988).

Writing-to-learn is the idea that writing causes the learner to synthesize information, much of which has never existed until he or she thinks and writes it, thus allowing the learner to become aware of the connections made and thereby knowing more than before writing it (Van Nostrand, 1979). Olson (1977) pointed out that written language must be explicit in its meaning, is permanent and subject to scrutiny, criticism, and reflection, and helps formulate abstract statements into factual knowledge. Thus, writing is "an instrument for the exploration of new

ideas” (Olson, 1977, p. 16) and a “specialized tool of analytic thinking” (p. 18), since meaning must be formed through explicit explanations that use logical grammatical structure. At the same time, the writer must also have knowledge of and experience with the concepts about which he or she writes in order to successfully convey information and ideas so that others will understand. It is these aspects of writing that are important for enhancing a writer’s cognitive processes.

Writing-to-learn is an appropriate cognitive addition to hands-on science activities because it helps students build knowledge, construct understanding, and engage in the reasoning and problem-solving processes of scientists (Glynn & Muth, 1994; Yore, Bisanz, & Hand, 2003). Science activities that involve inquiry provide students with an authentic purpose for writing-to-learn (Keys, 1999). As students use writing-to-learn tasks, they gain opportunities to develop written English skills (such as vocabulary, grammar, spelling, and punctuation), to create arguments and persuade others of scientific claims, and to learn the technical writing of science (Rivard, 1994; Yore et al., 2003). In my study, science notebooks served as the tool with which pre-service elementary teachers used write-to-learn strategies to reason about science topics and create scientific arguments using the claims-evidence-reasoning structure. Additionally, this enabled the purposeful connection to the Common Core State Standards for English Language Arts.

Findings from Pre-service Teachers’ Science Notebook Use with Elementary Students: Year One

During the first year of this study, I examined how pre-service teachers used science notebooks and elements of written arguments with their elementary students during a week-long science unit that they planned and implemented in an urban elementary school (Glen & Barry, 2012). Of the twenty-three unit plans analyzed for this part of the study (each unit plan was co-written and co-taught by two or three pre-service teachers working together on teaching teams), the teachers taught anywhere from two to six science concepts, with an average of three to four concepts taught during the five days of teaching. A “unit plan” is a series of five related one-hour-long science lessons surrounding a main topic chosen from state and national science standards. For example, a unit plan about sound would include five lessons. The following four main concepts, each possibly taking more than one lesson to teach, might be included: (1) sound is caused by vibrations; (2) sound travels through matter; (3) changing the volume of sound is accomplished by changing the intensity of the vibrations; and (4) changing the pitch of sound is accomplished by changing the frequency of the vibrations. I analyzed the unit plans for each concept taught by calculating the number and types of instances in which the pre-service teachers asked their elementary students to write in science notebooks. As mentioned above, I did not require the pre-service teachers to have their students write in science notebooks, but I did require them to have their students formulate claims and evidence.

Table 1 shows the number of unit plans for each concept taught that included components of a science notebook. Not all unit plans included five concepts, so the total number of unit plans for each concept is included in parentheses (e.g., twenty-three unit plans taught at least two concepts for the week, whereas only fourteen unit plans taught at least four concepts for the week). The

list of science notebook components was developed by looking at the individual lesson plans for each unit to see what elements of inquiry teaching and learning had been presented to students and then which of those elements students subsequently recorded in writing in science notebooks.

