

Connecting Preservice Teachers and Scientists Through Notebooks

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Abstract

The use of science notebooks in an elementary methods course can encourage preservice teachers' engagement in collaborative work and participation in science through writing (Morrison, 2008). In this paper we describe how we, a teacher educator and a scientist, collaborated to focus on how scientists use notebooks in their work, and how this compares and contrasts to how notebooks can be used in both a preservice elementary methods course and in the elementary classroom. We describe our facilitation of notebooks with preservice teachers and how we emphasize professional scientists' use of notebooks. Additionally, we offer recommendations based on our experiences in our collaboration and facilitation of notebook use with preservice teachers. Our intention is to provide recommendations that can be applied in a variety of university contexts, such as emphasizing the Science and Engineering Practices and the Nature of Science, including discussion about the work of professional engineers, and making connections to literacy.

Introduction

The use of science notebooks in an elementary methods course can encourage preservice teachers' engagement in collaborative work and participation in science through writing (Morrison, 2008). Furthermore, it can offer opportunities to preservice teachers to engage in working and thinking like a professional scientist, and to think critically about how this notion can be transferred to elementary science teaching. While there is prior work on using science notebooks with preservice teachers, the purpose of this paper is to demonstrate how collaboration across disciplines can support an emphasis in the methods course on how scientists work, or more specifically, how scientists use notebooks in their work. This paper describes how an elementary education faculty member (Ingrid) and a science faculty member (Sarah) collaborated on the integration of science, health, and engineering notebooks into an elementary preservice science and health methods course.

Ingrid is an Associate Professor in the Department of Elementary Education and Literacy and teaches the science and health methods course for elementary preservice teachers. Sarah is a lecturer in the Department of Earth and Atmospheric Sciences with expertise in environmental chemistry. In addition, she has taught the prerequisite science content courses designed for elementary preservice teachers. The idea to begin this collaboration was initiated by an interest by both authors to build a "real-world" connection for preservice

teachers about how scientists use notebooks in their work, and how this can potentially enhance preservice teachers' learning about science notebooks as well as their use of notebooks with their future elementary students.

Science Notebooks with Preservice Teachers

Prior research has indicated that use of science notebooks in preservice methods courses has been fruitful and has positively influenced preservice teachers' science learning (Morrison, 2005; Morrison, 2008). Morrison (2008) found that preservice teachers valued recording their science ideas. By the end of the semester they viewed the notebook as a learning tool, rather than as an assignment that was being graded. Indeed, they became less concerned about the neatness of their notebooks, and more focused on their use of the notebook. Further, preservice teachers indicated that they planned to use science notebooks in their future classrooms as a place for students to record their thinking and as a formative assessment tool. An earlier study by Morrison (2005) also noted that science notebooks supported preservice teachers' understanding of formative assessment. Dickinson and Summers (2011) found that preservice elementary teachers engaged in both written and graphic recordings of their thoughts in their science notebooks and the participants indicated they would like to use the notebooks they created in class as examples for their future students. Frisch (2018) examined preservice elementary and special education teachers' use of a hybrid digital/paper-and-pencil notebook. She found that preservice teachers most frequently chose to use a hard copy notebook (e.g., recording observations, writing reflections, creating concept maps) and included photos to demonstrate their learning.

Teachers Working with Scientists

We sought to build on prior work using science notebooks with preservice teachers by incorporating how professional scientists use notebooks in their work. In our work, we aimed to integrate rich examples of and discussion about how scientists use notebooks to enhance the use of notebooks in the methods class. Brown and Melear (2007) examined secondary preservice teachers' experiences working as apprentices with professional scientists. They found that the preservice teachers valued the experience working with professional scientists and the learning that took place, and that the experience supported their confidence to teach inquiry-based science. Further, the preservice teachers saw the value in supporting their own future students' interest when teaching science. Sadler, Burgin, McKinney, and Ponjuan (2010) conducted a review of literature of secondary students, college students, and K-12 teachers working as research apprentices on science research projects. They found that teachers' understandings of the Nature of Science (NOS) improved, as well as their confidence in their ability to do and teach science. They also found, however, that changes in teacher practice varied and that limitations existed with regard to transferability of the science research experience to the classroom context. More recently, Anderson and Moeed (2017) examined inservice teachers' beliefs about science after working with professional scientists for six months and found that the teachers developed a deeper understanding of

scientists' work and NOS. Tala and Vesterinen (2015) found that “teacher students” held a “deeper and more focused view” (p. 451) in their understanding of elements of the science practices (i.e., modeling) after engaging in contextualized interviews with scientists about their work.

