Introducing the NGSS in Preservice Teacher Education

by Tiffany Hill, Emporia State University; Jeni Davis, Salisbury University; Morgan Presley, Ozarks Technical Community College; & Deborah Hanuscin, Western Washington University

Abstract

While research has offered recommendations for supporting inservice teachers in learning to implement the NGSS, the literature provides fewer insights into supporting preservice teachers in this endeavor. In this article, we address this gap by sharing our collective wisdom generated through designing and implementing learning experiences in our methods courses. Through personal vignettes and sharing of instructional plans with the science teacher education community, we hope to contribute to the professional knowledge base and better understand what is both critical and possible for preservice teachers to learn about the NGSS.

Introduction

Research related to past reforms demonstrated that experienced teachers often view standards in a negative light (Donnelly & Sadler, 2009; Winkler, 2002), citing frustration, loss of power, increased paperwork, elimination of cherished activities, peer pressure, and loss of personal freedom associated with standards. In contrast, the literature suggests that new teachers tended to view these standards more positively because they perceive that standards promote accountability, foster alignment and consistency, and provide guidance for planning (Winkler, 2002). While this may make introducing the Next Generation Science Standards (NGSS) to preservice teachers sound like an easy task, we find this is not the case.

The co-authors of this manuscript, all science teacher educators, have collaborated to develop our pedagogy of teacher education, beginning as graduate students under the mentorship of the last author (Hanuscin) and now as colleagues teaching at different institutions. The NGSS pose a unique challenge to each of us, as our own classroom teaching experience preceded their release. We have documented our own efforts to understand and implement the NGSS elsewhere (King et al., in press; Hanuscin, Cisterna, & Lipsitz, 2018; Hanuscin, Arnone, & Bautista, 2016; Hanuscin & Zangori, 2016; Lee, Cite, & Hanuscin, 2014). In this article we undertake a more formal examination of our efforts to support preservice teachers enrolled in our elementary science methods courses in: (a) understanding the structure and contents of the NGSS and (b) implementing assessment and instruction that aligns with the NGSS. In doing so, our goal is to produce knowledge that might be useful to other teacher educators who are engaged in similar work.

Our reflection as teacher educators was prompted by questions including:

- How are we currently teaching the NGSS? What factors influence what and how we teach about the NGSS in our course?
- What aspects of our NGSS instruction seem to be working well and what aspects are not working well? What have we learned through our teaching?

Teacher Education and the NGSS

Given the complexity of reform, researchers have documented some of the challenges teachers face in understanding and implementing science standards. Although many of these studies have not directly addressed learning about the standards in teacher education, the implications for preservice science teachers are evident.

Lynch (1997) and Reiser (2013), speaking about the National Science Education Standards and NGSS, respectively, caution that if teachers lack clear images of what enactment of the standards "looks like" in K-12 classrooms, they may still teach in traditional ways despite exhibiting buy-in for and understanding of reforms. Field experiences provide an opportunity for preservice teachers to observe teaching and learning in progress; however, as teachers may not yet or may just now be engaging in the process of aligning curriculum, instruction, and assessment with the NGSS, it is unlikely that field experiences can provide opportunities for preservice teachers to see appropriate models of the NGSS in action.

Nollmeyer and Bangert (2015) highlight the distinction between teacher *understanding* of the standards and their *readiness* to teach the standards, suggesting that understanding of the standards does not guarantee transfer to practice. This is related to observations of Windschitl and colleagues (2014), who emphasize that while the NGSS describe what science learning experiences should enable students to understand and be able to do, the standards provide little guidance as to how a teacher might design and enact instruction to achieve these learning experiences. This is problematic given that designing and enacting instruction is particularly challenging for preservice teachers, who are still developing a beginning repertoire of pedagogical tools and strategies (Feiman-Nemser, 2001).

Smith and Nadelson (2017) reported barriers to implementing the NGSS among elementary teachers included a lack of professional development, a culture of support for science education, and instructional resources. Yet, the researchers also found that teachers' current practices were in some ways aligned already with several of the science practices, suggesting these practices could serve as leverage points for building their understanding and pedagogy through professional development. This suggests that finding similar leverage points for preservice teachers, perhaps based on their prior experiences as a learner of science, may be an important consideration for teacher educators.

