Developing Elementary Science PCK For Teacher Education: Lessons Learned From A Second Grade Partnership

By: Leslie U. Bradbury, **Rachel E. Wilson**, and Laura E. Brookshire

Abstract

In this self-study, two science educators partnered with two elementary teachers to plan, implement, and reflect on a unit taught in second grade classrooms that integrated science and language arts. The researchers hoped to increase their pedagogical content knowledge (PCK) for elementary science teaching so that they might use their experiences working in an elementary context to modify their practices in their elementary science method instruction. The research question guiding the study was: What aspects of our PCK for elementary science teaching do we as science educators develop by co-planning, co-teaching, and reflecting with second grade teachers? Data include transcripts of planning meetings, oral reflections about the experience, and videos of the unit being enacted. Findings indicate that managing resources for science teaching, organizing students for science learning, and reflecting on science teaching were themes prevalent in the data. These themes were linked to the model of PCK developed by Park and Oliver (Research in Science Education, 38, 261–284, 2008) and demonstrate that we developed PCK for elementary science teaching in several areas. In our discussion, we include several proposed changes for our elementary science methods course based on the outcomes of the study.

Bradbury, L.U., **Wilson, R.E.** & Brookshire, L.E. Developing Elementary Science PCK for Teacher Education: Lessons Learned from a Second Grade Partnership. Res Sci Educ 48, 1387–1408 (2018). https://doi.org/10.1007/s11165-016-9607-x. Publisher version of record available at: https://link.springer.com/article/10.1007/s11165-016-9607-x

Res Sci Educ (2018) 48:1387–1408
DOI 10.1007/s11165-016-9607-x

Developing Elementary Science PCK for Teacher Education: Lessons Learned from a Second Grade Partnership

Leslie U. Bradbury[1] · **Rachel E. Wilson**[1] · **Laura E. Brookshire**[1]

Published online: 22 June 2017

Abstract In this self-study, two science educators partnered with two elementary teachers to plan, implement, and reflect on a unit taught in second grade classrooms that integrated science and language arts. The researchers hoped to increase their pedagogical content knowledge (PCK) for elementary science teaching so that they might use their experiences working in an elementary context to modify their practices in their elementary science method instruction. The research question guiding the study was: What aspects of our PCK for elementary science teaching do we as science educators develop by co-planning, co-teaching, and reflecting with second grade teachers? Data include transcripts of planning meetings, oral reflections about the experience, and videos of the unit being enacted. Findings indicate that managing resources for science teaching, organizing students for science learning, and reflecting on science teaching were themes prevalent in the data. These themes were linked to the model of PCK developed by Park and Oliver (*Research in Science Education*, *38*, 261–284, 2008) and demonstrate that we developed PCK for elementary science teaching in several areas. In our discussion, we include several proposed changes for our elementary science methods course based on the outcomes of the study.

Keywords Pedagogical content knowledge · Elementary science education · University faculty elementary teacher collaboration

✉ Leslie U. Bradbury
upsonlk@appstate.edu

Rachel E. Wilson
wilsonre3@appstate.edu

Laura E. Brookshire
brookshirele@appstate.edu

[1] Appalachian State University, ASU, Box 32047, Boone, NC 28608, USA

The notion that direct experience in classrooms provides a powerful vehicle for learning about teaching is prevalent within science education literature as well as education literature more broadly (Lott 2013; Mulholland and Wallace 2001; Munby and Russell 1994). Park and Oliver (2008, p. 278) summarize the importance of experience stating, "Although teachers' knowledge can be influenced and improved by receptive learning, the most powerful changes result from experiences in practice." Using this idea as a guiding principle, we, as science educators, undertook a project in which we partnered with two elementary teachers. In this collaboration, we co-planned, co-taught, and reflected with the teachers on a unit about how insects produce sound with the teachers in their second grade classrooms in order to develop new and deeper understandings about elementary science teaching that would inform our instruction in our elementary science methods courses. Because we were interested specifically in our knowledge gains related to elementary science teaching, we used the construct of pedagogical content knowledge (PCK) to organize our evolving understandings (Shulman 1986, 1987).

While there are many studies that investigate PCK development for novice teachers (i.e., Mulholland and Wallace 2001; Nilsson 2008), relatively few examine PCK development for science teacher educators (Faikhamta and Clarke 2013). Of the studies that do exist, most focus on the PCK development of novice science teacher educators (i.e., Osmond and Goodnough 2011; Wiebke and Rogers 2014). Even though we are experienced science teacher educators, we see the improvement of our practice as a lifelong endeavor and therefore, we want to contribute to the research literature on PCK development for teacher educators by examining our experiences teaching in elementary classrooms.

Since we were investigating our teaching experience in the second grade context for the purpose of improving our teaching practice, we chose to frame the project through the lens of self-study (LaBoskey 2004). One goal for teacher educators engaged in self-study is to better align their beliefs about teaching with their enacted practices (Loughran 2007). In our case, we hoped to implement the type of reform-based science teaching integrated with language arts that we advocate in our methods courses in a real school setting. For the purposes of this paper, our definition of reform-based is consistent with the guiding principles outlined in the *Next Generation Science Standards* (NGSS) (NGSS Lead States 2013) in that we combined science content and practices to support student learning that is grounded in concrete experiences.

Our research question was: What aspects of our PCK for elementary science teaching do we as science educators develop by co-planning, co-teaching, and reflecting with second grade teachers?

Literature Review

PCK for Science Teaching

PCK, the term for the specialized knowledge that is needed for teaching specific subject matter, was first introduced by Shulman (1986, 1987). In his view, PCK goes beyond subject matter knowledge to include the transformation of that information so that it can be understood by others (Shulman 1986). Since that time, a number of models have been proposed to describe the various components that make up PCK for science teaching (i.e., Appleton 2006; Magnusson et al. 1999). For this study, we are using a more recent model developed by Park and Oliver (2008) which was modified based on the work of Grossman (1990), Tamir (1988), and Magnusson et al. (1999). In the Park and Oliver (2008) model, there are six components that make up PCK. Each of these components is listed and defined briefly in Table 1.

We chose this model because theirs was the only one to include Teacher Efficacy and reflection-on-action (Park and Oliver 2008). Based on research conducted in secondary science classrooms, they added Teacher Efficacy as a component of PCK due to its prevalence in teachers' discussions about their practice. Secondly, reflection is included not as one of the components but rather as an influence on the enactment and modification of all of the aspects of PCK. In their study, both reflection-in-action, the ability to develop and enact knowledge while teaching (Schön 1983), and reflection-on-action, the process of making sense of prior experiences for the purpose of improving future action (Ertmer and Newby 1996; Schön 1983), were pivotal to the changing PCK of the science teachers in their study. In our case, we hoped to improve our PCK for elementary science teaching by teaching in elementary classrooms and working closely with elementary teachers to plan and reflect on our teaching.