Prior research indicates the value of using notebooks with preservice teachers in methods courses, as well as providing teachers the opportunity to talk and work with scientists. Therefore, the purpose of this work was to make explicit connections between science notebooks at the preservice teacher and elementary school level, and notebooks professional scientists create. In the next section, we describe how we infused the use of notebooks in the preservice methods course, and how we made connections between how the preservice teachers were using their notebooks, how elementary students might use notebooks, and how professional scientists use notebooks.

Notebooks in the Elementary Science and Health Methods Course

The science and health methods course meets once a week for 2 hours and 35 minutes (plus a 15-minute break) over a 15-week semester. The preservice teachers in the science and health methods course are usually undergraduate juniors—the methods course is taken one or two semesters before they begin a year-long teaching residency. Most of the preservice teachers are majoring in elementary education, which includes all the coursework and experiences they need for state K-6 general education teaching licensure. The methods course is part of a block of co-requisite courses that includes the mathematics methods course and a shared 45-hour field experience. The preservice teachers are required to take two 3-credit science content courses in their general studies program as prerequisites to the science and health methods course. Sarah has worked extensively in revising and teaching the two science content courses for elementary teachers. The preservice teachers also take a 2-credit health and physical education course for elementary teachers. While they do not take an engineering course as a part of their program, Ingrid incorporates engineering into the science and health methods course because the new 2020 Colorado Academic Standards for Science (Colorado Department of Education, 2018) were developed based on the Next Generation Science Standards (NGSS) that integrate engineering concepts into the science standards. Preservice teachers have sometimes stated that they have experience creating a science notebook in their K-12 education, and/or they have created notebooks in other content methods courses in their elementary education program. The following sections describe how science, health, and engineering notebooks are introduced and facilitated throughout the semester in the methods course.

Introducing the Science, Health, and Engineering Notebook

Ingrid introduces notebooks to the preservice teachers in the first (or second) class session of the 15-week semester. The introduction begins with asking preservice teachers to read Nesbit, Hargrove, Harrelson, and Maxey's (2004) article titled “Implementing Science

Notebooks in the Primary Grades” before coming to class. This article provides an overview of how and why notebooks can be used in elementary classrooms. Preservice teachers are given the assignment to keep their own science, health, and engineering notebooks throughout the semester (see Appendix A for notebook assignment description and rubric). As stated in the assignment description, creating their own notebooks throughout the semester is designed to “allow [preservice teachers] to **explore if and how** [they] will use this tool **as a teacher** in [their] own science, health, and engineering instruction.” Preservice teachers use their notebooks during almost every class period (with the exception, for example, of class sessions when students plan and conduct teacher rehearsals), and create two entries: one “student” entry where they record information as they engage in an inquiry lesson suitable for elementary students, and one “teacher” entry where they analyze and record ideas on teaching methods and pedagogy. This is based on the idea of science interactive notebooks that suggests K-12 students create a two-sided notebook (Young, 2012). For school-aged students, the left side can contain “output,” or ideas to support students as they process and think critically about information and concepts. The right side contains “input,” or the data that students gather while investigating a concept (Young, 2012). Preservice teachers are asked to distinguish their entries a bit differently, as they choose one side of their notebook for “student” entries and one side of their notebook for “teacher” entries. This format is designed to indicate to preservice teachers which course activities are intended to model pedagogy (student entry) and which activities involve reflection, application, and metacognition about science teaching (teacher entry). For example, early on in the semester preservice teachers begin to learn about inquiry and the Science and Engineering Practices ([SEPs], NGSS Lead States, 2013). Preservice teachers read about the SEPs for class (Konicek-Moran & Keeley, 2015), and then in class engage in an abridged version of the Sheep in a Jeep lesson (Ansberry & Morgan, 2010) on the “student side” (see Figure 1). For the “teacher side,” small groups work together to create a summary of characteristics of each SEP and share this with the class. The preservice teachers then work in their table groups to reflect on and record their ideas about which and how the SEPs may be evident in Sheep in a Jeep lesson. Figure 2 demonstrates an example of this work as preservice teachers begin to develop an understanding of the SEPs at the beginning of the semester and how they connect to an inquiry lesson.

Figure 1 (Click on image to enlarge). Preservice teacher notebook of the “student” side.

