

Bridging the ‘Next Generation Gap’ – Teacher Educators Enacting the NGSS

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Abstract

Given the shifts required of K-12 education under Next Generation Science Standards (NGSS Lead States, 2013), it is inevitable that change is also required in universities that prepare teachers. While there are currently recommendations for NGSS related professional development for classroom teachers, the literature is less specific when it comes to prospective teachers and their unique needs; however, one consistent call is for the provision of images of the NGSS in action. Prospective teachers’ own K-12 science experiences inform their developing pedagogical knowledge. Given this, understanding what NGSS-aligned instruction might look like in action will be particularly challenging for today’s prospective teachers, whose K-12 science education experiences preceded the NGSS, and who often fail to understand the complexity that underlies teaching (Chval, 2004). A related challenge is that teacher educators’ own classroom teaching experiences preceded this reform as well, and as such they lack experience supporting K-12 students in achieving the performance expectations of the NGSS. Teacher educators can identify existing examples of the NGSS in action using such tools as video cases or create new examples from their own practice. Windshitl et al. (2014) suggest teacher educators take substantive steps to engage in reform by enacting a unit of instruction consistent with the NGSS for K-12 students, perhaps in collaboration with a local teacher. The authors of this paper are all teacher educators who have been acting on the above recommendations to plan and enact instruction that aligns with the NGSS, both with elementary teachers and students. In this manuscript, we highlight examples of NGSS-aligned instructional materials we have created, share insights from enactment of these materials, and articulate the resulting ‘wisdom of practice’ generated throughout this process.

Introduction

The Next Generation Science Standards (NGSS Lead States, 2013) and the foundational Framework for K- 12 Science Education (National Research Council, 2012) are the products of decades of research on how students learn science. Both of these key documents present a vision for science teaching and learning that represents a dramatic departure from what occurs in most science classrooms today (Banilower et al., 2013). While historically content knowledge has served as an indication of rigor, the NGSS is unique in that it calls for a blend of disciplinary core ideas, science and engineering practices, and cross-cutting concepts in order to help students master performance expectations (Pruitt, 2014).

As the United States engages in this landmark reform effort, it is no surprise that attention has turned toward teacher education:

...teachers are the linchpin in any effort to change K-12 science education. And it stands to reason that in order to support implementation of the new standards and the curricula designed to achieve them, the initial preparation and professional development of teachers of science will need to change (NRC, 2012; p. 255).

Given the shifts required of K-12 under NGSS, it is inevitable that change is also required in universities that prepare teachers. This may require incremental revisions to elements of teacher education programs, replacement of existing components, or complete revisions in the curriculum and the structures and strategies used to prepare teachers (Bybee, 2014). Since the release of the NGSS, implications for the practice of teacher educators has been a topic of consideration (Windshitl, Schwarz, & Passmore, 2014). While there are currently recommendations for NGSS related professional development for in-service teachers (e.g., Reiser, 2013), the literature is less specific when it comes to prospective teachers and their unique needs; however, one consistent call is for sharing images of the NGSS in action.

Challenge

Of particular challenge is that while the NGSS performance expectations (PEs) describe the kinds of things science education experiences should enable students to understand and do, they provide little guidance as to how a teacher might design and enact those experiences for students (Windshitl et al., 2014). As such, there has been a call for rich images of classroom enactment of the NGSS (Reiser, 2013), which have the power to act as models in teacher professional development. This can be especially critical for prospective teachers, whose own K-12 science experiences (which preceded the NGSS) inform their developing pedagogical knowledge. Given that prospective teachers often fail to understand the complexity that underlies teaching (Chval, 2004) *how they learn* from these models will be important. A related challenge, however, is that teacher educators' own classroom teaching experiences preceded this reform as well, and as such they must develop their own understanding of how to implement the NGSS—both with K-12 students and their prospective teachers.

Windshitl et al. (2014) suggest teacher educators take substantive steps to engage in reforms by enacting a unit of instruction consistent with the NGSS for K-12 students, perhaps in collaboration with a local teacher. They suggest this may be especially important at the elementary level (Windshitl et al., 2014), where there are multiple challenges with field experiences (Abell, 2006). Among these challenges are a lack of emphasis on science and a high percentage of elementary teachers who are inadequately prepared and thus do not feel confident teaching science. Prospective elementary teachers may not have opportunities in their field placements to observe science instruction at all, let alone instruction aligned with the NGSS.