PCK for Science Teacher Education

While the ideas are given different names, there seems to be a consensus that there is a specialized knowledge base that is needed for teaching science teachers that is distinct from the knowledge needed by a K-12 classroom science teacher. Berry and Van Driel (2012, p. 125) referenced a "pedagogy of science teacher education" that includes "common aspects of science teacher educators' expertise." The Association for Science Teacher Education described a set of professional knowledge standards for science teacher educators that incorporates topics such as a knowledge of science, science pedagogy, and knowledge of learning and

Table 1 Components included in Park and Oliver's (2008) model of PCK

PCK component	Definition
Orientations to Teaching Science	Teachers' beliefs about the purposes and goals for teaching science (Magnusson et al. 1999) serve as a concept map which guides instructional decisions (Borko and Putnam 1996)
Knowledge of Assessment of Science Learning	Knowledge of the dimensions of science learning that are important to assess and knowledge of the methods to assess that learning (Tamir 1988)
Knowledge of Instructional Strategies for Teaching Science	Composed of subject-specific strategies which are general approaches to science teaching such as the learning cycle and inquiry-based instruction, as well as topic-specific strategies which incorporate specific strategies useful for comprehending specific concepts and include representations and activities (Magnusson et al. 1999)
Teacher Efficacy	Teacher beliefs about their ability to enact successful teaching methods for specific teaching goals, specific to classroom situations and activities (Park and Oliver 2008)
Knowledge of Students' Understanding in Science	Knowledge of what students know about a concept and areas where they are likely to encounter difficulty with understanding (Magnusson et al. 1999), including students' understanding of particular topics, difficulties in learning, motivation, developmental level, differences in ability, and need (Park and Oliver 2008)
Knowledge of Science Curriculum	Knowledge about curriculum materials available for teaching particular subject matter, as well as the horizontal and vertical alignment for a subject and the relative importance of topics within the curriculum, enables teachers to identify central concepts, revise activities, and eliminate superfluous aspects (Park and Oliver 2008)

cognition (Lederman et al. 1997). Abell (2008) and Abell et al. (2009) proposed that there is a distinct PCK that exists for teaching science teachers.

Just as other researchers have developed models of PCK for teachers that include various components that interact to make up the whole, Abell et al. (2009) proposed a model of PCK for science teacher educators. In their model, orientations to science teaching provide a lens through which other aspects of PCK are filtered. Similarly, Faikhamta and Clarke (2013, p. 975) assert that the beliefs held by teacher educators "are reflected in the ways they teach student teachers in a classroom and are closely intertwined with PCK components." Other elements of Abell et al.'s (2009) model of science teacher educators' PCK include the following: (a) curricular knowledge for teaching methods courses, (b) knowledge of assessments in methods courses, (c) knowledge of instructional strategies for teaching methods courses, and (d) knowledge of teachers' understanding of science and science teaching. Further, Abell et al. (2009) argue that just as the PCK of classroom teachers can change over time, so too does the PCK of science teacher educators resulting in a professional continuum for teacher educators that changes with experience.

Though PCK has been posited as a framework for the knowledge needed by science teacher educators, there are few studies that directly investigate the development of PCK for teaching science teachers. In those studies that do exist, PCK has been investigated primarily through self-studies by novice science teacher educators. In each of the studies referenced below, the first author was the novice teacher educator who taught the methods class, while the second author was a more experienced *critical friend* who provided thoughtful feedback to the beginner. Though they were focusing on different grade levels, Faikhamta and Clarke (2013), Osmond and Goodnough (2011), and Wiebke and Rogers (2014) each investigated the match between their constructivist orientations to teaching and their practices in their science method classes, as well as additional aspects of their practice. In each of these self-studies, the authors used the construct of PCK to frame their understandings of their findings and to discuss aspects of their PCK for teaching science teachers that needed further development.

In the current study, our approach is similar to previous investigations in that we are using a self-study methodology to investigate our PCK for teaching teachers. However, there are two key differences between the current work and the previous research. First, existing studies investigate PCK development in novice science teacher educators, while this study investigates the PCK development of science teacher educators with more experience. Second, existing studies investigate PCK development while teaching a methods class, while this study investigates the PCK development of science teacher educators while teaching science in an elementary classroom.

Professors Returning to the Classroom

There are many examples in the literature where professors returned to an elementary, middle, or high school classroom setting for an extended period of time, often as part of a sabbatical from their university duties (i.e., Dias et al. 2011; Lott 2013). Professors who participated in K-12 classroom teaching expressed many reasons for engaging in the experience. In the work of Akerson et al. (2014), Akerson returned to the elementary setting to determine whether she could incorporate nature of science ideas in her instruction in a third grade classroom. Lott (2013) sought to rekindle a lab school relationship that had floundered. Eick wanted to implement a recently designed inquiry-based curriculum to enable him to test his conceptual knowledge about inquiry-based teaching against the practical realities of a middle school classroom (Dias et al. 2011). Each author commented on the impacts that the K-12 classroom experiences had on their instruction in their education courses. Whether explicitly stated or implicitly suggested, each of these science educators hoped to use their time in the classroom to close the gap between their theoretical understandings and their teaching practice.

Our own goals in this project are similar to these other university educators in that we value time spent in elementary classrooms as a means to improve our own knowledge. Our explicit aim was to develop our PCK for elementary science teaching by gaining additional experiences in K-12 classroom settings. In this study, we focused on a unit on sound. However, we hoped to learn from our experience so that we might apply our new knowledge to other science topics in the elementary curriculum. We used the approach of developing a community of practice with in-service elementary teachers so that we might learn from them and with them.

Methodology

Context

Place and Participants The elementary school where the project took place is located in a rural area in the Blue Ridge Mountains in the southeastern USA. Two of the authors have been working at the site for 2 years as a part of an ongoing school garden project which has evolved to include working with the teachers at the school on other science topics.

Leslie, the first author, has been working as an elementary science educator for 11 years, and Rachel, the second author, has been working as an elementary science educator for 5 years. The two second grade teachers vary in their teaching experience. At the time of the study, Annie was in her fourth year of teaching second grade and was selected as the Teacher of the Year for her school. Shelby was a National Board Certified teacher with 23 years of elementary teaching experience at a variety of grade levels. Helping with the project was Lindsey, a graduate student who assisted with data collection and analysis. Throughout the paper, the actual names of the two science educators are used; however, the names used for the teachers and second grade students are pseudonyms.

As we worked with the teachers, we brought our own beliefs about science teaching to the planning process. Leslie and Rachel both believe that it is important for elementary students to have direct experiences with the content that they are learning whenever it is feasible. We also feel that students should be supported by the teacher as they make sense of data and develop accurate understandings of science concepts. The science practices in the NGSS have become an important guiding force in our science teaching at both the elementary and college level, and we used those practices to anchor our discussions of activities to include in the insect sound unit (NGSS Lead States 2013). Specifically, we sought to engage the second grade students in the practices of developing and using models; analyzing and interpreting data; and obtaining, evaluating, and communicating information.

Integrated, Reform-Based Science Lessons As we worked with the second grade teachers on the insect sound unit, we incorporated science experiences along with activities where language arts skills were emphasized. We used an integrated approach for three reasons: (1) there is an emphasis placed on integration in current reform documents in science education (NGSS Lead States 2013), (2) there are cognitive processes shared by the disciplines of science and language arts (Baker 1991; Padilla et al. 1991), and (3) there are studies demonstrating that children learn more when the two disciplines are taught in an integrated manner (Bradbury 2014; Romance and Vitale 2001). Current reform documents in science education include "obtaining, evaluating, and communicating information" along with more traditional science practices such as asking questions, carrying out investigations, and analyzing data (NRC, 2012, p. 42). The *Next Generation Science Standards* incorporate links to the Common Core Standards for Language Arts within the text of the science standards (NGSS Lead States 2013). Additionally, there is a large and growing body of literature that supports the use of teaching approaches that integrate concrete science experiences with a variety of language arts skill such as reading, writing, and speaking to support student learning in both areas (i.e., Bradbury 2014; Romance and Vitale 2001; Varelas et al. 2014).

While there is a substantial body of research that supports the integration of science and language arts, one potential danger identified by teacher educators is that reading books about science may serve as a replacement for actually engaging in direct scientific experiences (Akerson and Young 2008; Cervetti et al. 2006). To address this concern, we structured the insect sound unit using a 5E learning cycle approach (Bybee et al. 2006) that included multiple opportunities for students to engage in scientific practices (NRC 2012).