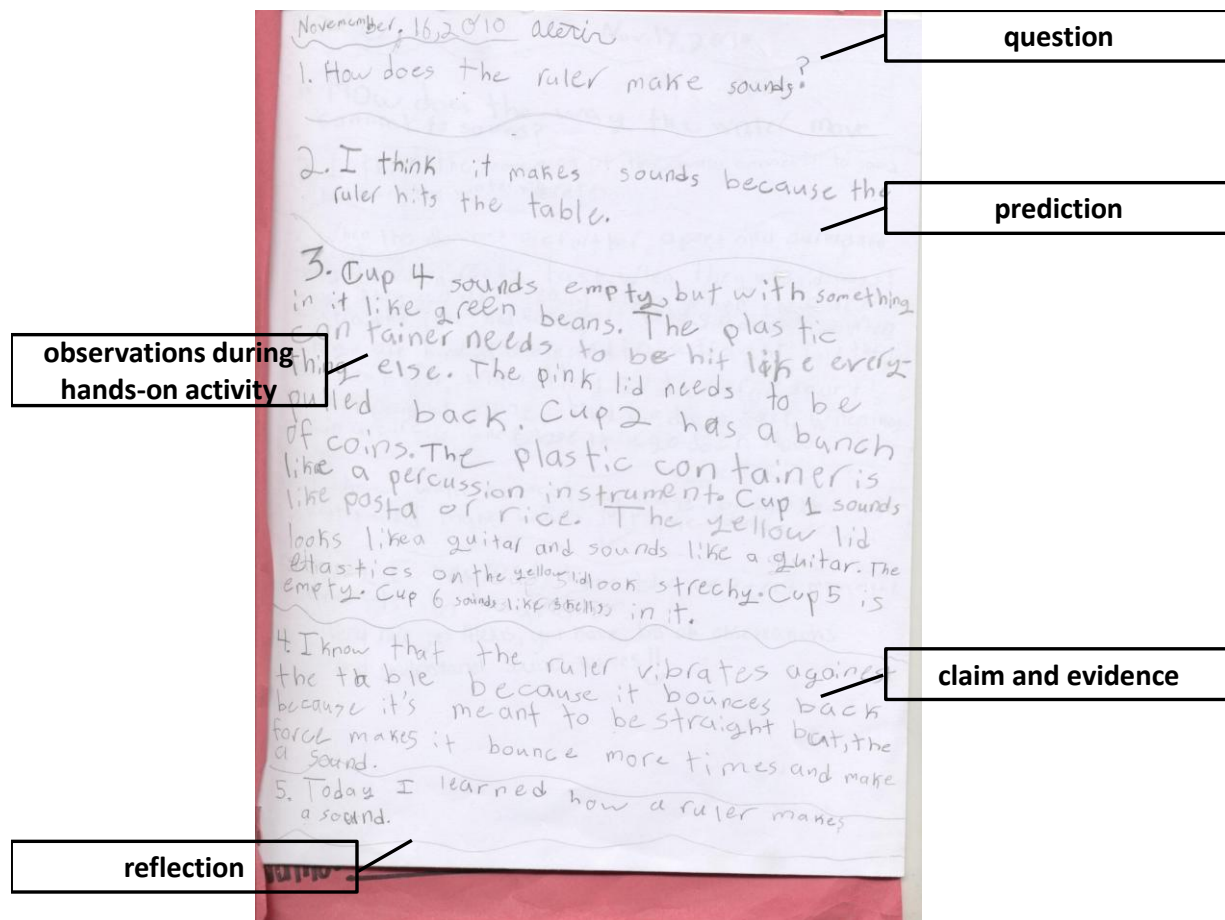
Table 1 Summary of Science Notebook Components for Concepts Taught in Week-Long Units

Science Notebook Component	Concept 1 (23 unit plans)	Concept 2 (23 unit plans)	Concept 3 (22 unit plans)	Concept 4 (14 unit plans)	Concept 5 (5 unit plans)
Guiding Question	10	10	7	3	0
Prediction	13	12	10	3	0
Data & Observations	19	18	16	3	3
Claims w/ Evidence	7	9	2	1	1
Claims w/out Evidence	6	2	1	1	2
Reason Created by Student	5	0	4	0	2
Definition Created by Student	5	5	6	5	0
Definition Created by Teacher	4	3	2	1	0
Reflection on Learning	6	6	4	2	0

Table 1 shows that the pre-service teachers most often asked their elementary students to record data and observations in science notebooks. Predictions and questions were the second most common type of entry. One reason for these results may have been that these elementary students did not typically encounter inquiry in their science instruction, and therefore data, observations, predictions, and questions may have been the easiest for them to write because such entries require less thinking and could be recorded more quickly. Additionally, these students did not know how to formulate claims, evidence, and reasons in science, and so learning these skills as well as writing about them may have been too much for the pre-service teachers to expect the students to accomplish. Finally, it seems that when the pre-service teachers tried to accomplish more concepts during the week, there were fewer components recorded overall in the science notebooks, particularly claims, evidence, and reasons. For example, one team of pre-service teachers attempted to teach a sixth concept during their unit (not shown in table), which was done entirely by lecture. Writing in science notebooks takes time, and so when the pre-service teachers tried to squeeze more concepts into a unit, the students simply had less time to write in their notebooks.