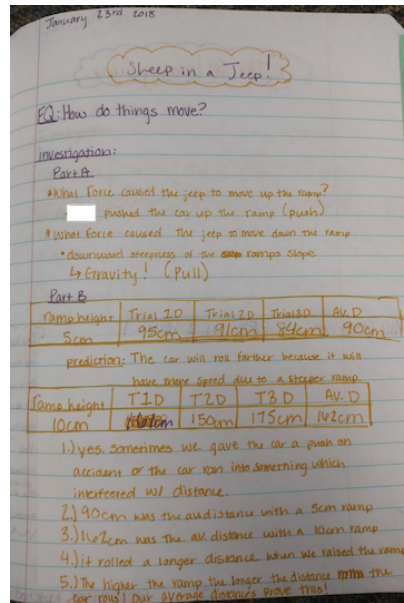
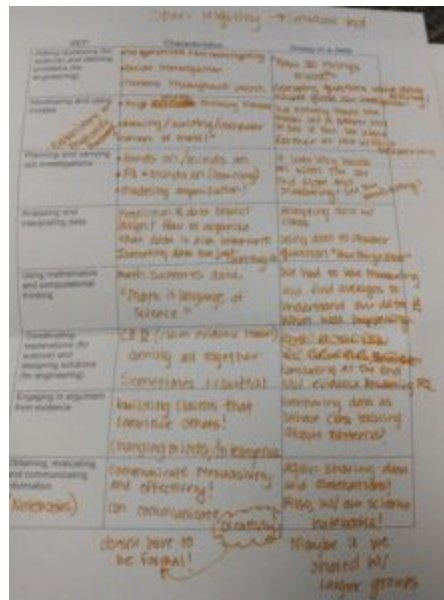


Figure 2 (Click on image to enlarge). Preservice teacher notebook of the “teacher” side.



The preservice teachers have indicated that having the student side and teacher side is helpful in distinguishing the two “hats” they wear in class, as they examine lessons through the student lens and through the pedagogical lens, and that creating a science notebook has helped them think about how to use them with their own students. We discuss in class that the elementary students’ notebooks can also have two sides with dual purposes—an experimental side and a reflections side (Young, 2012). When asked at the end of the semester what they gained (if anything) from creating a science notebook, one preservice teacher indicated:

I learned how to do it with students, basically. Like you said, like, hey, here is what we can do for the student side, we can do something, like you said with the teacher side, we can change this to have them do daily reflections, questions that pop up, they maybe go home and do outside research, but definitely having that experimental slash note side and then having that questions, reflection, what do you think on this side, I think that is very useful for me, it's like, this is how I can set it up.

Also related to learning how to implement notebooks with elementary students, one preservice teacher stated that it was helpful to create a notebook herself so that she knew what to expect:

I think it was really helpful to see the student side of it, specifically, 'cause how I, I never had them so, I think just jumping into residency or even teaching and having kids do it, or really knowing what you want them to get out of it, or your expectations, so I think this is a good way to set those expectations for myself for the students. Being able to actually do it so that I can show them how.

Interestingly, some preservice teachers indicated that their ideas about the value of creating their own notebook developed over the course of the semester. They developed an understanding of how the notebooks supported their own learning, for example, the notebooks helped keep them organized or provided them a resource about their learning in the course to which they could later refer.

Facilitating Use of the Notebook Throughout the Semester

In a typical class session, preservice teachers experience an inquiry lesson that includes either part or all of a 5E lesson (Bybee, 1997). In most cases, time permits engagement only in the first 3 E's (Engage, Explore, and Explain). During these lessons, preservice teachers record the focus question and data in their notebooks. Later in the semester, preservice teachers also record more detailed explanations from the data. During the lesson, Ingrid models a pedagogical strategy. After experiencing the three parts of a 5E lesson, the class debriefs, analyzes, and/or discusses the pedagogical strategy that was modeled. For example, preservice teachers engage in a lesson to compare solids and liquids and make Oobleck to explore an anomaly (non-Newtonian fluid). Throughout the lesson, Ingrid models elementary science assessment strategies, such as a solids and liquids card sort (Keeley, 2008) as a pre-assessment in the Engage phase, and Traffic Light Dots (Keeley, 2008) as a self-assessment, whereby preservice teachers place green, yellow, and red dots next to statements they have written in their notebook to indicate their level of understanding and/or comfort with the what they wrote and did. Ingrid also plans to incorporate a discussion of how to assess elementary students' notebooks into this lesson in the upcoming semester. Preservice teachers then discuss additional strategies that could be used to assess throughout the lesson.