Description of Insect Sound Unit Based on these considerations, our team developed a 2-week unit correlated to our state science standards that enabled second graders to engage in reform-based integrated science and language arts learning experiences. The unit followed the second grade students' recent experiences with basic sound concepts such as pitch and volume and used Eric Carle's book *The Very Quiet Cricket* as an anchor text for the activities (Carle 1990). During the unit, small groups of second graders chose one of the insects from the book to focus on as they investigated how and why that insect produced its sound. Students viewed preserved specimens, recorded observations, and made drawings about the insect they had chosen. The second graders explored materials that would enable them to produce a sound representative of their insect and tested their creations until they were satisfied at the match between their insects' sound and the sound they were able to produce using the materials.

Students were supported in their investigations with books about each insect, as well as a web page created specifically for this project with input from all study participants. The Discovery Education Board web page (referred to as a "Board") included videos of the insects producing their sound and detailed photographs of the insects' sound-producing structures, as well as grade level appropriate text related to sound production. The second graders used the Board to make additional observations about their insects' sound production. The Board was created because of the difficulty in finding an adequate number of texts at an appropriate reading level for the second graders that addressed the science concepts focused on in the unit (Ford 2006; Pearson et al. 2010). Additionally, the videos allowed students to observe insects producing sound in a way that would have been impossible in the classroom setting. As a culminating activity, each group presented their findings to the class using a combination of drawing and discussion.

Self-Study

A central tenet of self-study research is that it is aimed at improving teaching practice (Bullough and Pinnegar 2001; LaBoskey 2004). Because we undertook this project to enhance our knowledge of science teaching at the elementary level so that we might better our instruction in our teacher education courses, self-study was a fitting approach. Self-study is not a unique methodology, rather data collection and analysis approaches typically used in other types of research are employed to gain a deeper knowledge of oneself as a teacher and how one's teaching might be enhanced (Bullough and Pinnegar 2001). While self-study is initially focused on the growth of the researcher(s), outcomes should be shared in such a way that others can learn from them to consider for their own teaching practice (Bullough and Pinnegar 2001; Loughran 2007). The job of teacher educators is complex in that it

> is about using the cauldron of practice to expose pedagogy (especially one's own) to scrutiny. In so doing, collaborative inquiry into the shared teaching and learning experiences of teacher education practices can begin to bring to the surface the sophisticated thinking, decision making and pedagogical reasoning that underpins pedagogical expertise so that it might not only be recognized but purposefully developed (Loughran 2014, p. 275).

We hoped that the knowledge and insight that we gained by investigating our own thinking about science teaching as we worked with experienced elementary teachers could be shared with our pre-service teachers in our methods courses.

Steps to Ensure Quality

To ensure a trustworthy representation of our experiences, we used several strategies to strengthen the quality of the study. Multiple types of qualitative data were collected throughout the project to capture the ongoing thoughts and actions of participants and to enable triangulation across multiple data sources (Patten 2009). In the following sections, we share specific information about how our data was collected and analyzed so that others can see how we constructed our understandings (Feldman 2003). We used an "inquiry as stance" approach to the project based on the belief that "teacher knowledge can best be understood, transformed, constructed, and articulated by the teacher self in collaboration with others" (LaBoskey 2004, p. 826). In implementing this stance, we worked with a team of people with different types of expertise so that multiple perspectives were brought to bear at each stage of the process. We are providing a forthright accounting of our experiences as we shared our successes along with aspects of our teaching that still need modification (Bullough and Pinnegar 2001). Finally, we include a discussion of how we are thinking about changing our teaching practice as a result of what we have learned through this self-study (Feldman 2003).

Data Collection

To prepare for the insect sound unit, the five participants held two planning meetings that lasted approximately 2 h each. During these meetings, each member of the team shared ideas for activities and content for the unit. We discussed logistics and materials for each lesson and agreed to a plan for each day of the unit. The audio for each of these meetings was digitally recorded and transcribed. Copies of materials used with the students including all data collection sheets and the Board were included in the data set for the project. During each day of unit implementation, audio and video data were recorded and later transcribed. After the unit was completed, we reflected with Annie and Shelby individually to document their perceptions of the experience. Both Leslie and Rachel recorded oral reflections individually soon after the unit ended. In these reflections, we detailed our own feelings about our experiences in the second grade classrooms and recorded our ideas about what we were learning and how we might apply them in our teaching of the elementary science methods class. Consistent with the practices of self-study researchers (i.e., Akerson et al. 2014), we kept a shared reflective journal in which we posed questions to each other about the project and documented shared ideas.

Data Analysis

Data analysis occurred through a multistep process once data collection was complete. In the first stage, each member of the research team (Leslie, Rachel, and Lindsey) coded the same subset of data (one transcript of a planning meeting and all post-unit reflections). We coded data using an open coding approach looking for excerpts that were related to what we had learned (Corbin and Strauss 2008). The group reconvened to discuss the codes that we had used and the commonalities that we saw across each of the data sources analyzed. We agreed to a coding scheme, and each member recoded the same subset of the data so that the data included was coded using the new scheme.

Once this second round of coding was complete, we met to discuss patterns that were emerging in the data. During this stage of analysis, individual codes that were prevalent in the data set were collapsed into themes to represent the overall pattern. At this point in the process, the entire data set was coded using the agreed upon themes. Table 2 provides an overview of the codes that were collapsed to support each theme, along with a representative quotation from the data. In the final stage of analysis, we revisited the codes and themes and linked them to the components of Park and Oliver's (2008) model for PCK.

Findings

Findings for the study centered on three themes: managing resources for science teaching, organizing students for science learning, and reflecting on the action of science teaching. The first two themes focused on the coordination of materials and activities for students in the classroom in thoughtful and realistic ways so that there was the opportunity for science learning to occur. The third theme represented the thoughts of all of the participants on aspects of the unit that met our expectations and should be kept for the next iteration, as well as a discussion of activities in the unit that could be improved upon.

Managing Resources for Science Teaching

In planning and implementing the unit, all of the participants worked together to locate, create, and share resources to support student learning. The resources located by group members for the unit were science materials and nonfiction books, while we created data collection sheets and a Board (web page) for the unit. At the completion of the unit, the plan and some resources were shared with other teachers in the school system where Annie and Shelby worked.

The science materials used by students which were needed for the unit included specimens for each of the insects that were preserved in acrylic, as well as materials to enable the students to reproduce their assigned insect's sound. The specimens and some of the materials for sound production were purchased through a grant provided through the university where Leslie and Rachel work. Shelby was very appreciative of the ability to purchase the materials needed for the unit. She said, "I mean, we didn't have the specimens…you guys have such a wealth of

Table 2 Overview of themes with codes included and representative data examples

Emergent theme	Supporting codes	Representative data excerpt
Managing resources for science teaching	Locating resources (materials for science activities, books)	Rachel: So one thing I'm thinking that you're saying is that one of the struggles to truly integrate is the…lack of content-based resources at those particular levels.
	Creating resources (web page, data collection sheets)	Rachel: Really what I see the potential of [the web page] is you can kind of create the informational text for your particular purpose and you can include something like a sound or video to compliment what they're seeing and they're writing.
	Sharing resources	Annie [commenting on the web page created for the unit]: On the bottom you can add teacher resources and just have student pages and all that stuff, and these can just be uploaded. It literally would be an entire unit lesson ready to go.
Organizing students for science learning	Grouping students	Annie: I'm going to have one of my high readers in every group so they can read those words like 'compare' and things like that.
	Providing structure and direction	Shelby [before handing out iPads to students]: So, if it says Ned at the top, Ned does not hog that iPad. He doesn't keep it and mash all the buttons and do all the scrolling, and that doesn't mean he's in charge. It's a group effort.
Reflecting on the action of science teaching	Engaging students	Rachel: I remember hearing some excited exclamations from some students about the insect specimens and some 'eww' sounds from some of the other students, but I felt like by the end, I wasn't really hearing any 'ewws,' most of the kids were pretty engaged and interested in their insect.
	Integrating multiple approaches	Leslie: I felt that breaking things up, where you got to do something, like observing the specimens, then you had to write about it, then you got to do something else, observe the videos on the Board, and then read about it. So there was a nice sort of breaking up between stuff the kids would think was fun with stuff that they associate with school work.
	Bringing students back together	Leslie: I feel like maybe we skipped that [key science ideas]. … We went straight from them doing the hands-on things, to them doing their posters without pulling everybody back together.

stuff that we don't have." As the group discussed appropriate materials to use for students to recreate their insect sound, we brainstormed possible materials and discussed which resources were available at the school and university, and which would need to be purchased. Participants worked together to determine which materials would be suitable to help move the students forward in their understanding of sound production and then to locate sources.