Context of Our Work

As teacher educators we have been acting on the above recommendations to plan and enact instruction that aligns with the NGSS with in-service elementary teachers and elementary students, as well as prospective teachers. Hallway conversations at the annual meeting of the Association for Science Teacher Education (ASTE) enabled us to identify our similar pursuits, and to offer feedback and support to one another. Author 1 (Debi) and Author 3 (Nazan) were both mid-career faculty, and Author 2 (Annie) was a doctoral student—nonetheless, we all shared the challenge of understanding the enactment of the NGSS in elementary classrooms, but no longer being classroom teachers working ‘in the trenches’, so to speak. We approached this challenge in three very different ways, which we highlight through a series of vignettes. These are not intended to provide a representative nor exhaustive characterization of how teacher educators might undertake this work, but to provide a rich illustration of our own efforts that can inform and inspire others to take similar steps and share those practices within the science teacher education community.

A common theme across the literature regarding teachers’ engagement in reforms is that of collaboration, and its importance to challenging teachers’ beliefs, assumptions, and values as they work together toward common goals (Anderson & Helms, 2001). 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); and create opportunities to ‘dig beneath the surface’ of reforms to explore substantive issues of practice (Reiser, 2013). Our own collaboration, both on this manuscript and in our respective contexts, reflects this intent. In the sections that follow, we highlight examples of NGSS-aligned instructional materials we have created, share insights from enactment of these materials, and articulate the resulting ‘wisdom of practice’ generated throughout this process.

Adapting ‘Old Favorites’ to Align with the NGSS: Debi’s Story

As a former elementary teacher, I have a number of ‘old favorites’ among science lessons that I have implemented with elementary learners and that I use as model lessons in my methods course. While these are useful for illustrating a variety of pedagogical strategies and topics related to teaching elementary science, they preceded the NGSS and were based on the previous *National Science Education Standards* (NRC, 1996), which had been released during my teaching career. Just as many elementary teachers may wonder what changes the NGSS will require of them, as a teacher educator, I wondered what changes the NGSS would require of me—first and foremost, I believed that in order to teach prospective teachers to utilize the NGSS effectively, I would have to develop my own skills for doing so. Like many classroom teachers, I wondered would I have to get rid of my ‘old favorites’ in order to do so?

Working with two of my doctoral student interns (Lee, Cite, & Hanuscin, 2014), I set about adapting the well-known ‘mystery powders’ activity originally developed as part of the Elementary Science Study (1975) curriculum materials. I had previously used this activity with elementary students to teach about properties of matter and develop skills for observation. Over the years I had updated the activity to include the use of technology (observing the powders with digital scopes) and to reflect a growing popularity and student interest in forensic science (the white powder was found at a crime scene). Yet, I knew there would be ways that the activity would fall short of the kinds of science teaching envisioned by the NGSS—particularly in terms of scientific practices, as the lesson focused heavily on process skills.

Our first step was to review the activity for opportunities to engage students in the Science and Engineering Practices. We read through each of the descriptions in Appendix F of the NGSS and discussed where we saw similarities and differences to what students would be doing in the existing lesson. In order to adapt the activity to better align with the NGSS, we realized we would need to focus on argumentation. That is—not just developing skills for observation, but helping students use observations as evidence to support claims. By implementing the lesson with our methods students and then supporting them in implementing it with elementary students, we were able to better understand the difficulties that both groups would face in engaging in this practice, as well as identify specific scaffolds we could use to address those.

Specifically, we developed a better understanding of difficulties that prospective teachers may have in crafting scientific arguments – using claims, evidence, and reasoning – about the identity of mystery powders in the lesson. These included making claims that go beyond the evidence, not providing enough supporting evidence, and focusing on evidence that supports their claims while ignoring evidence that does not (Lee, et al., 2014). This challenged us to construct our own example arguments that we could use as models to support students’ learning. We developed sample strong and weak arguments, from which prospective teachers were able to generate examples of the criteria by which we should evaluate scientific arguments, both their own and those of elementary students (See Appendix A for examples).

