Enacting Wonder-infused Pedagogy in an Elementary Science Methods Course

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Abstract

Future elementary teachers commonly experience a sense of disconnection and lack of confidence in teaching science, often related to their own negative experiences with school science. As a result, teacher educators are faced with the challenge of engaging future teachers in ways that build confidence and help them develop positive associations with science. In this article, we present wonder-infused pedagogy as a means to create positive pathways for future teachers to engage with both science content and teaching. We first articulate the theoretical foundations underpinning conceptions of wonder in relation to science education, and then move on to share specific practical activities designed to integrate elements of wonder into an elementary methods course. We envision wonder-infused pedagogy not as a disruptive force in standard science methods courses, but rather an effort to deepen inquiry and connect it to the emotive and imaginative selves of our students. The article closes with thorough descriptions of wonder related activities including wonder journaling and a wonder fair in order to illustrate the pedagogical possibilities of this approach. We provide student examples of these artifacts and exit tickets articulating student experiences within the course. We also consider possible challenges that teacher educators may encounter during this process and methods to address those possible hurdles. We found that the process involved in wonder-infused pedagogy provided possibilities for future teachers to reconnect and rekindle a joyful relationship with authentic science practice.

Introduction

The concept of *wonder* challenges traditional science classroom pedagogy while simultaneously addressing what Tytler (2007) termed the *crisis of interest* in science education. This ‘crisis’ results from experiences with school science that often misrepresent the nature and processes of science itself in favor of pedagogy steeped in memorization and regurgitation of disconnected science facts (Kenny, 2012). This approach often creates future teachers with negative associations regarding science, who consequently hold unfavorable views concerning their ability to teach science (Gilbert, 2009; Brand & Wilkins, 2007). Van Aalderen-Smeets, Walma Van Der Molen and Asma (2011) argued that, “to achieve sustainable improvements in elementary science education, it is crucial for primary teachers to develop their own positive attitudes toward science” (p. 159). Furthermore, Egan (2005) asks educators to develop an attitude of mind to bring the wonder to bear on a regular basis as well as work to see the wonderfulness in the ordinary things in our everyday lives. In this way, wonder becomes the intellectual currency that drives a desire to know.

> “It would seem that a curriculum that enables the conditions for wonder to flourish and which is meaningfully connected to the lifeworlds of young people is now more necessary than ever” (Trotman, 2014, p. 33).

This article represents an effort to address Trotman’s call regarding the necessity to resuscitate wonder and connect science learning to the lives of students in our classrooms.

We argue for the idea of a *wonder-infused pedagogy* as a means to incorporate aspects of wonder into inquiry teaching towards a more authentic engagement with science content. To this end, we briefly articulate the theoretical foundations comprising *wonder* in relation to science education. This is followed by an in-depth exploration of wonder-infused pedagogical approaches with preservice elementary teachers. The goal is to present both the theoretical spirit of wondering as well as practical approaches that can be utilized to great effect with future teachers. Specifically, the examples used within this piece have taken place in the first author’s elementary science methods courses and were developed over the last five years as part of his teaching and research efforts. We contend that these wonder-infused processes, although aimed squarely at adults in a preservice teacher education program, also are relatable across K-16 contexts.

Purpose and Related Literature

Wonder as a Driver for Scientific Thinking

There is no question that we face a myriad of issues in elementary science teacher education. Science in elementary school contexts has often been enacted as a compilation of linear knowledge and unquestioned facts requiring memorization (Bybee, 2002). However, science should be viewed as a dynamic subject area involving engagement in a variety of scientific practices and processes (NGSS lead states, 2013; Atkins & Salter, 2015) as well as the creative and tentative aspects comprising the Nature of Science (Akerson, Morrisson, & McDuffie, 2006). We contend that we are not preparing future scientists, but rather trying to inspire future teachers to be interested in science in the first place. As such, wonder provides one possible avenue to develop that interest.

Wonder was instrumental in the thinking of ancient philosophers such as Plato and Aristotle, who both argued that philosophy begins in wonder (Schinkel, 2017). Indeed, many professional scientists and science communicators have articulated that a sense of wonder has inspired and sustained scientists for generations (Carson, 1965; Cobb, 1977; Cox, 2011; Einstein, 1931). Wonder, in this case, serves as the seed for inquiry and a mindset that better approximates the thinking and vexations that drive scientists to study the natural world. In particular, we operationalized wonder as:

> …the human experience at the center of that inquiry process, as opposed to the science content itself. Forging a pedagogy of wonder demands connection to the emotive embodiment of science as a uniquely human process that nurtures our intense need to know (Gilbert and Byers, 2017, p. 916).