Modeling of notebooks is a key aspect of introducing notebooks (Lewis, Dema, & Harshbarger, 2014). When Ingrid first started using notebooks with preservice teachers, she did not model using her own notebook, however throughout the years preservice teachers have indicated they wanted an example. Ingrid therefore began modeling the set-up of the notebook and the first few entries, and then gradually releasing this modeling. She has also found the assignment description and rubric are helpful—critical aspects of the notebook are creativity and to use the notebook as an exploratory tool. Ingrid has thus attempted to find a balance between supporting preservice teachers who prefer specific details related to assignment expectations while allowing space for freedom and creativity. In addition, preservice teachers sometimes request a review of required entries to ensure they have met the assignment requirements. To support their work, Ingrid provides one or two opportunities throughout the semester for preservice teachers to receive optional formative feedback, whereby Ingrid reviews the contents of the notebooks and provides comments and suggestions (e.g., to keep the table of contents up-to-date or to consider adding creativity to the notebook) on sticky-notes, so that the preservice teachers can remove the feedback and still feel ownership of their notebook (Nesbit et al., 2004). Ingrid has found over the years that preservice teachers appreciate the notebook having a point value in the class, as they have mentioned that it suggests that their work is valuable and important, and thus contributes to their course grade.

Throughout the semester, preservice teachers are asked to use their notebooks in various ways. For example, sometimes the preservice teachers are asked to write a reflection about the pedagogical topic of the class, or to write a Line of Learning (Nesbit et al., 2004). Mid-semester, preservice teachers are asked to set one goal they would like to achieve with their notebooks. For example, one preservice teacher wrote: “Goal Statement: Starting this/next week, I will start reflecting using the 3,2,1 countdown^[1] AND to decorate the cover of my notebook! Shoot for the stars!” The following week, preservice teachers review their goals to determine if they achieved them, make a plan to achieve them if they did not, and set further goals for their notebook use.

Explicitly Connecting Notebooks to Scientists’ Work

The purpose of Sarah’s visit is for preservice teachers to meet and interact with a professional scientist who uses notebooks in her work. She comes to the class midway through the semester (about week 7) so that preservice teachers have had some experience working with their notebooks, exploring inquiry, and examining the SEPs (NGSS Lead States, 2013). We consider Sarah being a woman an added benefit and encourage inviting scientists to the classroom that represent diversity in the STEM workforce.

The preservice teachers are assigned to read before class Chapter 4 of their *Questions, Claims, and Evidence* text (Norton-Meier, Hand, Hockenberry, & Wise, 2008) titled, “Writing as an Essential Element of Science Inquiry.” In this chapter, they read about writing to learn and the importance of combining students’ knowledge bases of science and writing. The

preservice teachers are also assigned to read an article by Schneider, Bonjour, and Bishop Courtier (2018) that connects notebooks to literacy, inquiry, and the SEPs (NGSS Lead States, 2013).

Facilitating the “Student” Side: How Do Professional Scientists Use Notebooks?

The class session begins (Engage phase) with Ingrid reading the book, *Notable Notebooks: Scientists and Their Writings* (Fries-Gaither, 2017), which describes how various scientists use notebooks in their work. The focus question for the “student” side of the lesson is “How do professional scientists use notebooks?” The lesson is framed as a “student” lesson because elementary teachers can bring scientists into the classroom and engage elementary students in a similar lesson. We introduce the focus question and facilitate a discussion about how the preservice teachers think scientists use notebooks. Preservice teachers are provided with a “data” sheet to tape into their notebooks on which they record their observations and inferences about how scientists use notebooks based on *Notable Notebooks* (Fries-Gaither, 2017) and on sample notebooks Sarah shares. The preservice teachers highlight activities such as planning experiments, creating hypotheses, and writing results. Classroom teachers may have students complete these writing activities in their notebooks, but they are not generally how scientists use their notebooks. Although there is quite a bit of variety from notebook to notebook, scientists mainly use notebooks to record data.

After this initial discussion, Sarah shares notebooks samples of her own work and that of her colleagues (see Figures 3-5) and discusses the various way scientists use notebooks in their work (Explore phase). Throughout this discussion, we ask the preservice teachers questions to guide their thinking: What kinds of data are the scientists collecting? How have the scientists organized their data? How did the professional scientists in the examples we just shared use their notebooks in different ways? What is the purpose of notebooks as professional scientists use them?

Figure 3 (Click on image to enlarge). Botany notebook featuring drawings of plants noted in the field.