Another ‘old favorite’ of mine is a lesson about the water cycle that I developed based on the “Go to the Head of the Cloud” activity from Project Learning Tree (American Forest Foundation, 1993). This simulation allows students to role play a drop of water traveling through the water cycle in a game of chance. I combined this activity with a read-aloud of *The Water’s Journey* (Schmid, 1990) and both a narrative and expository writing task. This remains a favorite of elementary students, teachers, and prospective teachers with whom I have used it. Whereas my adaptation of Mystery Powders enabled me to better understand the science practices, I realized that I was still falling short of the kind of ‘three dimensional learning’ that the NGSS supports—where Disciplinary Core Ideas, Science & Engineering Practices, and Cross-cutting Concepts come together. Within this particular lesson, I saw an

opportunity to accomplish this by focusing on the water cycle as a model of a system—emphasizing core ideas in Earth Science (ESS2), helping students develop and use models (SEP2) and connecting to the bigger concept of systems and system models (CCC4). In my adaptation of the lesson for my elementary science methods course, my prospective teachers not only developed their models as they role-played drops of water in the simulation, but evaluated models of the water cycle they found on the internet and in other resources in light of their experiences. This shifted the overall lesson from more of an isolated learning experience to being one that students could connect to a variety of things they learned in science—both other models and other systems—and also made them, as future teachers, more critical consumers of instructional resources.

In adapting this lesson, I found it useful to rely on the expertise of another science educator and colleague, Laura Zangori, who specifically studies elementary students' ideas about models and modeling (Zangori, Forbes, & Schwartz, 2015). Conversations with Laura helped me identify ways in which modeling was underemphasized, as well as missed opportunities within my lesson to engage students in building models, using models to construct explanations, and evaluating models. For example, when working with Laura to critically examine the lesson, she pointed out that my lesson involved students in developing their own models of the water cycle as well as evaluating other models, but that they weren't using models to explain phenomena. Based on this, I developed a list of questions for students to answer using their model, such as:

- Why does the Earth not run out of rain?
- Was the amount of water on Earth the same, greater than, or less than when the dinosaurs roamed?

In this case, understanding the NGSS was helpful for identifying broader areas and connections to modeling, but collaborating with a more knowledgeable other supported identification of specific ways that students could engage in modeling and model-based reasoning during the lesson.

From these two experiences adapting my 'old favorites' I have learned that existing science activities do not have to be discarded with new reforms, but can be leveraged in more powerful ways by using the NGSS. In both cases, I believed the modified lessons to be of higher quality and to promote a deeper level of understanding. Likewise, I have been able to reassure anxious teachers who are implementing the NGSS that they do not have to throw out their 'old favorites', and also to assure prospective teachers that if they can't find an activity that aligns with a specific NGSS performance expectation by Googling it, it doesn't mean there are no activities for them to use—only that there is a need to adapt activities that already exist to meet the NGSS. Knowing how to do this can be challenging, but by working with others you can overcome these challenges.

Co-Planning as a Transition from Teacher to Teacher Educator: Kathryn's Story

Up until 2012, I was an elementary classroom teacher and over the years had participated in multiple professional development (PD) opportunities to improve my science teaching abilities. Some of the PD experiences were useful in providing new strategies and lesson ideas, but even as I began my graduate study full-time I knew I had much more to learn. This became especially true in that I made the transition to graduate student at the same time that states were beginning the transition to the NGSS. The field was undergoing change just as I was undergoing a change in my professional role. In order to be successful in this role, I needed to develop expertise related to using the NGSS in elementary science teaching, but was no longer teaching elementary students!

The collegial connections I made as a classroom teacher (in the same district where my university was located) provided a unique opportunity for me to participate in the design and implementation of science lessons in the elementary classroom and to develop my understanding of NGSS-aligned instruction. Working with former colleagues helped facilitate my transition from a classroom teacher to a teacher educator as I was able to collaborate with my former mentor to develop lessons that aligned with the NGSS. We selected the first grade standard 1-PS4: Waves and Their Applications in Technologies for Information Transfer and Performance Expectation (PE) 1-PS4-1: *Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate*. While my colleague felt somewhat comfortable with planning and carrying out investigations, she felt less comfortable with wave properties (PS4.A). Thus, our collaboration challenged me to shift to the role of mentor.