Because the unit was integrated with language arts, we wanted to ensure that students had texts that aligned with the science content of the lessons that they could read after they investigated the insect specimens. In the planning stages, the second grade teachers frequently lamented their lack of access to nonfiction books that were at an appropriate reading level for their students for this unit and other areas in their curriculum. They also found it difficult to find books that directly related to the topics and insects included in the lessons. In the second planning meeting, Annie commented, "I wish that we had books for them… to see the text too. Some of the websites are just over their head as far as the information that's on there." Even after the members of the group had located as many resources as they could from the university and school libraries, the issue of access to developmentally appropriate books about sound was still problematic.

The difficulty in finding appropriate texts about insect sound production for the second grade students prompted the participants to develop a Board with photographs, video, and text that linked to the sound content of the unit. Annie introduced the idea of using the Discovery Education Board Builder tool as the platform for producing the website. Members of our group felt that it would be beneficial for students to be able to access developmentally appropriate multimedia resources in one place. The construction of the Board prompted a number of discussions between participants related to which resources should be included to best help students see how the sound was produced, how long videos of insects producing sound should be, and the structure and vocabulary level of the text to accompany each insect. In the following conversation, participants discussed the layout of the content of the Board.

Rachel: Do you want us to make one Board with all of the insects?
Annie: I think so, yeah. That would be easiest.
Shelby: They don't have to navigate.
Annie: They can just scroll down to the one that theirs is on.

The classroom teachers felt strongly that it would be more beneficial to have the information for all of the insects on one self-contained web page. They believed that it would be too difficult for their students to navigate between web pages and that if we organized it that way, valuable instructional time would be lost to technological difficulties that the students would have. As we developed the resources for the Board, it was important to us that we include videos that enabled the students to see the insects vibrating particular body parts as their sound was produced. The text included for each insect described how certain structures on the insect moved so that vibrations occurred.

A second resource created for the unit was the data collection sheets used at various stages during the lessons. Based on her experiences with student data collection in the past, Annie wanted to create data collection sheets in which the page was broken up into different sections. She also wanted to keep the instructions and questions on the sheets in a brief format. As the group brainstormed about the data collection sheets, Annie said, "Whenever I'm giving things like that, I try to give simple, if it's a really long statement or question, the ones that get easily frustrated are just done." A copy of one of the data collection sheets can be found in Appendix Fig. 1. The second grade teachers proposed the idea of the structure of the data collection sheets and developed them in a format that was different than what we, as science educators, had typically created for other elementary science lessons we had taught at the school. Based on the classroom teachers' input, the data collection sheets were structured to ensure that the second graders focused on key aspects of sound production.

For us, as teacher educators, locating and creating resources for the unit reinforced the idea that managing the materials for a new reform-based, integrated science unit is a difficult and time consuming endeavor. However, we learned about new resources the teachers had access to and how to create them from working in a collaboration with the second grade teachers. These experiences increased our PCK in the areas of Knowledge of Science Curriculum, Knowledge of Instructional Strategies, and Knowledge of Students' Understanding in Science. Our Knowledge of Science Curriculum was increased as we collaborated to locate science materials related to sound production and nonfiction texts appropriate for the unit. Listening to the members of the group share their knowledge of the resources available at their school and on the internet helped us to develop a better understanding of the existing resources for teaching about insects and sound. When we were unable to find resources to teach all of the content for the unit, we created the Board and data collection sheets with the teachers thereby increasing our Knowledge of Instructional Strategies to use with second graders. Learning about the platform to create the Board and discussing an appropriate structure and content for the information helped us to have a deeper understanding of the developmental level of second graders and their ability to use technology independently which influenced our Knowledge of Students' Understanding.

Organizing Students for Science Learning

In addition to the time spent discussing the location and creation of resources, a substantial amount of time during the planning sessions was spent identifying strategies for organizing students so that they could learn from the activities of the unit. In particular, the second grade teachers put a great deal of thought into how the students should be grouped to facilitate learning, and how directions should be structured to support student learning.

All of the participants in the project agreed that students should be placed in small groups of approximately four students in each group focusing on a particular insect from *The Very Quiet Cricket* and how and why that insect produced its sound (Carle 1990). Once that initial structure was settled, the second grade teachers thought deliberately about how to assign students to groups that would assist with productivity. Criteria that they used for grouping were student reading level, personality, and interests. For both Annie and Shelby, it was important that the students were grouped heterogeneously with at least one higher level reader in each group. Shelby commented, "With the mixed group, that one who was a higher-level reader could help with the words that might be trickier for an average kid or a below average kid." Given that several activities in the unit required students to read for content specific to how insects produced sounds, the second grade teachers wanted to ensure that each group had readers at a variety of levels and that at least one member of each group was strong in reading.

In assigning groups, student personality and interest were considered along with reading level. Shelby deliberately assigned people to groups so that each student could provide a particular strength for the group. She said, "And for another little guy who has a hard time reading, that was good for him because then he could draw, and that could have been his part...He's such an artist, such a drawer." Annie discussed one group in which she knew she had a natural leader as well as a student who excelled artistically, she said, "I know Dylan is a leader, I mean he's a born leader. He talk, talk, talks all the time, and I knew Kevin would be a killer artist, but at the same time he's real quiet, and so I didn't know how much he would step forward." As they considered how this first foray of the year into working in groups went, Annie and Shelby realized that the group dynamics in some cases did not work out and would need to be adjusted for subsequent lessons. While Annie was worried that in some groups, students had been willing to let the leaders do the majority of the work, Rachel also noticed that in one group, everyone wanted to be in charge. "I saw two students...not wanting to give up control...There were these three ladies who really didn't want to give up writing on the poster."

For us as science educators, the discussions with the teachers around the grouping of students served to reinforce the importance of the Knowledge of Students' Understanding in Science portion of PCK. While in hindsight, we feel that we should have spent more time developing an understanding of the students' knowledge of the science content related to insects and sound, hearing the emphasis that the teachers placed on how the students' difficulties with reading could interfere with their science understanding was illuminating. Additionally, the teachers did not use a single criterion for assigning groups, rather a student's ability level along with personality and areas of strength were considered. The teachers reflected on the learning needs of particular students as well as what roles might be motivating for various group members.

A second prominent area where we learned about organization of students from the teachers was in the amount of structure and repetition that they provided to the whole class before the students were released into their groups to complete the day's activities. Whether the students were engaging in science investigations using materials or whether they were using technology or books to gather additional information, the teachers were very explicit in their directions to students. In both classrooms, the teachers previewed the questions on the data collection sheets for the whole class and reviewed science vocabulary provided in the instructions that might be unfamiliar to some students. The teachers also shared their expectations for responses. For example, when Annie discussed a question related to drawing with the students, she asked, "Do you want to draw an insect that's like this big? [holds fingers really close together]." The class responded, "No." She continued, "No, because are you going to be able to label it if it's like this tiny?" The class responded, "No," again. She concluded with, "No, so you want to use up the whole section you have down there to draw a picture as best you can." In this direction-giving phase of the lesson, Annie also provided multiple opportunities to have students repeat back to her what they should be doing when they worked in their small groups.