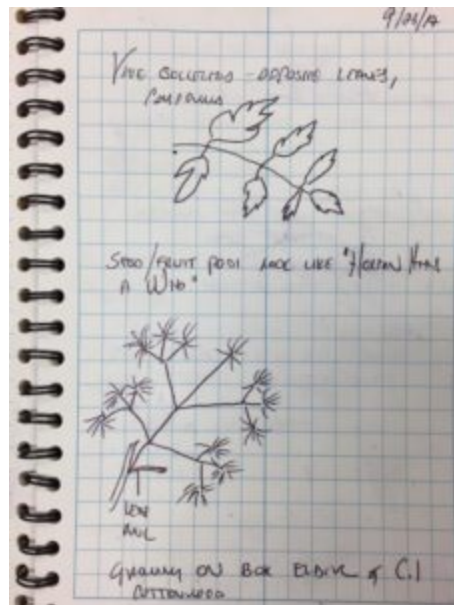


Figure 4 (Click on image to enlarge). Genetics notebook containing photos of gel electrophoresis (a DNA fingerprinting technique).

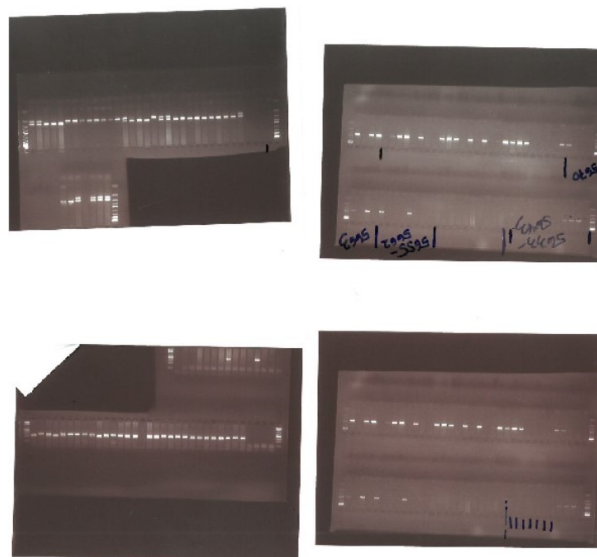


Figure 5 (Click on image to enlarge). Environmental science notebook containing tables of water quality measurements.

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	Temp1	Temp2	DO	pH	Phos	NH4	NO3	BOD
1	10.2	10.1	9.15	7.08	0.02	0.00	0.435	8.04
2	12.0	12.0	8.34	7.76	0.31	0.00	2.71	6.57
3	12.0	11.9	9.74	8.03	0.45	0.00	4.52	7.06
4	12.0	11.8	8.50	7.88	0.44	0.00	3.07	6.87
5	12.5	12.4	8.65	8.02	1.09	0.05	4.11	6.86
6	12.7	12.8	8.61	8.09	1.25	0.08	3.48	6.01
7	12.7	12.6	8.37	8.06	0.26	0.07	4.41	6.69
8	12.4	12.5	8.75	8.15	1.17	0.07	3.77	6.70
9	12.3	12.1	5.29	7.71	0.89	0.00	3.44	4.28
10	14.0	15.6	6.23	7.57	0.80	0.14	4.72	3.38
11	11.4	11.4	8.60	7.75	0.36	0.10	1.56	5.41
12	12.0	12.0	8.20	7.74	0.36	0.01	2.63	6.20
13	12.5	12.4	8.12	7.75	0.55	0.06	2.66	4.28
14	14.0	13.9	6.29	7.64	0.39	0.02	4.02	3.64

These notebooks demonstrate the wide variety of content present in scientific notebooks. For example, Sarah shows drawings of plants that one of her research assistants, who was double majoring in art and environmental science, completed while making observations in the field as part of one of Sarah's projects (see Figure 3). She also shows sets of numerical data from a study on soil chemistry. As the preservice teachers examine the notebooks, they are asked to make further observations about them. They often observe that each notebook is unique and serves as a place to record the work conducted by the scientist. They comment that some notebooks are filled with numbers, some with drawings, and some even have "artifacts" taped into them. Indeed, Sarah brings in an example of a scientific notebook that includes photographs of gel electrophoresis (a DNA fingerprinting technique) that the scientist inserted (see Figure 4). The discussion then returns to the focus question: How do professional scientists use notebooks? (Explain phase). We recommend facilitating a Claim and Evidence statements to answer the focus question that uses the preservice teachers' observational notes from *Notable Notebooks* (Fries-Gaither, 2007) and from the samples of scientists' notebooks to support their claims.