Overall, in only ten of twenty-three unit plans did the pre-service teachers ask their students to create claims supported with evidence for two or more concepts in that unit. In eight unit plans, the pre-service teachers asked students to create reasons for two or more concepts. Additionally, in eight unit plans, the pre-service teachers asked for claims supported with evidence *and* reasons for at least one concept, and one unit plan even did this for two concepts. However, all eight of these unit plans used some combination of written and oral discourse; thus, students were not always asked to record their arguments in notebooks. For example, Figure 2 shows a third grade student's science notebook entry for the first lesson in a unit about sound. This entry includes a guiding question, a prediction, observations, a claim supported with evidence, and a reflection, but does not include reasons to support the claim.

Figure 2 Science notebook entry from a third grade student for a lesson about sound.



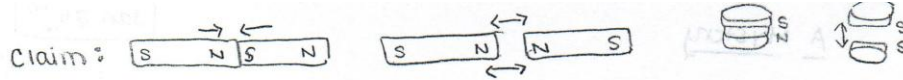
In only six unit plans did the pre-service teachers ask their elementary students to provide supporting evidence for *all* claims created. Contrary to this, in only three unit plans were students asked to provide claims *and never* supporting evidence. Thus, the teachers most often had students write a combination of claims supported with evidence and claims not supported with evidence. Finally, four unit plans seemed to confuse evidence and reasoning, in that they often had students produce a reason for a claim but not evidence.

In summary, when pre-service teachers asked their elementary students to write in science notebooks, the entries were most often data, observations, predictions, and guiding questions. These findings are only slightly different from previous studies that found in-service teachers most often asked students to record data and observations (Alonzo, 2001, 2008; Baxter, Bass, & Glaser, 2001; Ruiz-Primo et al. 2010). Most of the pre-service teachers included some aspects of a scientific argument, whether oral or written, one or more times during their units. Many of the pre-service teachers, although they did include aspects of scientific arguments, seemed to find it difficult or lacked the time to include claims *and* evidence *and* reasoning for each concept taught. It also seems that all of the pre-service teachers may not have fully understood the importance of having their students record in writing all components of a scientific argument, including claims, evidence, and reasoning, despite seeing these components modeled for them and utilizing science notebooks in this way for themselves.

Pre-service Teachers' Personal Science Notebook Use: Year Two

As a result of the findings of year one of this study, I realized that it would be important to look at what the pre-service teachers themselves were doing during my science education pedagogical course in their personal science notebooks in order to begin to understand why their use of written scientific arguments was limited during their science unit plans taught in the elementary school. Therefore, during the second year of this study, I examined forty-eight teachers' notebooks from the model science lessons taught to them by me and peer-taught to each other during my one-semester science education pedagogical course (Glen, 2013a). First, I highlighted the notebook entries from each pre-service teacher to show where the claims, evidence, and reasons were for each topic in the notebook. Entries were only highlighted if it was clear the teacher was writing a claim, evidence, and reason, typically indicated by headings containing those words, guiding questions provided by the instructor, or the placement of headings after a series of observations. One difficulty occurred when in one of the classes, during the peer teaching experience, many of the pre-service teachers used the words "prediction" and "claim" synonymously, sometimes leading to difficulty determining if the teacher was indeed writing a claim. I then gave the highlighted entries in each science notebook a numeric score that followed with McNeill's (2011) argument coding scheme: claims could earn 0-1 points, evidence 0-2 points, and reasons 0-2 points. The one change I made was that, unlike McNeill, who coded both no entry and vague/inaccurate entries as 0, I used a 0 only for vague/inaccurate entries and I did not code entries that were not present. Instead, I calculated the number of students who wrote arguments for each topic, which is presented with the findings. Figure 3 is a science notebook entry written by a pre-service teacher about the topic of magnets, responding to the guiding question of, "How are the [doughnut] magnets staying apart [on the straw]?" that shows a maximum score possible for claim (1), evidence (2), and reason (2).