The key for us as teacher educators became how do we introduce this notion of wondering about the mysteries of our world to a generation of students who too often have been conditioned to desire simplistic answers where the boundaries of knowledge only stretch as far as that of state and national standards or the Praxis exam?

Wonder as Deeply Connected to Imagination and Emotion

A handful of recent studies have investigated the role of wonder in the sciences including: building science content understanding (Hadzigeorgiou, 2012; 2016); connecting science to the emotive (Gilbert & Byers, 2017); lessening future teachers' fear of science content (Gilbert, 2013), and emphasizing that self-awareness and science content learning are inextricably linked (Bianchi, 2014). Egan (2005) argues that the first step in evoking wonder is to ask teachers to consider not what they know about a topic, but what they *feel* about a topic, which is often quite foreign in teacher preparation approaches. This direct appeal to our emotions flies in the face of most depictions of engagement with scientific thinking that are usually steeped in objectivity and work to eliminate subjectivity. Egan (2005) further argues that imagination is an essential bridge to linking science content with wonder. However, many teachers (as well as parents) treat imagination, even with our youngest students, as a luxury or superfluous to meaningful learning, but increasing attention to the imaginative abilities of children can "lead to improvements in all measures of educational achievement, including the most basic standardized tests" (Egan, 2005, p. xvii). The following section focuses on the practical approaches to explicate what wonder-infused pedagogy entails in the classroom.

Wonder-infused Classrooms

Trotman (2014) examined programs from around the world both inside and outside of school contexts and compiled several traits regarding both curriculum and pedagogy associated with wonder and how it is operationalized across a multitude of contexts:

> 1) "…creation of environments where exploration, chance and serendipity are valued as necessary features of education,
>
> 2) …curriculum that generates vivid imaginative and emotional connection
>
> 3) …empathetic teaching techniques
>
> 4) …attunement to the reception and generation of moments of wonder
>
> 5) …not driven by pre-specified and instrumental outcomes
>
> 6) …opportunities for young people to pursue projects of personal interest" (Trotman, 2014, p. 37-38).

Our reading of these processes associated with wonder is not necessarily something that teachers *do*, but rather something that teachers *embody*. In addition, several aspects of this list mesh well with typical inquiry approaches that are a mainstay of many current teacher education science programs. We do not see *wonder-infused pedagogy* as disrupting those approaches, but rather an effort to deepen inquiry and connect it to the emotive and imaginative selves of our students.

As teachers, we must nurture these moments of wonder and wondering without overtly structuring student thinking because that would take away from the effect and impact of the student journey. Accordingly, teachers should embrace the moment, acknowledge the wonder, raise student awareness for the richness and value of those thoughts, and plan for opportunities to support and extend those wonders (Bianchi, 2014). Building confidence and connection is a vital aspect of wondrous classrooms (Atkins and Salter, 2015) because *wonder-infused pedagogy* asks students to take risks, think about the unknown, ask difficult questions and ultimately push themselves intellectually, which also can include embracing failure. Whitin and Whitin (1997) depicted the importance of these approaches, stating, "As teachers, we realized the value of struggling with confusing, complex, and sometimes frustrating experiences. Traditionally, schools have been organized to make things easy for learners, shielding them from the messiness, ambiguity and challenge of intellectual ventures" (p. 10). The key here was helping our preservice teachers become more comfortable with uncertainty. This is the space where many scientists start their investigations with anomalous data or a vexing question. The following descriptions highlight how we worked to bring wonder-infused pedagogy into practice with preservice teachers. This prior research surrounding wonder was instrumental in framing how we designed wonder-infused pedagogy as an innovative tool to facilitate the engagement of preservice elementary teachers in a semester-long science methods course.

Process of Wonder-infused Pedagogy

Course Context

In many ways, the science methods course utilized approaches that are common across science education. These common approaches included synthesizing course readings and lesson and unit planning, coupled with science content expectations. The class itself was steeped in a 5E inquiry approach (Engage, Explore, Explain, Elaborate and Evaluate) and as such, we utilized classic readings (Bybee, 1992; Llewellyn, 2002) as well as more recent depictions that demonstrate this process in elementary classrooms (e.g., Mangiaracina, 2017). The preservice teachers designed 5E units that they taught in local professional development school sites associated with the university and were aligned with Next Generation Science Standards (2013). Typically, the approaches in both the university course as well as the units designed by the preservice teachers generally followed a guided-inquiry approach as described by Bybee (2015). We consider the development of these inquiry approaches are important for the development of preservice elementary teachers and represented a major aspect of the methods course. This baseline regarding inquiry provides the classroom context onto which we enacted the more novel course approaches that involved *wonder-infused pedagogy*. Mainly, the use of wonder journaling and a wonder project fair as a means to engage preservice teachers in thinking about science content. The journaling was carried out from day one of the course and the wonder fair was the culminating activity on the final night of the semester.