Facilitating the "Teacher" Side: Notebooks Across Contexts

The observations preservice teachers make about scientists' notebooks offer the opportunity to begin to distinguish the similarities and differences between scientific and classroom notebooks. To begin thinking of the lesson as teachers, we facilitate a discussion about how scientists' notebooks compare to both the preservice teachers' notebooks and elementary students' notebooks. For example, how are the ways that professional scientists use their notebooks similar/different to how we are using notebooks in this class? How is this similar/different to how elementary students use science notebooks? What is the purpose of notebooks as elementary students use them? How is this the same/different from how we are using them this semester? The preservice teachers generally see connections between classroom and scientific notebooks, for example, both are personal records of thoughts, observations, and questions. The authors of each make decisions about what is included and how—notebooks usually have a system of organization which is chronological. The preservice teachers are required to date every entry, a practice that scientists often consider critical as well. This chronological organization can demonstrate growth or learning over a time period: the student over an academic year, the scientist over the course of a study. Elementary teachers also usually ask their students to date their notebook entries. Further, we discuss how the scientists' notebooks shared were all created in hard copy and how the preservice teachers also create hard copy notebooks. While there are merits to maintaining digital work, we discuss the importance of scientists using hard copy notebooks (e.g., so that they can bring them into the field regardless of the weather). One concept we emphasize is that scientists generally do not erase any work in their notebook, but cross it out if they need to make a change. This is an important point because scientists want to see their thought-processes and therefore it is helpful to keep all their work. Similarly, elementary teachers may ask their students to cross out their work rather than erase it, for the same reason of

being able to see students' thought processes. We point out that although the preservice teachers (and perhaps elementary students) may not bring their notebooks outside, hard copy notebooks may support creativity so that students do not have to navigate technology while creating their notebook. Furthermore, hard copy notebooks allow students to easily insert artifacts and handouts into the notebook as perhaps, a scientist may do (as in the DNA example).

Preservice teachers also discuss how the notebooks they are creating in the methods course differ from scientists' notebooks, for example, their notebooks have a "student" side and a "teacher" side, and their notebooks contain notes, ideas, and reflections on science teaching and learning. Likewise, elementary students' notebooks may contain a "data" or "observations" side and a "reflections" side (Young, 2012). The science notebooks that Sarah shares largely contain numerical or descriptive data, whereas the notebooks created by preservice teachers and elementary students contain a variety of notes and reflections. The preservice teachers' notebooks also contain a required system of organization, which includes a table of contents and a glossary (see Appendix A). This system is intended to model how to support elementary students as they create their notebooks, however scientists will likely not use this type of system in their own notebooks.

Preservice teachers are asked to consider how they would use a notebook in their future class or how they have observed their cooperating teachers in their field experiences use notebooks in the classrooms in which they are working. Indeed, preservice teachers are given a field reflection assignment about notebooks for class that day. Through a discussion, the preservice teachers identify the learning objectives elementary teachers may have when using notebooks including building organization and literacy skills. They also see the notebooks as a way for students to demonstrate growth over a unit, semester, or year, and reflect back on their work throughout the school year. In contrast, preservice teachers may view scientific notebooks as mechanisms for thinking about and carrying out scientific investigations. At this point in the lesson, we ask preservice teachers to complete a t-chart that lists the SEPs (NGSS Lead States, 2013), and how scientists' notebooks reflect how scientists engage in the SEPs (please see Recommendations section below for a modification to this approach).

Lastly, the class is asked to consider the value in bringing a professional scientist to visit the class to talk about their work and how they use notebooks. The preservice teachers again comment that meeting a scientist makes science seem more approachable and less abstract. At the end of the semester one student stated:

I think when you brought in like the real science, like the real scientists' notebooks like for us to see that was really cool, too, because it just kind of like, I like the idea of um, ya know, think like a scientist.

When Sarah visits the class, she describes her work by explaining what she does and why it is important. This discussion helps to demystify science and scientists. If a scientist is able to explain exactly what they do in their work, it can perhaps make it easier for students to envision themselves in the role. During the discussion, we encourage the preservice teachers to invite scientists into their own future classrooms so that elementary students can also see how scientists work. We suggest that they begin by emailing faculty from local colleges, including community colleges. Other possible locations include government agencies (local, state, federal), non-profits, engineering firms, environmental consulting firms, zoos/ aquariums, museums, and hospitals. We point out that since many professionals are busy their emails may go unanswered, but we encourage preservice teachers to persist in finding someone who can visit their classroom. We also encourage them to speak with the scientist before their visit to discuss the content so that it is grade-appropriate and to discuss their learning goals—we note that since they are education experts, it is their responsibility to ensure that the visit goes smoothly.