Figure 3 Science notebook entry showing a maximum score possible for claim, evidence, and reason for a lesson about magnetic properties.



Claim: Opposite sides of the bar magnet came together and like sides of the bar magnet would not.

Reasoning: Opposites attract and like sides repel, so the sides of the doughnut magnets that were sticking together were opposite sides and the sides of the doughnut magnets that were repelling were like sides.

One way that I learned more about the pre-service teachers' construction of arguments during science lessons was to calculate the percentage of pre-service teachers who wrote claims, evidence, and/or reasons in their science notebooks for each topic taught. Figure 4 shows this data. (A score of 1 on the graph is equal to 100% of students). The first four model lessons, which were taught by me, had the highest incidence of written arguments in the teachers' science notebooks, ranging from 86% of teachers for the first lesson to 92% and higher for the other three lessons. The other three model lessons taught by me at the end of the semester, about technology and electrical and acoustical engineering, had a much lower percentage of students who wrote scientific arguments in their science notebooks, even though part of these lessons included specific guiding questions and time for writing arguments. The rest of the lessons in Figure 4 (Moon Shape through Magnetic Materials) were taught by the pre-service teachers to their peers at the mid-semester point. Of these lessons, the ones that generated the most scientific arguments in the teachers' notebooks were the lessons about magnetic materials (68%) and the shape of the moon (66%). The lessons for which the least number of teachers had arguments written in their notebooks were those about electrical circuits (36%), food chain components (40%), and condensation (45%). Thus, it seems that despite modeling scientific arguments and encouraging pre-service teachers to write them in their notebooks at the beginning of the semester, the number of teachers who wrote arguments or encouraged their peers to do so during peer teaching lessons and during my end-of-semester model lessons was much less than at the beginning of the semester.

Figure 4 Percentage of students who wrote claims, evidence, and/or reasons for each lesson.