Rachel and Leslie had similar reactions to the classroom management strategies of the teachers. While Leslie's is the comment shared, Rachel expressed similar sentiments in her reflections. As Leslie described key aspects of the success of the unit, she discussed the teachers' management strategies, commenting, "Before every lesson, they were very clear with the students about what they were going to do and what the expectations were. They did a lot of modeling. They did a lot of discussing of what you would do versus what you shouldn't do."

The structure and management strategies used by these teachers would fit into the category of general pedagogical skills described by Shulman (1987), rather than PCK for science teaching. Our experience in the second grade classrooms, however, allowed us to see the importance that these management skills have on a teacher's ability to implement the instructional strategies for teaching about sound production that our group believed were appropriate and meaningful. Without the classroom management skills of these teachers, we would not have been able to implement the appropriate instructional strategies for teaching science that we had carefully planned within our group.

Reflecting on the Action of Science Teaching

Members of our group placed great importance on reflecting-on-action in order to make sense of our experiences so that we might improve our future teaching (Ertmer and Newby 1996; Schön 1983). Given our belief in the benefits of reflection-on-action, once the insect sound unit had been completed, members of our group reflected individually and as a group about our perceptions of the success of the unit. In these reflections, we discussed aspects of the teaching that we deemed successful in supporting student understanding and other portions of the unit that needed modification. Themes emerging from our reflection-on-action related to aspects of the unit that worked well, including student level of engagement and the use of an integrated approach to teaching the science content. An area that required significant modification was placing additional emphasis on students' understanding of accurate science content.

The students' level of engagement with the insect sound unit was noted by all of the participants and was seen as a motivation for us as teachers to continue developing integrated reform-based units. Annie explained that she had a meeting in her class each morning where the whole group reviewed the overall plan for the day. She reflected, "Whenever I would say we're going to work on our sound project, 'Yeah!!!' Every day. 'Yes, I can't wait! When is that going to be again?'" She exclaimed, "I feel like their responses to it [insect sound unit] just motivated you more to make it even more awesome because they were loving it so much." Leslie had a similar reaction to the students' enthusiasm stating, "One thing that was reinforced was how much kids really get excited about doing science...how much they really, really love getting to participate and getting to do things." Each of the participants was pleased by the level of student engagement in the activities that we had designed and felt that our overall unit plan successfully motivated the students to want to participate and learn about how insects produced their sounds.

A second characteristic of the unit that was seen as effective was the use of an integrated approach that enabled students to interact with the science content in multiple formats. During the unit, students examined preserved specimens, used common household materials to recreate their insects' sound, and collected data as they watched close up videos and photographs of the insects producing their sound in nature. These experiences were supplemented with nonfiction texts about their insects, as well as teacher-created text located on the Board. In reflecting on the teaching experiences in the unit, this multimodal approach was seen as essential to the success of the unit by each of the participants.

Annie considered the importance of multiple sources of information for the students in the following statement, "Being able to see the insects with real pictures on the Board and with text...the books that they had, and them being able to have two different types of media to refer to for that information was really great." Rachel's perceptions of the importance of the integrated aspect of the unit were similar to Annie's. Rachel reflected, "I think getting to see actual specimens, getting to look at pictures, photographs in books… and watch videos of insects moving and making its sound, I think all of that made it...more real to the students." During individual reflections and group conversations, members of our group commented many times about the contribution of the integrated nature of the unit to its success. The opportunities for students to interact with the content in multiple ways were perceived by all members of our team as essential.

While group members felt that it was important that the content for the unit was presented in multiple formats, Rachel and Leslie later reflected on the value in providing several means for students to share what they were learning. In particular, both Rachel and Leslie were struck by the emphasis that students placed on their drawings during the data collection portion of the unit and on the posters that they created and delivered during their final presentations. Commenting on student responses to the drawings incorporated in the unit, Rachel said, "A lot of the students really like the drawing part. I remember there was that table in Shelby's class, the praying mantis group with Ross and Hunter, they were really focused on drawing their praying mantis, and the same went for Lucas in the cicada group and the bee group."

As Rachel and Leslie reflected on the unit, there were areas where we felt our PCK for science teaching had been reinforced or had grown. The students' level of enthusiasm and commitment throughout all of the activities of the unit reinforced our Guided Inquiry Orientation to Science Teaching (Magnusson et al. 1999). In the unit, we planned activities that fit into this orientation so that students participated as a community of learners who worked together to understand the world around them. We provided a scaffolding where we supported students' efforts to use the materials and tools of science to determine patterns and test explanations. Our hope was to offer just enough support so that students could begin to be more independent in using their experiences and the available resources to develop their understanding of how the insects produced their sounds. This approach seemed to be successful in this context and reinforced our approach to teaching science in this manner.

Planning with the second grade teachers and implementing the lessons with the students served to increase our PCK for Knowledge of Instructional Strategies in relation to sound as we saw students interact with the specimens, materials, and texts used in the unit. The integration of multimodal activities that connect science experiences with supporting texts was a successful strategy in this context as evidenced by the students' enthusiasm for participating in the insect sound unit. Actually, experiencing the students' responses to the integrated activities that we had planned served to bolster our Teacher Efficacy for planning and implementing integrated science and language arts lessons for elementary students. This unit enabled students to use their science practices such as developing and using models to represent insect sounds; analyzing and interpreting data from multiple sources; and obtaining, evaluating, and communicating information (NGSS Lead States 2013). These experiences working in a classroom with second graders reinforced our belief that our integrated design for the unit was effective and increased our confidence that we would be able to apply these same approaches in other elementary classrooms.

While many pieces of the unit design worked well for participants, there was one key area that needed improvement. We felt that the students needed additional opportunities to come back together as a large group to review and make sense of the science content related to sound production. In the original plan for the unit, once students had observed their specimens and learned more about their insect's sound production through the videos and text on the Board and through reading nonfiction texts about their insect, each class was supposed to come back together as a whole group to discuss what they had learned and review core science concepts related to sound production. Part of this explanation was to involve a discussion about which part of each insect was vibrating and how the structure of the body part of the insect facilitated sound production. However, in reality, the crucial step of reviewing and revisiting content never occurred and students moved straight into preparing their presentations. All members of the group felt that students' understanding had been hampered by this omission. As she reflected on the lessons, Rachel maintained, "We didn't stop and talk about sound and making sound and reviewing [that] sound comes from vibrations and that when insects move body parts, they're making vibrations. We kind of forgot to include that part in the lesson, and so when it came to presentation time, some of the students didn't necessarily have correct ideas." The feeling among participants was that we had been so excited by the students' enthusiasm and effort during the unit that we had omitted a crucial step from our plan and that this step of coming together to discuss what had been learned was a vital step in supporting student understanding.

While we decided that these components of the unit needed modification, reflecting on our experiences still contributed to our PCK for elementary science teaching. As we listened to the student presentations and realized that we had neglected to bring them back together as a whole group to discuss the science content, both our Knowledge of Instructional Strategies and our Knowledge of Students' Understanding in Science were impacted. While we had planned to include this step in the unit, experiencing the effect of neglecting this piece of the instructional plan served to reinforce its importance. Students needed the opportunity to make sense of their own science experiences and language art-based research through discussions scaffolded by input from the teacher. This sense-making component of the plan would have fit into the "Explain" portion of a 5E lesson plan, and neglecting it undermined students' science understandings.