We were both familiar with the 5E learning cycle (Bybee, 1997), and realized that we could still use this lesson design framework in planning our lesson on sound. This was reassuring, as one concern we had about shifting to the NGSS was that it would require us to throw out our existing tools and resources. Our first step was to pull together activities on sound to see what we could use in our lesson. Important at this stage was making sure the content of the lesson was accurate and the objectives and goals were aligned with NGSS. There were times when we had a great activity that we thought would work and so put it into the lesson, only to realize it didn't fit into the overall objective and it needed to be removed. For example, we had an activity that focused on what sounds "looked like" and thought it might fit into our lesson. However, we realized the lesson might actually portray a misconception to students that sounds have a physical appearance. We decided that we needed an activity that would help students understand that sounds could be measured but that the sound itself did not have a physical appearance. We discussed this struggle at length as we were both used to focusing on observable phenomena at the elementary level. We finally determined the best way to accomplish this was to use a computer model, or in our case, an iPad application that measured sound. This occurred multiple times throughout the planning process as we weeded through a variety of activities together and engaged in conversation about how they

each contributed to (or detracted from) the overall goal of the lesson. I found myself drawing on the work I had done as a graduate research assistant, analyzing the coherence of the conceptual storyline of science lessons (see Hanuscin, Lipsitz, Cisterna, Arnone, van Garderen, & de Araujo, 2016). My colleague and I met in person twice and sent versions of our lesson back and forth via email multiple times before we were satisfied with our plan. See Arnone and Morris (2014) for the complete lesson, which engages students in connecting sounds they hear to concepts of pitch and volume, and how those properties are represented by waves.

As we co-taught the lesson, I supported my colleague's instruction by asking questions that encouraged student thinking about what they were experiencing and how those questions could lead them to new investigations. For example, I posed questions to support students in interpreting what they saw on an iPad app they were using to represent recorded sounds as waves. Below is an example of an interaction I had:

Student: Look at these squiggly lines.

Me: Why do you think some of these squiggly lines look longer than the others?

Student: I don't know.

Me: What happens to the squiggly line when you change the sound you make? Why do you think some of them look longer than the others?

Student: Is it because the sound was bigger?

Me: Bigger than what?

Student: Bigger than the other sounds I heard.

Me: What do you mean by bigger?

Student: Well, I think the sound might have been louder, not bigger, but I'm not sure.

Me: What can we do to find out?

Student: I think I might need to try out a few more sounds to see.

I encouraged the student to continue collecting sound recordings to determine what the longer "squiggly lines" represented, to critically consider the data s/he collected, and to document everything in a science notebook. In this way, I was able to provide support for students in analyzing the data for patterns, and checking the data to see whether it supported or refuted their initial ideas. I also was able to provide support for my mentor as she built her confidence in her knowledge of and teaching about sound waves.

After the lesson, we reflected on the lesson and discussed what went well and what did not, things we noticed her students were doing or not doing, areas where she felt she could have improved, and areas where I thought she did very well. As we looked through all of the student artifacts from the lesson, my colleague noted that her students had developed questions about what they were observing, and were able to generate ideas about how to investigate those questions. Not only that, her students also were beginning to develop explanations using the evidence they gathered. This provided her with a concrete illustration of what these Science and Engineering Practices ‘look like’ in a first grade classroom. .

Our co-planning, co-teaching, and co-reflecting experiences provided my mentor with an experience that challenged her thinking and teaching practice regarding instructional planning, student questioning, and lesson implementation as it related to the NGSS. For example, my mentor commented on how challenging it was for her to get students to get to the point where they were able to ask their own questions that led to investigations. She noted that I posed questions that encouraged students to consider possible investigations that could lead them to an answer as opposed to a question that required a direct answer. She commented on how watching my questioning provided her with a model to see how changing the way she questioned students could help guide them towards asking their own questions that could lead to investigations—she observed my interactions and replicated my line of questioning with other students during the lesson.