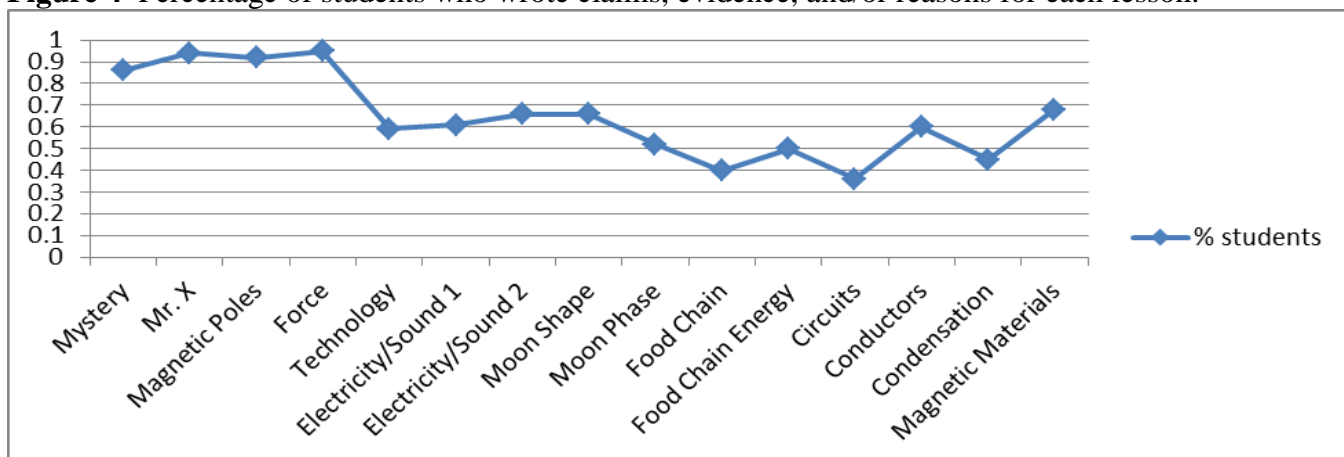
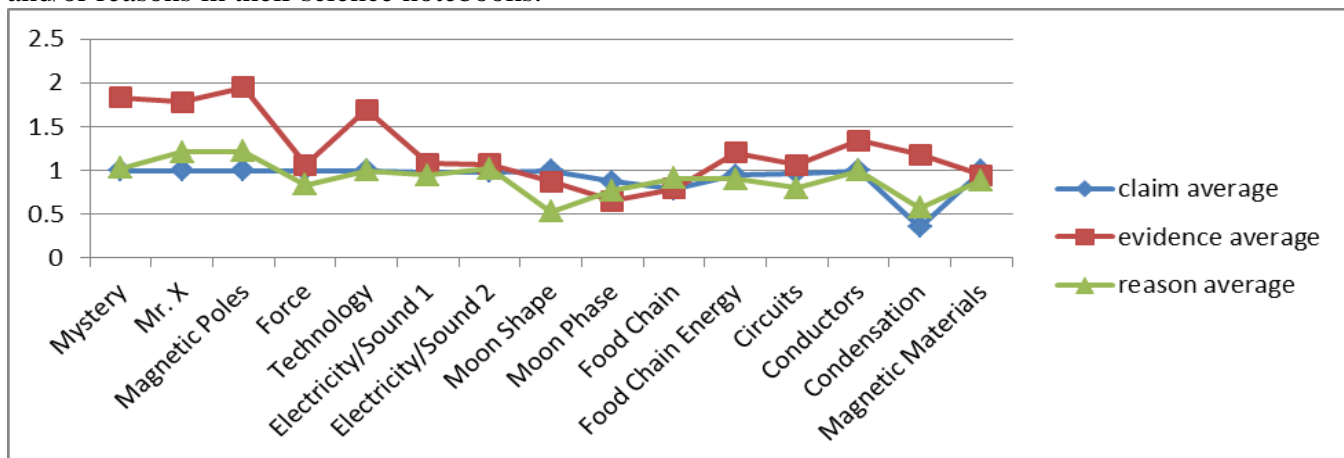


Figure 5 shows the pre-service teachers' abilities to construct accurate and appropriate claims, evidence, and reasons for each topic taught. As mentioned above, the science notebooks were only coded if these components were present. Claims were coded as 0 or 1, evidence as 0, 1, or 2, and reasons as 0, 1, or 2 (McNeill, 2011).

Figure 5 Average argumentation scores of pre-service teachers who wrote claims, evidence, and/or reasons in their science notebooks.



The claims written by the teachers were usually accurate and appropriate and were coded as 1. The two exceptions to this were the claims made about condensation, with an average claim score of 0.35, and food chain components, with an average of 0.79, both with higher incidence of inaccurate claims than with other topics. The topics for which the pre-service teachers had the most appropriate amount of evidence recorded that was also accurate were topics taught by me, with the exception of force and electrical and acoustical engineering. For these two topics, the teachers tended to have only one supporting piece of evidence, whereas the coding scheme requires students to have two or more pieces of accurate supporting evidence to earn a score of 2. The topics taught by the teachers to their peers tended to have less supporting evidence than the topics taught by me. Finally, the pre-service teachers seemed to have the most trouble writing accurate and sufficient supporting reasons for claims about the topics taught. This seemed to be

the case no matter who taught the lesson, with perhaps the exception of the Mr. Xavier mystery lesson and the magnetic poles lesson taught by me, where the average score for reasons was 1.21 and 1.22, respectively.