There is also evidence that working in collaborative teams can enhance teacher sense-making about reforms (Putnam & Borko, 2000), foster critical discussions about the goals of reform as teachers implement new curricula (Lynch, 1997), create opportunities to "dig beneath the surface" of reforms to explore substantive issues of practice (Reiser, 2013), and reduce resistance to change an innovation (van Driel et al., 2001). While norms of privacy and isolation often characterize the teaching profession (Little, 1990), the teacher education classroom lends itself towards collaboration, which may be advantageous in this regard.

While the above are broad or general challenges that teachers encounter in aligning their practice to the NGSS, several researchers have elucidated more specific difficulties preservice teachers have in learning about the NGSS. Ricketts (2014) documented preservice teachers' confusion about the purpose of modeling and the conflation of argumentation and explanation building. Hanuscin and Zangori (2016) described the difficulties preservice teachers have in comprehending the Crosscutting Concepts and their relevance to instruction and assessment. Yet, there are also promising ideas preservice teachers bring to the learning experience that we, as science teacher educators, can build upon. For example, Ricketts (2014) identified preservice teachers' emphasis on argumentation and communication between scientists, acknowledgement of the importance of critical thinking, and recognition of asking and answering questions as the goal of science as leverage points for learning about the Science and Engineering Practices.

Overall, however, fine-grained information about preservice teachers' resources and difficulties with regard to understanding and implementing specific aspects of the standards remains sparse. Our own experiences working in teacher education have shed light on particular challenges to teaching preservice teachers about the NGSS, and has led us to develop a series of activities to address these challenges while leveraging resources we found preservice teachers brought to the learning experience. In this article, we aim to share our collective "wisdom of practice" to articulate our experiences in ways that can help other teacher educators anticipate, elicit, and respond to these challenges in their own courses and programs. In the sections that follow, we each provide a vignette describing our implementation of a specific NGSS learning experience. In the vignettes that follow, each author reflects on what led to the creation of the specific lesson, describes the lesson in action, and unpacks preservice teachers' learning. While we each highlight a single learning experience below, we have made a full collection of seven classroom activities available for use by other science teacher educators via Google Drive. Figure 1 provides a brief description of each of the seven classroom activities.

Figure 1 (Click on image to enlarge). Description of classroom activities in Google Drive. Activities featured within the article are identified with an asterisk (*).

Learning Experience 1. Is it in the NGSS
Preservice teachers identify science topics and experiences from their own K-12 education and investigate the NGSS to see whether these will be part of the science they will teach their future students.

Learning Experience 2. Then and Now*
Preservice teachers complete a card sort activity of learning experiences in which they identify the crosscutting concept featured in each learning experience.

Learning Experience 3. Three Dimensions Concept Attainment*
Preservice teachers participate in a concept attainment experience to develop their understanding of the three dimensions of the NGSS. Preservice teachers then write a personal definition of each dimension for reference in subsequent activities.

Learning Experience 4. Snapshots of Practice
Preservice teachers participate in a card sort of two to three sentence classroom learning "snapshots." Preservice teachers sort the snapshots according to the Science and Engineering Practice in which learners are engaged and/or the Science and Engineering Practices the teacher could emphasize as a part of instruction.

Learning Experience 5. Crosscutting Concepts Card (CCC) Sort*
Preservice teachers complete a card sort activity of learning experiences in which they identify the crosscutting concept featured in each learning experience.

Learning Experience 6. Aligning Instruction to the NGSS
Preservice teachers work with a partner to analyze and modify an existing lesson plan (one of their own or an online lesson plan) to align with NGSS.

Learning Experience 7. Using the CCC as a Lens*
Preservice teachers use the CCC as a lens to frame a science investigation for students.

Understanding How Standards Shape Science Education

As a novice teacher, I (Hanuscin) was familiar with "standards" but do not recall viewing these as anything more than a checklist of things to teach. As I have progressed in my career, I have also progressed in my understanding of standards and the role they play in shaping what and how science is taught. Over time, and as I have moved from state to state, I have seen different sets of standards with very different underlying visions for science education. When I encountered the NGSS, I knew the ambitious vision put forth in this reform was far different from what my students would have encountered in their own education, and perhaps the vision they had already formed for themselves as a teacher of science based on that experience. This activity grew out of this awareness, and a desire to help students not only understand, but embrace this vision.