This experience helped illustrate to me the need for elementary teachers to have support and guidance as they implement the NGSS. I now understand that both teachers and teacher educators need more models of and practice in creating and implementing instruction that aligns with the vision of the NGSS. During our reflections my mentor commented on how critical it was for her to have a colleague for support during this lesson’s development as well as during the implementation, as it was on a topic she had only recently learned. Planning and teaching the lesson together reduced her apprehension, as I was in a supportive, rather than evaluative role. Areas of my own weakness were brought to light when my mentor asked questions about how or why I did something and I wasn’t sure how to explain it. I was forced to make my practice explicit in a way that was challenging but necessary for my mentor to understand my actions. As a developing teacher educator who left the classroom just as the new standards were being released, I realized how much more I had to learn about how to implement the NGSS myself, and how to support teachers in that process.

In sum, it was a beneficial experience for me to take on the role of the mentor while my former mentor took on the role of the learner. Prospective teacher educators like me can benefit from opportunities to work with teachers to develop and enact NGSS-aligned instruction. With both teachers and teacher educators working in tandem, the vision of the NGSS may become clearer in elementary classrooms.

Crowd-sourcing Integrated STEM Lessons: Nazan’s Story

I have been working with prospective early childhood teachers over the last 13 years and during this time I have often witnessed that the area prospective teachers have the most difficulty is seeing the relevance of science content to their own lives. Their schooling background is filled with experiences in which they learned STEM disciplines as disparate subject areas which, consequently, prevented them from seeing the interconnectedness of these disciplines and how they work together in solving or addressing real life situations. This is one of the main issues I target in my science methods courses for early childhood majors and I believe the NGSS provides a valuable framework to accomplish my goal.

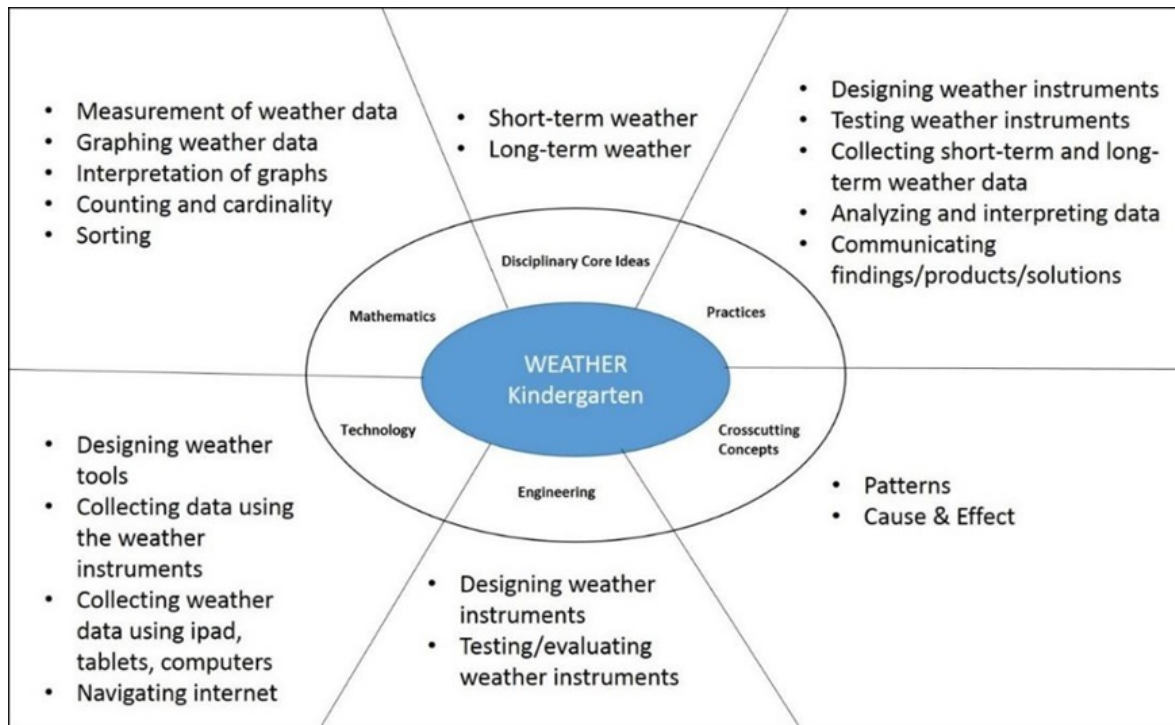
I develop instructional activities using an integrated approach to teaching STEM concepts as outlined in the NGSS. Educators defined integrated STEM teaching as an instructional approach in which science and mathematics disciplines are taught through the infusion of scientific inquiry practices, technology, engineering design process, mathematical analysis, and 21st century skills (Johnson, 2013). This approach has been especially popular in the area of engineering education (i.e., Stohlman, Moore, & Roehrig, 2012). Because the NGSS explicitly includes practices and core disciplinary ideas from engineering alongside those for science, raising the expectation that science teachers will teach science and engineering in an integrated fashion.