The results of this part of the study suggest that despite modeling how to write scientific arguments, using guiding questions to help pre-service teachers write arguments in their science notebooks, and providing additional articles to read that explains this facet of inquiry, many of these teachers still have difficulty writing scientific arguments. The pre-service teachers in my study seemed able to write accurate claims more often than other components of an argument. Perhaps claims were easier to write because they involved simply answering the guiding inquiry question for the lesson and required less writing than other components of the argument, or because the pre-service teachers had some prior knowledge of many of the topics taught and could therefore more easily formulate accurate claims after experiencing the topic again in a hands-on way. The pre-service teachers often had at least one accurate and appropriate piece of evidence for the topics taught, but the findings of my study suggest that I need to emphasize more during class that claims need multiple pieces of evidence to be well-supported. Finally, the pre-service teachers were quite vocal about their difficulty in writing reasons. Although they knew basic information and could write accurate claims, they did not feel they had enough formal science experience or specific background knowledge to write accurate reasons. My findings also suggest that I need to emphasize more during class how reasons must link back to the claim. Many teachers had accurate reasons for several topics but failed to write enough about these reasons to actually explain and support the claim. For example, in the magnetic poles lesson, most teachers wrote an accurate reason for why the circle magnets were staying apart when placed on a straw: "Opposite poles attract, like poles repel." However, this simple statement does not link back to the claim and explain why this scientific phenomenon allows unlabeled magnets to push each other apart on the straw. Thus, the above reason was coded as 1.

Finally, it seems that when the pre-service teachers were left to plan the lessons on their own and were given the option to have their peers write and/or orally produce arguments, not all of them asked their peers to write arguments. So, although all of their lessons were required to include claims, evidence, and reasons, many of the pre-service teachers had their peers do this orally instead of in writing. Or, for those lessons where some peers wrote arguments and others did not for the same lesson, there was no accountability for written explanations in their notebooks because the notebooks were not collected or graded.

Overall Discussion and Implications

There are few strategies available to teachers for supporting students' argumentation construction in science (Driver et al., 2000; Zeidler, 1997), but science notebooks can be one. However, the pre-service teachers in my study used science notebooks in limited ways, both with their elementary students and for their own science learning while in the methodology course. These findings suggest that I need to be more explicit in explaining to pre-service teachers the connections between what learning looks like in science and how it can be accomplished through writing, including writing in science notebooks. I do not think the teachers in my study fully understood how writing aids learning and can be used as assessment; therefore they were unclear

as to why they would want to take the time to have students record claims *and* evidence *and* reasons for concepts they teach. This is not to discount the role of oral discourse in learning and argument construction, which researchers have found to be important as well (Mason, 1998; Rivard & Straw, 2000). However, as described earlier, writing-to-learn enables the learner to make connections among information that cannot be achieved orally, and writing arguments in science is one way to write-to-learn science.

Secondly, the pre-service teachers seemed to struggle with writing complete arguments for the science lessons taught, even during those lessons in which I had specific scaffolds to help them write an argument. One reason for this may have been their understanding of the purpose behind writing a scientific argument. Berland and Reiser (2009) note three important reasons to write claims, evidence, and reasons: to make sense of the phenomenon studied, to articulate these understandings, and to persuade others. The pre-service teachers most likely had few opportunities to persuade others about science before taking my course and may not have recognized that as a rationale for why claims, evidence, and reasons are important to formulate. Additionally, in order to persuade someone about a phenomenon in science, you need to have something important and contestable to persuade them about. A focus on the tentativeness of science by creating engaging and motivating lessons where a specific, correct answer is neither known nor expected may be needed to better model the role of argumentation in science. This can be aided by examining with the pre-service teachers the science practices put forth in *A Framework for K-12 Science Education* (NRC, 2012). In accordance with this framework, I already teach the science practices of explanation and argumentation within the context of science content in my course. However, possibly missing from my instruction of argumentation is the point that “all ideas in science are evaluated against alternative explanations and compared with evidence” (p. 44) to allow the assessment and acceptance of the most satisfactory explanation (2012). Perhaps a new approach I need to take during the model science lessons would be to ask the pre-service teachers to evaluate each other’s evidence-based claims and to brainstorm alternative arguments for the situation.