During the first week of the methods course, we use a Science Autobiography (Koch, 1990) assignment to get to know our students and the science experiences that have shaped their view of science and science teaching. Through this assignment, students come to realize the important role their teachers played in shaping their positive (or negative) feelings about science. This helps them understand the important role *they* will play in their future students' lives as well. Yet, as instructors, we often find the nature of students' learning experiences to be quite different from the types of experiences envisioned in the NGSS. Many students recall doing activities that were hands-on and fun, but rarely can they recall what they learned in science beyond memorizing facts. Despite this, many remain satisfied with their science education (particularly if they received good or passing grades). In problematizing this view of science teaching, we run the risk of vilifying their previous teachers– many of whom they recall fondly and look to as role models for the kinds of teachers they want to be. In doing so, we also run the risk of alienating students for whom these teachers embody an ideal they wish to emulate. To avoid this, we developed a learning experience to help our students understand how standards embody a particular vision for science education, and

how that vision shapes the learning experiences teachers plan for students. This helps them develop a more empathetic view of their teachers, and the shortcomings they will come to identify in their own science education as we move through the course.

The Learning Experience: ***Then and Now***

We begin this learning experience by selecting excerpts of two sets of standards for similar topics or concepts. We draw from both the NGSS and the previous state standards that were in place during our students' own elementary education. We have found "standards" is a vague term, and preservice teachers are often confused about what the term refers to– given the three dimensions of the NGSS, as well as the Performance Expectations, we develop a convention in class that when we say "standards" we mean the entire NGSS– whereas, the individual components of the standards will be indicated by their names (e.g., Disciplinary Core Ideas).

In small groups, students compare the two excerpts to each other and discuss the following:

- How are the two sets of standards alike? Different?
- What does each emphasize as being most important for students to know and be able to do?
- If you were using these standards to guide your teaching, how might your instruction be different in each case?

We have found that preservice teachers immediately picked up on the key differences between the two sets of standards. Our previous state standards really foregrounded learning facts and information, while the NGSS is more focused on "big ideas." Furthermore, the NGSS includes– in addition to a focus on science content– practices and cross-cutting concepts. In deciphering the underlying emphasis of the two standards, preservice teachers describe the previous state standards as conveying that it is important for students to *know science*, while the NGSS conveys that is important for students to *do science* and *use what they know* about science to solve problems. When asked how they might teach if they were using the former state standards, preservice teachers often recognize that it would be quite similar to the way they were taught and what they described in their science autobiographies. Asking *how do you think your science autobiographies might read differently if your teachers had been working with the NGSS?* helps them begin to articulate the vision of the NGSS, and realize the ways in which the standards will require them to teach in ways that are different than how they were taught. In this manner, they can both appreciate the efforts of their previous teachers, as well as seek alternative approaches and strategies.

While this learning experience certainly impacts their beliefs, this learning experience alone is insufficient to prepare them to teach in ways that align with the standards. Research on challenges new teachers face by Davis and colleagues (2006) emphasized the discrepancies that often occur between preservice teachers' beliefs and practice. This suggests that translating their understanding and beliefs about standards into practice may

prove difficult for preservice teachers. We find that sharing our own efforts to transform our practice to be more consistent with the NGSS (Hanuscin et al., 2016; Lee et al., 2014) helps reassure preservice teachers that, while challenging, it is possible for them to progress towards this goal.

Understanding Three-Dimensional Learning

Upon reading the Framework for K-12 Science Education (National Research Council [NRC], 2012) for the first time, prior to the release of the NGSS, I (Hill) was struck with the realization that most of the experiences I had as a learner of science prior to and in high school emphasized science content, but often overlooked the two other dimensions presented in the report. At the same time, I had the even scarier realization that I had not done much better for the students who I taught as a classroom teacher. Although the lessons I planned for students sometimes engaged them in the practices of scientists, I was certain that I had never helped them make the connections that the Crosscutting Concepts demand. In other words, I had never experienced or planned a three-dimensional learning experience– this was a concerning thought. After reading the Framework, these realizations were immediate and profound for me; however, the account below demonstrates that upon teaching the three dimensions to preservice teachers for the first time, their reactions were much different.