Recommendations

In this section, we provide reflections and recommendations based on our experiences in our collaboration and facilitation of notebook use with preservice teachers. Our intention is to provide recommendations that can be applied in a variety of university contexts.

Building a Collaboration

The university setting can make cross campus collaboration difficult—it may be common for faculty to remain in their disciplines, and these disciplines can be geographically separated by different buildings. Such work is possible, however, if faculty explore opportunities at the university, for example, by participating in service outside of the department, school, or college. Our collaboration and friendship began with a service project that involved faculty from the School of Education and the College of Letters, Arts, and Sciences. The service does not need to be specifically related to the intended project, as any service outside the department can be a valuable to meet faculty outside of teacher education. If such a service opportunity is not available, it may be possible to establish a relationship by reaching out to individuals that are likely to share a mutual interest. Although Sarah is a scientist and teaches in a science department, she also teaches a class for preservice teachers. Thus, it is not surprising that she has an interest in pedagogy and science instruction.

Emphasizing Professional Use of Notebooks with Preservice Teachers

We believe a critical component of emphasizing scientists' work is to share real-life examples of scientists' notebooks. Please note that this may take some time since the scientists will need to ensure that the information they are sharing is permitted by IRB. When sharing examples of scientists' notebooks, it is important to compare/contrast the way scientists use notebooks not only with how the preservice teachers use notebooks in the methods class, but also how they can be used with elementary students. As we continue our collaboration,

we have obtained various insights into ways that we could further enhance our emphasis of how professionals use notebooks, and how that relates to how preservice teachers, and elementary students, use notebooks.

Explicit and continued connection to scientists' notebooks. First, we plan to explicitly connect and reflect back to Sarah's visit throughout the semester. This can be done by asking questions after the inquiry investigations done in class such as: How do you think a professional scientist would conduct an investigation to answer the same focus question? What kind of data could/would they gather, and how could they organize it? Further, this connection can be extended and emphasized through discussion about the work that scientists may record in notebooks and how this relates to the SEPs (NGSS Lead States, 2013) and to the Nature of Science (NOS). Tables 1 and 2 provide some ideas for how to connect professional scientists' notebooks to the SEPs and NOS.

Table 1 (Click on image to enlarge)

Connections Between Science and Engineering Practices and Scientists' Notebooks

Science and Engineering Practice	Professional Scientists' Notebooks
Asking questions (for science) and defining problems (for engineering)	In our scientists' notebooks, we did not see the questions or the problems explicitly, but Author 2 described the research studies.
Developing and using models	One of the most basic models is a linear regression. This type of model is commonly used to analyze data. The results of this type of statistical analysis are included in one of the notebooks.
Planning and carrying out investigations	Scientists' notebooks sometimes contain methods (protocols) for carrying out investigations and contain collected data.
Analyzing and interpreting data	Scientists' notebooks may contain the results of statistical analyses.
Using mathematics and computational thinking	Scientists' notebooks may contain graphs, results of statistical analyses, and calculations.
Constructing explanations (for science) and designing solutions (for engineering)	Scientists generally do not use notebooks to carry out this task.
Engaging in argument from evidence	Scientists generally do not use notebooks to carry out this task.
Obtaining, evaluating, and communicating information	Scientists generally do not use notebooks to carry out this task.

Table 2 (Click on image to enlarge)

Connections Between Nature of Science and Scientists' Notebooks

Tenets of Nature of Science (Lederman & Lederman, 2014; NGSS Lead States, 2013)	Professional Scientists' Notebooks
Scientific investigations use a variety of methods (e.g. there is no one scientific method)	Scientists' notebooks may display a variety of data types, from numbers, to descriptions, to drawings.
Scientific knowledge is based on empirical evidence (e.g. requires evidence)	Scientists' notebooks are generally filled with data that provides empirical evidence for scientific knowledge.
Scientific Knowledge is open to revision in light of new evidence (e.g. scientific knowledge is tentative)	Scientists generally do not use notebooks to carry out this task.
Science models, laws, mechanisms, and theories explain natural phenomena (e.g. through observations of data and inferences about those observations)	This principle is not directly tied to the use of notebooks; however, scientists' work is generally based on frameworks within the science community.
Science is a way of knowing (e.g. science is only one way of knowing, and is different from other ways of knowing, such as philosophy, art, etc.)	By examining scientists' notebooks, students can see that scientific investigations involve empirical evidence.
Scientific knowledge assumes an order and consistency in natural systems (e.g. this assumption enables scientists to search for patterns in the data, draw conclusions and develop scientific knowledge)	Statistical analyses are designed to search for anomalies, which can highlight something that departs from this consistency. These anomalies identify new information.
Science is a human endeavor (e.g. though science seeks to be objective, scientists are human and therefore there is an element of subjectivity, scientific knowledge is embedded in human culture, and is also a product of human creativity)	Scientists' notebooks demonstrate the effort put forth by scientists to collect data.
Science addresses questions about the natural and material world (e.g. science cannot answer all questions, such as those that are religious or metaphysical)	Scientists' notebooks are generally filled with empirical evidence, which is different than evidence that supports religious or metaphysical knowledge.