From a practical perspective, I need to place more emphasis on helping pre-service teachers record more pieces of evidence, ensure they understand the importance of evidence in supporting claims, and help them write reasons that are both scientifically accurate and that link to the claim more specifically. I might accomplish these goals with better guiding questions when teaching pre-service teachers how to write arguments and by helping the teachers create guiding questions for use during their own teaching of science lessons. I also need to place more emphasis on the importance of writing arguments during science lessons rather than presenting them all orally. This will allow me to also teach about integrating authentic scientific writing (Glen & Dotger, 2013b), such as explanation and argument construction, and demonstrate how written arguments can serve as an assessment and record of students’ science knowledge. Finally, I should present to the pre-service teachers the actual rubric from my argument coding scheme, along with examples of what a 0, 1, and 2 look like for each category, in order to better help them write their own scientific arguments. They might then create their own argument-scoring rubric to be used with their elementary students during the science units they teach. During the pedagogy course, although I used specific guiding questions to help the teachers write claims, evidence, and reasons for all of the lessons I taught, and the teachers read articles describing how to best formulate scientific arguments, I never presented examples or the rubric itself.

Connections to the Common Core State Standards

Another implication of these findings is that we should help ensure pre-service teachers understand how writing scientific arguments, and writing in science notebooks, can help teach many of the college and career readiness anchor standards for writing in grades K-5 Common Core State Standards for English Language Arts (CCSS; National Governor's Association Center for Best Practices, Council of Chief State School Officers, 2010). So, for example, using a writing tool such as a science notebook, regardless of what components of science inquiry are written in it, expects students to "write routinely over extended time frames" (p. 18), a writing standard in the CCSS (2010). Students' notebook entries can be used to turn their newfound science knowledge into the genres expected in a school's writing curriculum, such as expository, persuasive, or narrative writing. Thus, students' science notebooks can double as writers' notebooks where ideas are planned and tried before committing them to more formal published writing (McQuitty, Dotger, & Kuhn, 2010). This enables students to "develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach" (p.18), an expected standard of the CCSS (2010). The CCSS expects students to "write arguments to support claims ... using valid reasoning and relevant and sufficient evidence" (2010, p. 18), goals that are the focus of this essay as well. The CCSS also states that students can best meet its standards by gaining "discipline-specific expertise" and gathering "experimental evidence in science" (2010, p. 7). This supports the scientific practices of *A Framework for K-12 Science Education* (NRC, 2012). Therefore, teachers should engage their students in scientific practices such as constructing explanations and arguments in science notebooks, and eventually turning this writing into the expository and argumentative genres that are a part of the writing standards. Through gathering experimental evidence and learning via scientific inquiry to write scientific explanations and arguments, students learn to "conduct short as well as more sustained research projects based on focused questions" (p.18), another expected writing standard from the CCSS (2010).

Helping pre-service teachers understand the connections between how they are learning to teach science and how that science instruction pertains to writing standards is important. Previous research has found that in many elementary classrooms, science is skipped over during the day to make time for language arts, mathematics, and other non-curricular activities (Plourde, 2002), because many elementary teachers feel more comfortable with their ability to teach language arts rather than science (Dickinson & Young, 1998). Therefore, encouraging pre-service teachers to make connections between what they tend to feel more comfortable with, such as language arts, and what they do not, such as science, may lead to more standards-based teaching in both subject areas. Writing scientific arguments and recording them and other scientific information in science notebooks allows teachers to meaningfully connect writing standards with content areas like science. During my course, I typically take one class period to examine the CCSS and note its connection to science. However, doing so more routinely for each science lesson I teach and expecting the pre-service teachers to point out the relevant writing standards during their own science lessons might help demonstrate the importance of using writing-to-learn during science instruction.

The data presented in this essay is from two different years of working with pre-service teachers, so a direct link cannot be made between how well pre-service teachers are able to write scientific arguments in their own science notebooks and what they then ask their elementary students to do during science unit teaching. However, pre-service teachers' abilities to write their own scientific arguments in science notebooks may have direct implications for how well they are able to have their own elementary students do the same during science lessons. Future analysis of additional data collected as part of this study, including analysis of pre-service teachers' science notebooks from the same semester that their science units and elementary students' written science work are analyzed, may help show this connection and the importance of ensuring that pre-service teachers have strong knowledge of, and rationale for, creating and teaching scientific argumentation prior to their teaching in an elementary classroom. Then, more specifically connecting science teaching to writing standards will hopefully encourage and build the pre-service teachers' - and ultimately their elementary students' - generation of ideas, information, and skills in both subjects.

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