An essential part of the methods course involves helping preservice teachers to understand the three dimensional learning that is central to the NGSS. To develop this understanding in the past, we engaged preservice teachers in course readings and discussions that covered the structure of the standards (e.g., Duncan & Cavera, 2015). In these discussions, it was common to hear preservice teachers make comments, such as, “This just isn’t that different from how I learned science in third grade.” These statements were often a surprise to us; after all, these students did not grow up under these standards, so one would assume their experiences with three dimensional learning would be limited. It also suggested to us that preservice teachers had a superficial understanding of the three dimensions from reading about them.

Planning from a reflective orientation (Abell, Appleton, & Hanuscin, 2010), we developed the following learning experience to provide preservice teachers with structured opportunities to compare their previous educational experiences to this new, unfamiliar idea of three-dimensional learning. In other words, I wanted them to have the profound realization that I had when I first learned of the three dimensions. The purpose of the learning experience is to help preservice teachers to recognize the presence– or absence– of the dimensions in their prior learning. In turn, we also intend for preservice teachers to also develop a more robust understanding of the three dimensions.

The Learning Experience: ***Three Dimensions Concept Attainment***

To begin, we ask preservice teachers to record their two most memorable science learning experiences, each on a different Post-it note. We explain that the memories need not be “good” or “bad,” just those learning experiences with which he or she has the most vivid recollection. Once preservice teachers recall from those learning experiences all that can be remembered, we ask for volunteers to share their memories aloud with the entire class, one at a time. As the preservice teachers share their memories, we place their Post-It notes on a three-ring Venn Diagram until there are enough memories posted for students to infer possible meanings for each ring.

The Venn Diagram is designed so that each ring represents a different dimension (e.g., a blue ring for the Science and Engineering Practices). However, we do not share the meaning for the color coding scheme with students, other than to tell them that the NGSS have three different dimensions, and each ring represents a different dimension of the standards. Their job is to infer the meaning of the three different dimensions, based on the memories that are placed on the Venn Diagram. The more memories that are posted on the Venn Diagram, the better preservice teachers are able to infer the meaning of each of the three dimensions.

After students develop a basic definition of each dimension, we supplement with more formal definitions, and often refer them to course readings that provide additional information (e.g., Duncan & Cavera, 2015). Although the Venn Diagram experience can be implemented after preservice teachers have read about the three dimensions, we recommend doing it before reading, if possible. As such, the placement of memories on the Venn Diagram creates a concept attainment learning experience, so the preservice teachers can formulate an initial understanding of each dimension before learning about it in the course reading.

After memories are placed, preservice teachers often notice that most of their memories were not three dimensional and, in response to this observation, conclude that we cannot teach science as we learned it. As a result, we notice that preservice teachers express dissatisfaction with their prior experiences as a learner of science. While this dissatisfaction often serves as a motivator for some preservice teachers to learn more about the NGSS, others become uncertain, and therefore lose confidence, about their potential success as a teacher of science. Subsequent opportunities for preservice teachers to learn more about the three dimensions and to experience three-dimensional learning through model lessons can help to address discouragement.

Understanding the Crosscutting Concepts

As I (Presley) began to incorporate the NGSS into my science methods course and ask students to reflect on their previous science experiences, it became clear that while they had experience with content (the Disciplinary Core Ideas) and the scientific process (the Practices), they had little to no experience with identifying concepts that applied across science disciplines. Indeed, I had little experience with Crosscutting Concepts as an elementary student and limited training in how to teach Crosscutting Concepts to preservice

teachers. When I first started teaching the NGSS, I tended to gloss over the Crosscutting Concepts and focused on the other dimensions of the framework. This activity was developed to remedy my exclusion of Crosscutting Concepts and as it was developed, I began to understand what Crosscutting Concepts are, how they should be addressed in the elementary classroom, and how to develop learning experiences that connected with one or more crosscutting concepts.

When we taught the previous learning experience about the three dimensions of the NGSS, we noticed that preservice teachers had prior experiences with learning science content and the act of doing science and engineering, but had little experience thinking about those concepts that have application to all areas of science. In fact, numerous groups of preservice teachers with which we have worked have been unable to identify *any* references to crosscutting concepts in their prior experiences.

With an awareness that preservice teachers experience difficulties in comprehending the Crosscutting Concepts and their relevance to instruction and assessment (Hanuscin & Zangori, 2016), the following learning experience was designed to familiarize preservice teachers with the Crosscutting Concepts outlined in the NGSS, and to recognize occurrences of Crosscutting Concepts in the elementary classroom. Furthermore, the learning experience highlights the importance of preservice teachers' intentional integration of and reference to the Crosscutting Concepts in lessons that are planned for the elementary classroom.