Discussion

As we engaged in this self-study of our experiences collaborating with second grade teachers, our overarching goal was to improve our PCK for elementary science teaching so that we might modify and enhance our instruction in our elementary science methods courses. While PCK has been thought of as specific to particular science content topics, in the context of elementary schools, science is often thought of as a unique discipline with its own specific set of pedagogical knowledge and skills. Therefore, while we were focused on the topic of sound, our goal was to broaden our knowledge and experience in a manner that would enable us to be more successful teaching any science topic at the elementary level. Our experiences working together with elementary teachers provided a fruitful environment affording multiple opportunities to strengthen our PCK. As other scholars have noted, the components of PCK are not discrete entities, rather they overlap and influence each other (Magnusson et al. 1999; Park and Oliver 2008); however, PCK models that include specific aspects of PCK provide a useful heuristic for thinking about science teaching. Our findings indicate that working in the second grade classrooms served to bolster our Teacher Efficacy and reinforce our Orientation to Science Teaching. Furthermore, we enriched our PCK in the areas of Knowledge of Science Curriculum, Knowledge of Instructional Strategies, and Knowledge of Students' Understanding in Science. In addition to our changes in our PCK for science teaching, we recognize the vital role that general pedagogical knowledge plays in the success of science lessons with elementary learners.

Orientations to Science Teaching and Teacher Efficacy

In their seminal work, Magnusson et al. (1999) included a definition and a description of nine orientations to science teaching. As we discussed these orientations to determine which categories matched our beliefs, we agreed that while there may be some aspects of the others that fit our work, the Guided Inquiry Orientation aligned most closely with our approach. The definition provided by Magnusson et al. (1999, p. 100) states that Guided Inquiry "constitutes a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science." Types of instruction that occurred in the insect sound unit that matched with a Guided Inquiry Orientation included determining patterns, testing explanations, and using the material and intellectual tools of science. Given the positive response that the elementary students and teachers had to the unit and the outcomes we saw in student discussions and products, our comfort with and belief in this approach was strengthened.

The previously described reactions also strengthened our Teacher Efficacy, defined as teacher beliefs about their capacity to implement effective teaching methods for particular teaching goals (Park and Oliver 2008). Our experiences aligned with others who have noted that one way to strengthen Teacher Efficacy is through successful teaching episodes (Mulholland and Wallace 2005). We believe that our Teacher Efficacy increased because we have a better understanding about the developmental appropriateness of data collection procedures for second graders and a more realistic view of the structure needed to support students as they engage in direct experiences while maintaining a level of control in the classroom that enables productive learning to occur. Given our experiences in the second grade classrooms, we are encouraged to continue with our reform-based integrated approaches in other elementary classrooms and in our methods courses.

Knowledge of Science Curriculum

Knowledge of the materials and resources available for teaching specific science topics is a central component of Knowledge of Science Curriculum (Park and Oliver 2008). Working in a community of practice to plan the insect sound unit contributed to our knowledge about new resources for teaching the topic of sound and how they might be realistically incorporated in an elementary setting. One additional outcome of our collaboration is that these experiences served to strengthen our understanding of the difficulties that elementary teachers face in obtaining the resources needed to teach science and language arts in an integrated manner based on reform-based principles. We were able to overcome these difficulties by using resources available through the university and by creating our own. However, it took a great deal of time and the expertise of all members of the group to provide the materials needed for all aspects of the unit.

Knowledge of Instructional Strategies for Teaching Science

This project enabled us to gain Knowledge of Instructional Strategies, such as how to use web-based tools with elementary learners (the Board). The collaboration with the second grade teachers and each other allowed us to reinforce and to deepen our understanding of the value of using an integrated approach to science teaching and the importance of devoting time to sense making after direct science experiences.

Our conversations with the teachers around the building of the Board provided rich opportunities to use their expertise to help us understand how a web page should be constructed so that the level of science vocabulary and length and subject matter of videos that students would collect data from would match the developmental level of the students. Seeing the implementation of the Board with the second graders has led us to consider how we might use this strategy in other grade levels and with other science topics.

Given the strength of feeling that each of the teachers, including Rachel and Leslie, had about the benefits of an integrated instructional approach, we are encouraged to continue using instructional strategies that integrate science and language arts. Our experiences align with the research literature that suggests high student motivation when these approaches are used (Patrick et al. 2009; Romance and Vitale 2001).

Finally, while we have always believed in the importance of providing an opportunity for students to make sense of data with each other and the teacher so that their understanding of science content and vocabulary is supported, accidentally omitting that step from this unit served to reinforce that it is a crucial component of science lessons. As Varelas et al. (2014, p. 1266), have noted, “stressing and focusing on hands-on activities in science teaching does not offer children enough opportunities to engage in developing networks of ideas that are linked together.” In their study, Varelas et al. (2014) suggested that students need additional support to make connections between science activities and texts through opportunities for discussion, an idea that resonated with our experience.

Knowledge of Students' Understanding in Science

Discussions with Annie and Shelby about their students and how they would be grouped for the activities of the unit were enlightening for us as we realized the amount of effort that they assigned to the task. Like others (e.g., Nilsson 2008), these teachers deemed that the creation of successful groups was crucial to the learning opportunities afforded to students. Given the importance placed on students collaborating and working together in the NGSS (NGSS Lead States 2013), consideration of how to organize and develop functioning groups of learners is essential.

While our understanding of the importance of careful group selection increased, there were other areas of Knowledge of Students' Understanding in Science that we still need to address in relation to our PCK development. As we plan future units with other elementary teachers, we need to consider how we can learn more about what students know and understand about particular science concepts and particular areas where they are likely to encounter difficulty (Magnusson et al. 1999; Park and Oliver 2008). Developing appropriate instructional strategies for all students is dependent on deepening our understanding in this area of PCK.

Knowledge of Assessment of Science Learning

While there were areas of our PCK that we did reinforce and strengthen through our experiences working in these two second grade classrooms, there were other areas of our PCK that we did not address, including Knowledge of Assessment for Science Learning. Recognizing the enthusiasm and attention to detail that students displayed when working on their drawings has piqued our interest in this area and has led us to think about how we might engage more thoughtfully with assessment in our future classroom work. Given the documented importance of assessment to student learning (Black and Wiliam 1998), this area of our PCK needs additional consideration.

General Pedagogical Knowledge

While some aspects of our learning in the second grade context might be considered general pedagogical knowledge rather than PCK, in our experience, these types of knowledge are essential for the successful implementation of reform-based science teaching in the elementary classroom. In order to successfully implement cooperative learning groups that can function in a hands-on exploration with materials, we experienced firsthand the importance of considering various strategies for grouping students and the need for clear, explicit directions for students before they begin their investigations. The importance of these skills was also noted by Mulholland and Wallace (2005) who studied one elementary teacher for 10 years. They found that in the early years of her teaching, her lack of general pedagogical skills hampered her science teaching and slowed the growth of her PCK for this subject. However, over time, these skills became a major portion of her science PCK. When Lott (2013), a university professor, returned to the elementary classroom, she also noted the importance of management skills to the success of science lessons declaring that "unless you have good classroom management strategies in place, science learning cannot occur (p. 247)." While both Rachel and Leslie have had experience teaching in elementary classrooms, having a recent experience observing elementary teachers implement successful management strategies was an important reminder of how crucial these are in achieving reform-based science teaching.

Potential Modifications to Our Science Methods Teaching

The knowledge that we gained in this project leads us to consider modifications that we might make to our instruction in our science methods course. In our context, the pre-service elementary teachers (PSETs) take their science methods course in the final semester before they student teach. Their courses are set up in a block system so that the PSETs are enrolled in their methods courses for each content discipline as a cohort. They spend the first 10 weeks of the semester attending university courses 4 days a week and visiting their internship placement at an elementary school 1 day a week. For the final 5 weeks of the semester, they attend their internship placement on a full-time basis participating in classroom life and implementing lessons that they designed during their methods courses.