Wonder Journals

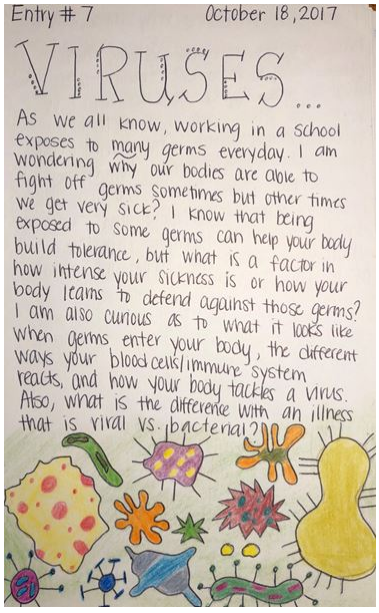
Students engaged in wonder journaling over the course of the semester, where the goal was to simply describe the things they wondered about. The only rules were that each journal must be connected to science (there was considerable latitude here), include a sketch, and be hand written in a physical journal. Entries often ranged in content and approach and were only graded for completion. The goal was not to judge the quality of their wondering (if that would even be possible), but merely to get students wondering. (Connects to Trotman traits: 1-6). They were asked to complete ten entries over the course of the semester. This sounds simple in terms of expectations, but students were often confronted by two things: 1) the intentional lack of an instructor-imposed structure and 2) having to sort through a multitude of ideas. For the first week, the students were not given much guidance beyond what was written in the syllabus (See Appendix A). This description was met with vastly different reactions from the students in the course; while some thrived with the openness of the assignment, others were extremely worried about whether “they were doing it right.” One overarching goal that we had for this process was to intentionally disrupt future teachers’ notions that there is only one “right” way to pursue an idea. However, we were sensitive not to further alienate these future teachers from science, so for the start of week two, we provided the following journal format for any students who felt they would like a more “structured” process:

> a) What do you notice and what do you wonder?
>
> b) What specific details arise through your observations or your thinking?
>
> c) What are your hypotheses that might explain or be related to your wonder?
>
> d) How might you experiment or find answers to your wonders?
>
> e) What new questions do you have?

The week after students were provided this format, preservice teachers (at their table groups of four people) were asked to share one of their entries with the table group and discuss the general science ideas and topics that were covered. We then discussed these as an entire class. This process provided insights for the rich range of thinking and approaches those individuals took as they worked through their wonders. This also worked to alleviate fears that they were doing things "wrong." This session provided the instructor with opportunities to help students connect their wonders to possible hypotheses that could explain the phenomena about which they were wondering. This process then set the stage for the rest of the entries and framed the multiple possibilities and pathways to complete the journal assignment.

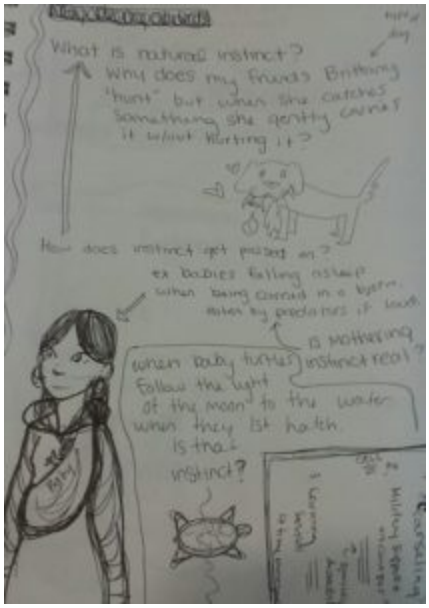
The sample journal entries (below) provide insights into both the range of ideas that students engaged with as well as the vastly different means that students utilized to consider their wonders. Nearly all journal entries began with some individual connection to an idea. Figure 1 depicts worries of the so-called elementary classroom "petri dish" and thinking about viruses and virus transmission. Most of the questions associated with this journal entry would be answerable and available through some basic research.

Figure 1 (Click on image to enlarge). Sample journal regarding viruses.



In Figure 2, a vastly different connection to observing a friend's dog led to a series of more difficult questions that had considerably less clear answers about human nature. This process was not designed as an exhaustive approach to understanding a scientific issue; rather, it was a means to remind preservice teachers that they have valuable and interesting questions about science.

Figure 2 (Click on image to enlarge). Sample journal regarding questions about instincts.