The Learning Experience: ***Crosscutting Concepts Card Sort***

This learning experience begins with preservice teachers reading about Crosscutting Concepts (Duschl, 2012) and talking with their peers about the article. We have found that discussions of preservice teachers often reflect their belief that the Crosscutting Concepts are vague. In particular, preservice teachers did not often understand the connection between the concepts and how they might apply to lessons that are planned for the elementary classroom. Preservice teachers also tended to view the Crosscutting Concept as the main purpose of instruction, verses an integrated concept.

Using preservice teacher discussions as a guide, we then explain essential information related to the misconceptions that were overheard (e.g., Crosscutting Concept should be explicit and integrated). Further, we provide preservice teachers with time to review the definitions of each Crosscutting Concept. From our experience, we have found that preservice teachers were able to make sense of the concept of *Cause and Effect* by connecting to literacy standards; however, the concepts of *Energy and Matter, Structure and Function,* and *Stability and Change* are more challenging for the preservice teachers to understand.

After students develop a basic definition of each concept, we engage students in a card sort (Keeley, 2008) related to the Crosscutting Concepts. Each card details an elementary science scenario that highlights a Crosscutting Concept. For example, one card reads: *students ask questions to identify magnetic relationships* and another card reads: *students design an investigation to compare the effects of different surfaces on the speed at which a car moves down a ramp.* For this scenario, there are opportunities for the concept of *Cause and Effect* to be integrated. In general, the card sort allowed preservice teachers to apply their knowledge of Crosscutting Concepts to elementary science scenarios, and consider how they might highlight certain Crosscutting Concepts in the elementary classroom.

During this task, we found that preservice teachers had difficulty sorting the cards that did not explicitly connect to one of the concepts. For example, preservice teachers sorted the card, *after observing mealworms, students draw a model of their life cycle*, with *Systems and System Models* because the word "model" was on the card, but did not know where to place the card, *develop a model to help students understand that matter is too small to be seen*, because 'model' and "matter" are related to two different crosscutting concepts. Likewise, any relationship between two or more science concepts was perceived as related to *Cause and Effect*. While these points of confusion lead to useful discussion about the "right" answer, we recognize that such confusion is indicative of superficial, not deep understanding of the Crosscutting Concepts. This observation suggests that additional time spent on Crosscutting Concepts would be beneficial; however, available time in a methods course is limited. Thus, we experience an ongoing tension in our teaching. Even several model lessons related to a single Crosscutting Concept may fail to support preservice teachers in understanding how to utilize the Crosscutting Concepts to make connections across several units in their own instruction. We have continued to develop additional learning experiences related to this dimension of the NGSS (see Google Drive).

Understanding Standards-Based Lesson Planning

As a first year teacher, I (Davis) used BSCS Science Tracks curriculum and was introduced to the 5E model (Bybee, 1997). While my state had state-developed science standards, I did not use standards to guide instruction. Instead, I turned the page in the BSCS teacher's manual and trusted I was doing my job. Over the years, and working in different states and with different curricula, I began to learn more about the 5E model and inquiry-based strategies for students to discover scientific knowledge on their own; however, I had curricula (i.e., FOSS, Delta) to guide my instructional decisions– never looking to state standards. In graduate school, I was introduced to standards as a measure of what we want students to know, or be able to do, and exposed preservice teachers to state-level standards to guide the development of their own 5E lesson plans. As a science teacher educator in an NGSS-adopted state, I have had to work hard to understand NGSS. Working with colleagues, I now design and teach about science lessons aligned with the NGSS three-dimensions grounded in the nature of science. In my experience, I have noticed that preservice teachers do not

know where to begin when planning a lesson and quickly turn to Google or Pinterest for ideas. This learning experience was developed to help preservice teachers see that lesson design does not need to start from scratch, but in most cases, lessons need to be modified to align with NGSS.