Advocates of integrated STEM approaches believe that teaching through integration can enhance student motivation for learning and improve student interest, achievement, and persistence (Honey, Pearson, & Schweingruber, 2014). In so doing, it addresses calls for greater workplace and college readiness as well as increasing the number of students who consider a career in a STEM-related field. However, in order to accomplish this important mission, prospective teachers themselves must engage in such learning experiences or the instructional activities that model ways to teach STEM disciplines in an integrated fashion.

I start developing integrated STEM activities around a big idea or a question, which ultimately determines the science disciplines (e.g., biology, physics), mathematics concepts, type of technology, and engineering activities that I will teach. The example I prepared for early childhood classrooms focused on short-term and long-term weather changes. Making sense of short-term and long-term weather requires more than observation of daily and day-to-day weather based on the principles of NGSS. In this unit, young learners construct their understanding of order of numbers (less than, greater than, and equal to), learn to use thermometers and associate numbers with hot, cold, and warm temperature values (e.g., 35 °F cold, 90 °F hot), construct weather instruments and test the appropriate locations for the weather instruments through experimental design, and use weather instruments to gather temperature, precipitation, and sky coverage information throughout the day to observe daily weather changes and throughout the semester to observe the weather patterns for different seasons (long-term weather changes) at their location (see Figure 1). My aim here was to provide an authentic context for the young learner to make sense of the numbers (Common Core State, Standards: MP.2, MP.4, K.CC.A, K.MD.A.1, K.MD.A2, and K.MD.B.3) and an

Earth and space science (DCI: ESS2.D; K-ESS-2) concept, while also developing an understanding of the role of technology and engineers (CCC: 1, 2; SEP 1, 3, 4, 5, 7, 8, and ETSI.A).

Figure 1 (Click on image to enlarge). Integration of STEM concepts to teach short-term and long-term weather.



The success of any instruction or activity in helping students meet the learning outcomes depends on the meaningful implementation of the planned instruction. Therefore, in order for practicing teachers to accept and implement this unit, we decided to check the feasibility of this integrated unit by employing a “crowd-sourcing” approach. Crowd-sourcing is a process by which one solicits contributions of ideas from a large group of people. In the development of the Kindergarten level “Short-Term and Long-Term Weather” unit, I used crowd-sourcing as a way to gather feedback and ideas from a large group of practicing early childhood teachers in an online environment. I used Google docs to make the entire unit available to the teachers and emailed the link for the unit to 20 of the local area early childhood teachers and encouraged them to invite other practicing teachers to edit, modify, and comment on the document, as well as implement the lessons included in the unit (see Appendix B for unit materials).

The crowd-sourcing approach had several benefits for both teachers and me as a teacher educator. First, it allowed teachers to have a voice in the developed instruction, which made it more likely for them to adapt and implement the unit in their classrooms. Second, the unit was not static and continued to evolve as more teachers edited and modified the document. Third, I could share the evolving document with prospective teachers in my methods courses to provide practicing teachers’ insights and practices. The last one is especially important

given that most early childhood education majors do not consider science as one of the content areas they are expected to teach, nor are they likely to observe cooperating teachers develop a science lesson.

Crowd-sourcing helped me to ensure that the integrated STEM classroom activities I developed were indeed applicable to real classroom settings and developmentally appropriate for the target student groups. However, I have several recommendations for those who are interested in using this approach to develop new instructional activities. First, they should be aware of the time it requires to mobilize teachers to participate in the editing, modifying, and commenting on the activities. It will take additional time if the teacher feedback from the implementation of activities in real classrooms are required. Second, they should also be very clear with the directions they provide to the teachers. Do they want teachers to provide comments in comment boxes or in-text? Will teachers edit the document and if so how should they do it so that the teacher educator can effectively monitor how the document has evolved (e.g., teacher educator can request teachers do not modify another teacher's edits; instead they can provide a comment on the same section using a comment box). Finally, they should monitor changes on the document consistently (e.g., daily) to be able to reflect on the changes and modifications and prepare the best and final draft of the shared document.