As preservice teachers engage in inquiry activities and make connections between elementary science learning, the SEPs (NGSS Lead States, 2013) and NOS, they can also reflect on how this relates to professional scientists' work and their use of notebooks. Connecting scientists' notebooks to the SEPs and NOS can support preservice teachers' thinking about how elementary science can relate to the work of professional scientists. This is critical so that preservice teachers continue to see and think critically about how notebooks are used across contexts: in elementary classrooms, in their own methods course, and by professional scientists. We recommend asking preservice teachers to think about these connections through a three-column chart: one column lists the SEPs (NGSS Lead States, 2013) and/or the tenets of NOS, one column asks preservice teachers to make connections between the SEPs and how scientists use notebooks, and the third column asks preservice teachers to either make connections between the SEPs/NOS and how they are using notebooks or how elementary students can use notebooks. Alternatively, preservice teachers could complete a Venn diagram with three circles, one for each role (elementary student, preservice teacher, professional scientist) to compare/contrast how different roles use notebooks. As preservice teachers continue to engage in inquiry lesson as "students," and reflect on pedagogy as teachers, they may begin to see more and deeper connections between the different contexts of notebook use.

Connections to the work of professional engineers. Next semester, we also hope to incorporate deeper discussion about how engineers use notebooks. We plan to read Fries-Giather's (2018) *Exemplary Evidence: Scientists and Their Data*, which includes ideas about how engineers work. We can examine how the work of engineers compares/contrasts to the work of scientists, again using the SEPs (NGSS Lead States, 2013) and using the *Framework for Science Education's* "Distinguishing Practices in Science from those in Engineering" (National Research Council, 2012, pp. 50-53) to guide the discussion. Preservice teachers can make the connection that while the practices are similar as they

relate to both science and engineering, science tends to focus more on exploration and explanation, while engineering tends to focus more on solving problems. As mentioned above, connections between engineers' notebooks and NOS can also be made.

Connections to literacy. Finally, we recommend making explicit connections between the science notebooks, literacy, and supporting language development (Schneider et al., 2018). There are a number of resources that discuss how to integrate literacy into science notebook use with elementary students (e.g., Fulton & Campbell, 2014). We suggest having class discussions about how notebooks support language and literacy, as well as facilitating an activity that allows preservice teachers to examine the state literacy and/or English Learner standards to find connections to science notebook use. Furthermore, children's literature can be a valuable way to introduce how scientists use notebooks (before a scientist visits the class), to review/revisit how scientists use notebooks (after the scientist's visit), and to think critically about how notebooks are used. As mentioned previously, we really like the two books by Fries-Gaither to introduce and discuss with preservice teachers how scientists work and how they use notebooks.

Conclusion

In conclusion, we have found our collaboration to be fruitful in our facilitation of notebook use with preservice teachers. An interesting and unanticipated benefit for Ingrid has been an enhanced understanding of how scientists work. Her knowledge of how scientists work has become clearer and deeper as the authors have discussed the various ways Sarah and her colleagues collect and analyze data. Preservice teachers have often mentioned the value of Sarah's visit and sometimes refer back to it throughout the semester. Further, many preservice teachers know Sarah from the science content courses for elementary teachers they have taken. This seems to support an added level of comfort and familiarity with her when she visits the classroom. Sarah has also benefited from this collaboration as she has furthered her understanding of scientific pedagogy that has allowed her to improve her own teaching of undergraduate science courses for both elementary majors and non-majors. Finally, we believe that connecting scientists' notebooks to the work of preservice teachers and elementary students and how that relates to the SEPs (NGSS Lead States, 2013) and NOS can provide a larger context and bring to life these dimensions of the Next Generation Science Standards.

Author Note

[1] We believe this refers to: 3 new facts I learned, 2 "ah-has," and 1 question

Supplemental Files

[Appendix-A.docx](#)

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