In our experience, the curriculum materials available to elementary teachers vary widely from state to state and district to district. It is difficult for us to predict what curriculum might be available to our students in their future classrooms, and we know as well that even when a specific text or kit series is used, teachers will often supplement that with additional curriculum materials and resources. While some materials may claim to be "aligned to the NGSS," a close analysis often reveals that quite the opposite may be true. This requires that teachers think critically about the activities and resources they locate, and identify ways to adapt them to reflect the three-dimensional learning outlined in the NGSS. We implement the learning experience described below with equipping our students to be savvy consumers of curriculum materials– whether these are provided to them or whether they seek them out.

During the first week of the methods course, we use the Lesson Planning Task (Abell, et al., 2010) as a pre-assessment to elicit preservice teacher knowledge of science lesson planning. The submitted lesson plans are not connected to the NGSS (some are connected to Common Core State Standards, 2010), typically follow a gradual release model (Fisher & Frey, 2008), lack connection to the nature of science, and are very procedural and teacher-directed in nature.

The Learning Experience: ***Aligning Instruction to the NGSS***

After participating in several modeled lessons, reading articles from *Science and Children*, and discussing *what* is science, *why* science should be taught, and *how* science should be taught according to the NGSS, preservice teachers are asked to bring into class 2-3 science lesson plans (or activities) from a text series, curriculum guide, activity book, website, or ones they have written. In small groups, preservice teachers discuss their lesson plans/activities (i.e., grade level, where the lesson plan/activity was found, the purpose of the lesson plan/activity, and why they selected the lesson plan/activity).

As preservice teachers discuss the lesson plans brought in, many excitedly share a personal connection to the lesson. Some preservice teachers remember doing the activity in elementary school, some thought the activity looked "fun," and some share a lesson plan provided by their mentor teacher in which they are being asked to teach. The instructor leads a discussion about how teachers often utilize previously published lesson plans and/or activities for science teaching and learning. And although the activity may look "fun" or "ready to use," a close analysis of these lesson plans and/or activities brings to light a missed connection to what science is and the NGSS.

As preservice teachers explore the lesson plans for evidence of Disciplinary Core Ideas, Science and Engineering Practices, Crosscutting Concepts, and the Nature of Science, I begin to hear murmurs. Preservice teachers often notice a lack of content– that the lesson is "just a fun activity" but does not really teach any "big ideas." In addition, preservice teachers begin to realize that the lesson is teacher-directed. Even in the lesson plans that explicitly state the NGSS, not all three dimensions are included and the nature of science is rarely addressed. I can sense their confidence in identifying "cookbook" lesson plans, yet their frustration is evident in their critiques. "How can they publish this?" is a question preservice teachers ask when they realize the shortcomings of the resources they identified.

When prompted, preservice teachers are quick to share the connections (or lack of connections) to the NGSS. They report out ideas such as, "students are asked to record observations, but the lesson plan does not explicitly connect to the practice of Obtaining, Evaluating, and Communicating Information." After sharing strengths and limitations of the lesson plan/activity preservice teachers are asked to modify the lesson plan to align with the NGSS. However, even though preservice teachers see the absence of one dimension, they are unsure how to modify the plan. They are leery of their own content knowledge and have a hard time seeing connections to the NGSS Disciplinary Core Ideas. Also, they tend to focus on rewriting the entire lesson instead of incorporating terminology to explicitly address the NGSS Practices and Crosscutting Concepts. While this learning experience allows preservice teachers an opportunity to apply their understanding of the NGSS, we see preservice teachers still struggle to understand how to incorporate and deliver a three-dimensional lesson in the classroom.

While the next step would be for preservice teachers to have the opportunity to implement their modified lesson in a field experience, few preservice teachers have the opportunity to do so for a variety of reasons. In some cases, preservice teachers are placed in districts that are doing something different than what is considered NGSS-aligned. Even in adopted states, districts may not have modified *all* lessons to highlight the three-dimensions and mentor teachers may be unfamiliar with the NGSS and unable to support the preservice teacher in explicitly addressing each dimension. In addition to supporting preservice teachers' understanding of the NGSS, we also need to consider how to support preservice teachers as they navigate a field experience that may not align with the science methods course.

Discussion

In this article, we have articulated our collective "wisdom of practice" in implementing NGSS learning experiences in the hopes of supporting other teacher educators in their efforts to help preservice teachers understand and successfully implement NGSS-aligned instruction. We note there are several factors that have influenced what and how we teach about the NGSS. Primary among these are our own personal learning and sense-making about the NGSS, our understanding of our students' experiences as science learners, and the

constraints of our specific courses and contexts. As we reflect on aspects of our instruction that have been more effective and less effective in providing students with what they need to understand and successfully implement NGSS-aligned instruction, we have also gained several insights from our experiences that can help inform the efforts of others.