Our approach to teaching the science methods course in the past has been that we engage the PSETs in reform-based science activities during class that would be appropriate for use in an elementary classroom and that are aligned to our state science standards. We structure the lessons in a 5E format (Bybee et al. 2006) so that there is the opportunity for direct experience followed by group sense making of the science content. Additionally, we spend time discussing appropriate pedagogical approaches for teaching science and we support students as they plan a 5E lesson that they will teach during their internship placement. While we have received positive course evaluations from students, our second grade teaching experiences are prompting us to reflect more deeply about how we might modify the course to better help PSETs develop their own PCK for science teaching.

One area of focus is how we might better use modeling pedagogical techniques in the course since we learned so much from the modeling provided by the second grade teachers. We are considering strategies for how to make our own thinking about our instructional choices more explicit during the class (Dinkelman 2003; LaBoskey 2004), while avoiding creating a contrived modeling of elementary pedagogy in a university context (Lunenberg et al. 2007). For example, we can model concrete science experiences as well as activities that integrate science and language arts instruction in a meaningful way for multiple elementary grade levels. In these lessons, PSETs could experience the seamless connection that can occur when direct science encounters are supported by nonfiction texts and technology-based resources. These opportunities for message abundancy (Gibbons 2015), or being exposed to the same content through a variety of formats, can help the PSETs understand the power of that strategy. These shared experiences in the methods course provide a space where we can model how to conduct a discussion that supports people as they use their concrete science experiences to construct their science understandings and vocabulary with support from the teacher. The use of appropriate questioning strategies and student data collected to facilitate concept development are essential in any science classroom. Finally, we feel that it is important to model and explain how we use our conversations with each other and Annie and Shelby to improve our practice. In this instance, our community of practice enables us to develop better science learning opportunities for elementary students and PSETs. We can share our experiences as lifelong learners as teachers (Akerson et al. 2014) as we model this behavior for our students.

In addition to modeling appropriate pedagogical practices, we believe that we need to establish additional opportunities to scaffold PSETs as they locate and create resources for their own classrooms such as data collection sheets and developmentally appropriate teacher-created technology resources. Our feeling is that, in this case, it is not sufficient to model the use of these strategies, but rather students need support if they are to create them on their own. Not only do they need exposure to the technological tools that will allow them to do the creating, but they also need assistance with decisions about developmental appropriateness, length, and content that is suitable to share in this format. We feel strongly that the technology should not be a replacement for direct experiences, but rather should supplement them.

The importance of reflection-on-action to our own PCK growth is leading us to ponder how we might increase the role of reflection in the methods course during both the university and school-based portions of the course. As others have noted (i.e., Dinkelman 2003), reflection can be a critical component in PSET learning. In the past, we have had PSETs reflect on their teaching during the internship, but we think there are other approaches that can provide opportunities for reflection to facilitate significant learning. In particular, we are contemplating how we might incorporate multiple types of reflection in a variety of small and whole group formats. These contexts might include having the PSETs reflect on our own instruction in the method course, videos of science lessons being taught in elementary classrooms, episodes where their cooperating teacher is teaching science, and situations where PSETs teach science during their internship. We see the use of reflection as particularly helpful for situations where we want PSETs to reflect on what happens in real elementary settings.

Implications

There is an increasing interest in the knowledge and work of teacher educators as researchers observe that there is a lack of formal training to prepare individuals for this work, and little is known about how teacher educators develop their expertise (Berry and Van Driel 2012). Given the complexity of the work of teacher educators, it is important for them to have opportunities to grow professionally (Loughran 2014). Like other science educators who returned to the classroom (i.e., Akerson et al. 2014; Lott 2013), we found working closely with classroom teachers in the elementary setting provided a valuable learning experience. Collaborating with the second grade teachers to plan and implement lessons offered a meaningful context for professional development for us as science educators and enabled us to build our PCK for elementary science teaching while also experiencing professional renewal. This outcome is noteworthy given the lack of formal structures for professional development for science educators once they move beyond their doctoral programs (Johnston and Settlage 2008). However, there is a growing body of evidence that when science educators return to the classroom and study the experience in a systematic way, there is the opening for professional growth (Akerson et al. 2014; Dias et al. 2011).

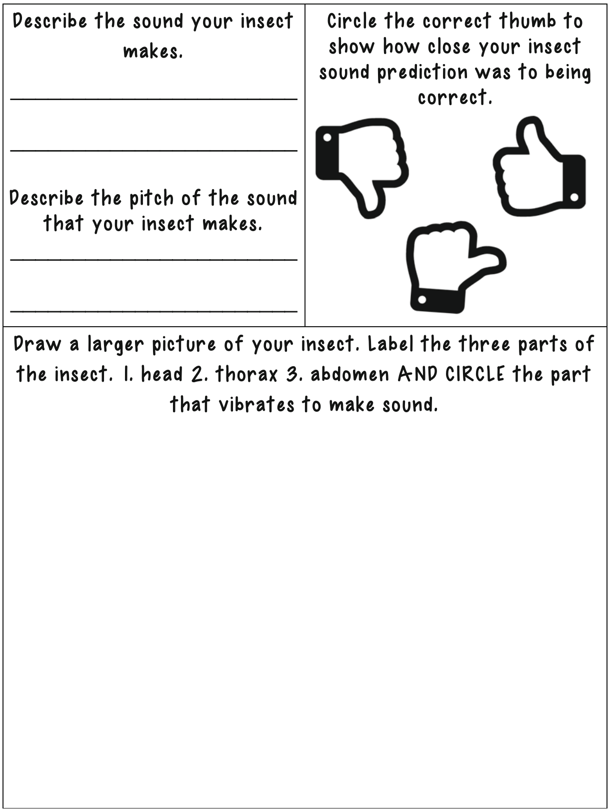
Our goal is to translate our newly expanded PCK for elementary science teaching into a more robust PCK for teaching science teachers (Abell et al. 2009). We hope to use the knowledge that we have gained to help narrow the theory-practice gap that is believed to exist between university teacher education programs and public schools. Though it was beyond the scope of this study, we plan to research the outcomes of the modifications in our courses on the beliefs and practices of the PSETs that we teach. Participating in this project has helped us to realize that opportunities for conversations about our teaching as science educators and its impact on our students are scant in the research literature, though there are calls for teacher educators to accumulate and disseminate their knowledge in a research-supported manner (Loughran 2007; Zeichner 2007).

An additional implication is that our time working with the second grade teachers and students on a unit where we attempted to integrate science practices and content with language arts skills has led us to consider what components might be necessary in a PCK for integrated teaching at the elementary level. While we certainly feel that our PCK for science teaching was impacted by our experiences, we also feel that there were areas of growth in our knowledge base that occurred in relation to integration that do not fit into the models of PCK that currently exist. Investigating a PCK for integrated teaching is a promising area of future research.

Acknowledgements The authors wish to thank the Reich College of Education at Appalachian State University which supplied classroom materials for this project through a Partnership Mini-Grant which encourages collaborations between public school teachers and university teacher educators. We also wish to thank our elementary partners in this project.

Appendix

Fig. 1 Sound data collection sheet



References

Abell, S.K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*(10), 1405–1416.

Abell, S. K., Park Rogers, M. A., Hanuscin, D. L., Lee, M. H., & Gagnon, M. J. (2009). Preparing the next generation of science teacher educators: a model for developing PCK for teaching science teachers. *Journal of Science Teacher Education, 20*, 77–93.