Conclusions & Implications

Our work contributes to bridging the gap between teacher educators' own K-12 teaching experiences and the kind of science teaching and learning envisioned by the NGSS by providing concrete illustrations of ways in which teacher educators can act on recommendations in the literature in their respective contexts. While the NGSS performance expectations describe what students should understand and be able to do, they provide little guidance as to how a teacher might design and enact instruction to achieve that. Our efforts add to building a portfolio of ambitious practices (Windschitl et al., 2014) and much-needed images of the NGSS in action (Reiser, 2013).

The advent of the NGSS presents teacher educators with a unique challenge to revisit their K-12 teacher selves to understand how to implement the NGSS with K-12 students. However, a conundrum is that given the newness of the NGSS, we lack prior experience utilizing the NGSS as K-12 teachers. Considering the lack of accumulated knowledge bases for how best to implement the NGSS, we build from our own understanding and interpretation of the NGSS while developing new experiences for teachers and K-12 students. We revisit the research-based strategies and lessons that have already been shown effective and modify, alter, and revise them based on our own developing understanding of the new reforms. In that sense, as teacher educators, we must be open to constant evolution in our professional body of knowledge, skills and attitudes, and must be able to adapt rapidly to changes in our field.

Important to each of our efforts was the willingness to interrogate our own practice- to position ourselves as novices rather than experts. Teaching in ways that align with the vision of the NGSS requires a strong commitment to standards-based, reform-minded teaching and its assumptions about knowledge, learning, and teaching (Wang & Odell, 2002). The goals of reform can be difficult for novice teachers to comprehend, and without this understanding they may implement instruction that differs from the intent of reforms (Lynch, 1997). In order to support prospective teachers, teacher educators must not only understand the content and structure of the NGSS, but also how to adjust their teaching practice to meet these standards (Reiser, 2013; Windschitl, et al., 2014).

As we developed our expertise, we found it helped to work with others. Given the lack of professional development opportunities for teacher educators – except for the opportunities provided in annual meetings of professional organizations, such as ASTE, creating a space where educators shared and revisited their beliefs, understandings, and experiences allowed us to have access to diverse ideas and opinions. The body of literature regarding teachers’ engagement in reforms includes frequent references to collaboration and its importance to challenging teachers’ beliefs, assumptions, and values as they work together toward common goals (Anderson & Helms, 2001). 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); and create opportunities to ‘dig beneath the surface’ of reforms to explore substantive issues of practice (Reiser, 2013). In doing so we better understood our own difficulties, and that of our collaborators, in enacting NGSS-aligned instruction. Through implementation of lessons we developed, and discovering our own obstacles to teaching in line with the NGSS, we continue to deepen our knowledge of how to best support learners (and, in our case, teachers) in addressing difficulties they encounter in reaching the level of learning envisioned in the NGSS.

Windschitl and colleagues recommend that “science teacher educators must engage with the NGSS in substantive ways that go well beyond familiarizing themselves” (2014, p.3). As our science curriculum and teaching practices go through reforms, we first have to reflect, revise, and reframe our previous understandings (Wenger, 1998). For example, vignettes 1 and 2 both challenge the belief that teaching in line with the NGSS means abandoning current pedagogies and activities. This belief may serve as a barrier to teachers transitioning to the NGSS. Vignette 1 highlights the importance of questioning assumptions about the extent to which our instruction fully aligns with the vision of the NGSS—for example, that if we are addressing models, we are doing so in a robust manner consistent with modeling practices. Vignette 3 emphasizes the need to act on our values—in this case, collaboration, as well as the expertise that resides among practitioners.

Collaborating with other educators, K-12 teachers, and prospective teachers can help develop a portfolio of activities aligned with the NGSS, but that is merely a first step. Teacher educators must also investigate the effectiveness and feasibility of these activities in K-12

classrooms, and be able to model teaching NGSS-aligned activities in professional development for practicing teachers and methods courses for prospective teachers. In addition, they must provide opportunities for prospective teachers to plan and enact the activities developed.

Supplemental Files

[Hanuscin-Appendix-A-and-B.docx](#)

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