Throughout the design of the learning experiences we have described, our own experiences learning to teach and/or learning about the NGSS have remained in the forefront of our minds. The newness of the NGSS allows us to empathize with our students' efforts to make sense of the standards. In reflecting on our own sense-making, we have been able to target potential areas of confusion and focus our attention on aspects we know to be particularly challenging when first encountering the NGSS. For example, our own difficulty in coming to understand the Crosscutting Concepts led us to develop several different learning experiences targeting this dimension of the NGSS. Other teacher educators might similarly reflect on how they came to understand the NGSS to identify strategies for anticipating challenges and supporting their students. Of course, this does not imply that the entry points and inroads for veteran teachers and novice teachers will be the same; it is important to identify the resources you drew upon to make sense of the NGSS and consider whether those same resources are available to preservice teachers. For example, our learning experience *Then and Now* recognizes that the way in which the vision embodied by educational standards shapes the nature of teaching and learning is not something obvious from the perspective of the learner or gleaned through an apprenticeship of observation. Thus, making that visible to our students is important to their learning.

Another important factor has been the understanding we have developed about our specific students– not only as future teachers but as science learners. Both the Science Autobiography and Lesson Plan Task assignments that we implement in our methods courses have been key to helping us develop this understanding. While it can be easy to view students' prior K12 experiences from a deficit perspective (i.e., as a "lack of appropriate science experiences"), we have strived to use their experiences as a foundation for their learning and as assets to their sense-making about the NGSS. Knowing both *what* our students experienced as learners and *how* they view that experience (and themselves as science learners) has been invaluable in adapting our instruction to better meet their needs.

Furthermore, knowing our students' passions as well as their insecurities has helped us address not only the cognitive dimensions of their learning, but also affective dimensions. We have come to realize our students need not only to *know about the NGSS*, but also to *know they can plan and teach in ways that align with the vision of the NGSS.* Just as we have empathized with our students' efforts to make sense of the standards, we have empathized with their experiences evaluating their own readiness to teach in this way. Acknowledging the complexity of the NGSS and the ambitious teaching required to implement the standards has to be balanced by emphasizing the benefits and rewards of the undertaking. In this sense,

modeling NGSS-aligned instruction is not just important for demonstrating particular teaching approaches, but also for allowing students to experience the satisfaction of deep understanding through one's own participation in the practices of science.

Finally, we were differentially influenced in our design and implementation of these learning experiences in that we operate under the institutional constraints of our particular course and practicum experiences, as well as in our broader state context in which the NGSS may be fully adopted or slightly adapted. The cycle of reform and progress made towards implementing the NGSS differs from state to state, district to district, and– as we've found– classroom to classroom. Because of this, our own courses are often the primary vehicle through which preservice teachers form an image of the NGSS in action. As a result, we experience a tension between the deep learning we want to foster and the limited amount of time students spend in our courses. Additionally, the nature of the learning we can support in our courses as opposed to field experiences is different. The actual opportunity to *practice* implementing the NGSS is essential, and we are challenged to work within the constraints and affordances of our specific field experience designs– or to redesign those experiences to better support our students' learning to teach (see Hanuscin & Zangori, 2016).

Conclusions

Just as we teach our preservice teachers that learning is based on prior knowledge, we have recognized the importance of their prior knowledge and experience as learners for shaping their learning about the NGSS. While that learning is often in stark contrast to the vision of the NGSS, it nonetheless offers important points of contrast that we can explore along with our students to make particular aspects of the NGSS more salient. These experiences as learners become important leverage points for their learning as teachers. Our experiences also illustrate that not only is it important for preservice teachers to learn about the dimensions of the NGSS, and the underlying rationale for these components as described in the Framework (NRC, 2012), but also the bigger question of what standards *are* and the role they play in education more broadly.

As we reflect on our instruction, we realize the immensity of the task before us and the diversity of instructional supports that are necessary for preservice teachers to both understand and implement NGSS aligned instruction. We continue to ask ourselves what is *most critical* for our students to learn as beginning teachers and what is *possible* for them to learn during their teacher education programs. We invite other science teacher educators to help answer these questions and contribute to the professional knowledge base for teaching about the NGSS in teacher education, and invite them to share their learning experiences with others. Faculty interested in contributing to the lesson archive in our Google Drive folder are encouraged to contact the authors.