Akerson, V., & Young, T. A. (2008). *Why research on interdisciplinary language arts and science instruction. Interdisciplinary language arts and science instruction in elementary classrooms: applying research to practice* (pp. 3–11). Mahwah, NJ: Lawrence Erlbaum Associates.

Akerson, V. L., Pongsanon, K., Weiland, I. S., & Nargund-Joshi, V. (2014). Developing a professional identity as an elementary teacher of nature of science: a self-study of becoming an elementary teacher. *International Journal of Science Education, 36*(12), 2055–2082.

Appleton, K. (2006). Science pedagogical content knowledge and elementary school teachers. In K. Appleton (Ed.), *Elementary science teacher education: international perspectives on contemporary issues and practice* (pp. 31–54). Mahweh, NJ: Lawrence Erlbaum Associates.

Baker, L. (1991). Metacognition, reading, and science education. In: Santa, C. M., & Alvermann, D.E., *Science Learning Processing and Applications* (pp 2–13).

Berry, A., & Van Driel, J. H. (2012). Teaching about teaching science: aims, strategies, and backgrounds of science teacher educators. *Journal of Teacher Education, 64*(2), 117–128.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in education:Principles, policies, and practices, 5*(1), 7–71.

Bradbury, L. U. (2014). Linking science and language arts: a review of the literature which compares integrated versus non-integrated approaches. *Journal of Science Teacher Education, 25*(6), 465–488.

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (Eds.). *Handbook of educational psychology* (pp. 673–708). New York: Macmillan.

Bullough Jr., R. V., & Pinnegar, S. (2001). Guidelines for quality in autobiographical forms of self-study-research. *Educational Researcher, 30*(3), 13–21.

Bybee, R.W., Taylor, J.A., Gardner, A., Van Scotter, P., Powell, J.C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: origins and effectiveness.* Retrieved from: http://bscs.org/bscs-5e-instructional-model.

Carle, E. (1990). *The very quiet cricket*. New York: Philomel Books.

Cervetti, G. N., Pearson, P. D., Bravo, M. A., & Barber, J. (2006). Reading and writing in the service of inquiry-based science. In R. Douglas, M. P. Klentschy, & K. Worth (Eds.), *Linking science and literacy in the k-8 classroom* (pp. 221–244). Arlington, VA: NSTA Press.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.

Dias, M., Eick, C. J., & Brantley-Dias, L. (2011). Practicing what we teach: a self-study in implementing an inquiry-based curriculum in a middle grades classroom. *Journal of Science Teacher Education, 22*(1), 53–78.

Dinkelman, T. (2003). Self-study in teacher education: a means for promoting reflective teaching. *Journal of Teacher Education, 54*(1), 6–18.

Ertmer, P. A., & Newby, T. J. (1996). The expert learner: strategic, self-regulated, and reflective. *Instructional Science, 24*, 1–24.

Faikhamta, C., & Clarke, A. (2013). A self-study of a Thai teacher educator developing a better understanding of PCK for teaching about science. *Research in Science Education, 43*, 955–979.

Feldman, A. (2003). Validity and quality in self-study. *Educational Researcher, 32*(3), 26–28.

Ford, D. J. (2006). Representations of science within children's trade books. *Journal of Research in Science Teaching, 43*(2), 214–235.

Gibbons, P. (2015). *Scaffolding language, scaffolding learning: teaching English language learners in the mainstream classroom* (2nd ed.). Portsmouth, NH: Heinemann.

Grossman, P. (1990). *The making of a teacher: teacher knowledge and teacher education*. New York: Teachers College Press.

Johnston, A., & Settlage, J. (2008). Framing the professional development of members of the science teacher education community. *Journal of Science Teacher Education, 19*(6), 513–521.

LaBoskey, V. K. (2004). The methodology of self-study and its theoretical underpinnings. In J. J. Loughran, M. L. Hamilton, V. K. LaBoskey, & T. Russell (Eds.), *International handbook of self-study of teaching and teacher education practices* (pp. 817–869). Dordrecht: Kluwer Academic Publishers.

Lead States, N. G. S. S. (2013). *Next generation science standards: for states by states*. Washington, DC: National Academies Press.

Lederman, N. G., Kuerbis, P. J., Loving, C. C., Ramey-Gassert, L., Roychoudhury, A., & Spector, B.S. (1997). Professional knowledge standards for science teacher educators. *Journal of Science Teacher Education, 8*(4), 233–240.

Lott, K. (2013). Reestablishing the role of the university professor in the laboratory school: retooling in an elementary classroom. In M. Dias, C. J. Eick, & L. Brantley-Dias (Eds.), *Science teacher educators as K-12 teachers: practicing what we teach* (pp. 243–251). New York, NY: Springer.

Loughran, J. (2007). Researching teacher education practices: responding to the challenges, demands, and expectations of self-study. *Journal of Teacher Education, 58*(1), 12–20.

Loughran, J. (2014). Professionally developing as a teacher educator. *Journal of Teacher Education, 65*(4), 271–283.

Lunenberg, M., Korthagen, F., & Swennen, A. (2007). The teacher educator as a role model. *Teaching and Teacher Education, 23*, 586–601.

Magnusson, S., Krajick, J., & Borko, H. (1999). Nature, sources, and development of edagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95–120). Boston: Kluwer Academic Publishing.

Mulholland, J., & Wallace, J. (2001). Teacher induction and elementary science teaching: enhancing self-efficacy. *Teaching and Teacher Education, 17*, 243–261.

Mulholland, J., & Wallace, J. (2005). Growing the tree of teacher knowledge: ten years of learning to teach elementary science. *Journal of Research in Science Teaching, 42*(7), 767–790.

Munby, H., & Russell, T. (1994). The authority of experience in learning to teach: messages from a physics methods class. *Journal of Teacher Education, 45*(2), 86–95.

National Research Council (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Nilsson, P. (2008). Teaching for understanding: the complex nature of pedagogical content knowledge in pre-service education. *International Journal of Science Education, 30*(10), 1281–1299.

Osmond, P., & Goodnough, K. (2011). Adopting just-in-time teaching in the context of an elementary science education methodology course. *Studying Teacher Education, 7*(1), 77–91.

Padilla, M. J., Muth, D., & Padilla, R. K. (1991). Science and reading: many process skills in common? In C. M. Santa & D. E. Alvermann (Eds.), *Science learning: processing and applications* (pp. 14–19). Newark, DE: International Reading Association.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization for pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261–284.

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: is there a gender gap and does integrated inquiry and literacy instruction make a difference. *Journal of Research in Science Teaching, 46*(2), 166–191.

Patten, M. L. (2009). *Understanding research methods*. Glendale, CA: Pyrczak Publishing.

Pearson, P., Moje, E., & Greenleaf, C. (2010). Literacy and science: each in the Service of the Other. *Science, 328*(5977), 459–463.

Romance, N. R., & Vitale, M. R. (2001). Implementing an in-depth expanded science model in elementary schools: multi-year findings, research issues, and policy implications. *International Journal of Science Education, 23*(4), 373–404.

Schön, D. A. (1983). *The reflective practitioner: how professionals think in action*. New York: Basic Books.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: foundations of a new reform. *Harvard Educational Review, 57*(1), 1–22.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education, 4*(2), 99–110.

Varelas, M., Pieper, L., Arsenault, A., Pappas, C. C., & Keblawe-Shamah (2014). How science texts and hands-on explorations facilitate meaning making: learning from Latina/o third graders. *Journal of Research in Science Teaching, 51*(10), 1246–1274.

Wiebke, H., & Rogers, M. P. (2014). Transition to science teacher educator: tensions experienced while learning to teach lesson sequencing. *Studying Teacher Education, 10*(3), 222–238.

Zeichner, K. (2007). Accumulating knowledge across self-studies in teacher education. *Journal of Teacher Education, 58*(1), 36–46.