References

Abell, S. K., Appleton, K., & Hanuscin, D. L. (2010) *Designing and teaching the elementary science methods course.* New York, NY: Routledge.

Bybee, R.W. (1997). Improving İnstruction. In *Achieving scientific literacy: From purposes to practice*. Portsmouth, NH: Heinemann.

Davis, E.A., Petish, D., Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*, 607-651.

Donnelly, L. A., & Sadler, T. D. (2009). High school science teachers' views of standards and accountability. *Science Education, 93*, 1050-1075.

Duncan, R. G., & Cavera, V. L. (2015). DCIs, SEPs, and CCs, oh my! Understanding the three dimensions of the NGSS. *Science and Children, 53*(2), 16-20.

Donnelly, L. A., & Sadler, T. D. (2009). High school science teachers' views of standards and accountability. *Science Education, 93*, 1050-1075.

Duschl, R. A. (2012). The second dimension–crosscutting concepts. *Science and Children, 49*(6), 34-38.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record, 103*, 1013-1055.

Fisher, D. & Frey, N. (2008). *Better learning through structured teaching: A framework for the gradual release of responsibility*, Association for Supervision and Curriculum Development: Alexandria, VA.

Hanuscin, D., Arnone, K.A., & Bautista, N. (2016a). Bridging the 'next generation' gap: Teacher educators implementing the NGSS. *Innovations in Science Teacher Education, 1*(1). Retrieved from http://innovations.theaste.org/bridging-the-next-generation-gap-teacher-educators-enacting-the-ngss/

Lee, E., Cite, S., & Hanuscin, D. (2014). Mystery powders: Taking the "mystery" out of argumentation. *Science & Children, 52*(1), 46-52.

Hanuscin, D. Cisterna, D. & Lipsitz, K. (2018). Elementary teachers' pedagogical content knowledge for teaching the structure and properties of matter. *Journal of Science Teacher Education*, *29*, 665-692. DOI 10.1080/1046560X.2018.1488486

Hanuscin, D. & Zangori, L. (2016b) Developing practical knowledge of the Next Generation Science Standards in elementary science teacher education. *Journal of Science Teacher Education, 27*, 799-818.

King, K., Hanuscin, D., & Cisterna, D. (In Press). What properties matter? Exploring essential properties of matter. *Science & Children.*

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards*. National Governors Association Center for Best Practices, Council of Chief State School Officers: Washington D.C.

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

Little, J. W. (1990). The persistence of privacy: Autonomy and initiative in teachers' professional relations. *Teachers College Record, 91*, 509-536.

Lynch, M. (1997). *Scientific practice and ordinary action: Ethnomethodology and social studies of science*. Cambridge, UK: Cambridge University Press.

National Research Council. (2012). *A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

Nollmeyer, G. E., & Bangert, A. (2015). Assessing K-5 elementary teachers understanding and readiness to teach the new framework for science education. *The Researcher*, *27*(2), 7-13.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning. *Educational Researcher, 29*(1), 4-15.

Reiser, B. J. (2013). What professional development strategies are needed for successful implementation of the Next Generation Science Standards? Invitational Research Symposium on Assessment, K-12 Center at ETS. Retrieved from http://www.k12center.org/rsc/pdf/reiser.pdf

Ricketts, A. (2014). Preservice elementary teachers' ideas about scientific practices. *Science & Education*, *23*, 2119-2135.

Smith, J., & Nadelson, L. (2017). Finding alignment: The perceptions and integration of the next generation science standards practices by elementary teachers. *School Science and Mathematics, 117*, 194-203.

van Drie., J. H., Bijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practice and knowledge. *Journal of Research in Science Teaching, 38,* 137-158.

Windschitl, M., Schwarz, C., & Passmore, C. (2014). *Supporting the implementation of the next generation science standards (NGSS) through research: Pre–service teacher education.* Retrieved from https://narst.org/ngsspapers/preservice.cfm

Winkler, A. (2002). Division in the ranks: Standardized testing draws lines between new and veteran teachers. *Phi Delta Kappan, 84*, 219-225.