Wonder Investigation

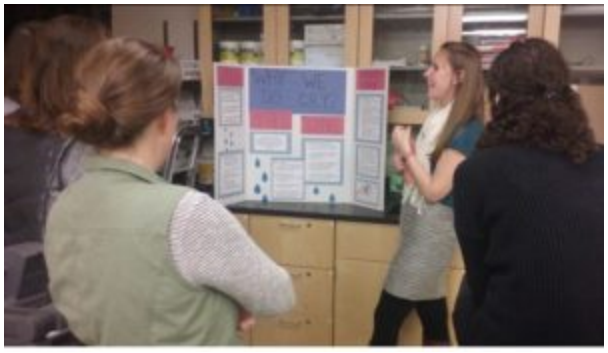
For the wonder investigation project, preservice teachers were asked to choose one of their wonder journal topics, explore it in depth, and then share the experience and their learning with the class during a public *wonder investigation fair.* The intention of this design was for students to embark on their own journeys of discovery to engage their wonders, think through possible answers, pursue and generate more questions, and articulate some new understandings related to the wonders they addressed (See Appendix B for syllabus description of the project).

The wonder investigation fair took place on the last day of the methods class, when students presented their projects in a dynamic science-fair-type atmosphere. Each student shared a visual display they created about their journey with wonder and described the process of how they engaged with the topic, how they developed their ideas and questions, and the new thoughts that had emerged during the process. These projects represented a wide range of content that was deeply connected to the lives and interests of the students. Some sample projects included: a controlled experiment investigating the effects of butter temperature on cookie quality, an investigation into the science involved in making ricotta cheese from a family recipe passed down over several generations, exploring the physical and emotional

conditions related to anxiety, the scale of plastic pollution on ocean environments, and a myriad of other science-related questions these future elementary teachers carried with them (Connects to Trotman traits: 1-6).

The wonder projects typically represented a cycle of observing, wondering and investigating that grew and evolved over time, and the process did not often end with one simple answer; rather, it opened up new questions to consider. This, of course, mimics the processes and approaches to science itself. This wondering led to multiple hypotheses and thinking that primed the pump for connecting to and learning more sophisticated science content. These approaches to inquiry and public sharing led to a burgeoning collaborative community. Figure 3 also seems to capture a measure of joy and connectedness that was palpable during the event. Many mentioned the community-building aspect of this process and how this project helped them connect with their classmates, as exemplified by the following anonymous quote from an exit ticket after the wonder fair: “I really love how I got to connect with my classmates on a deeper level…the concept of wonder definitely brings forth a stronger community.” The vulnerability required to engage with this project and then commit to making a public demonstration was impactful across the cohort.

Figure 3 (Click on image to enlarge). A student presenting her project on the physiology of crying.



Notably, the exit tickets were administered anonymously and collected by the second author of this piece, who was not an instructor for the course. This was intentional so as to procure the most honest responses possible. These artifacts provided insights into real time reactions to *wonder-infused pedagogy* and offered important considerations for those tasked with preparing future elementary teachers.

The overarching narrative across the wonder fair was the positivity that came through all of the student exit tickets. The consistent descriptions of joy were a surprise considering that many of the students had articulated frustrations with science throughout their lives at earlier stages in the course. The *wonder-infused pedagogy* provided an alternate experience, one that valued and centered on the questions that students felt were relevant and interesting. In addition, it provided a low-stakes atmosphere to take on scientific thinking without the worries they have typically associated with science in the past.

Issues and Complications When Enacting a Wonder-infused Pedagogy

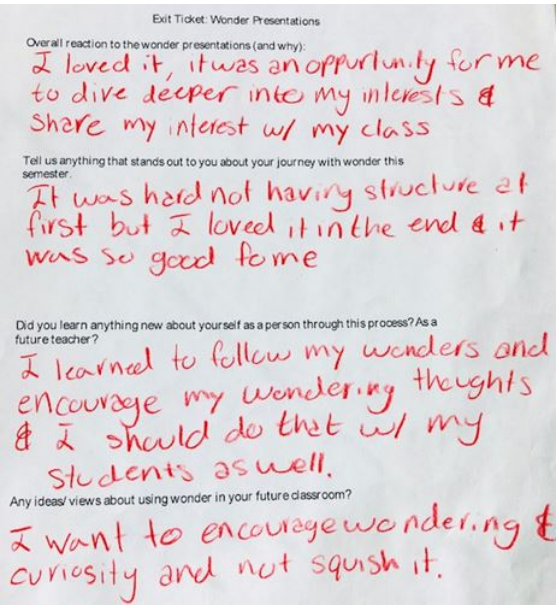
The very nature of wonder does not mesh well with traditional structured measurement approaches. In fact, *wonder-infused pedagogy* was intentionally designed in an open manner to provide ample opportunities and possible avenues for students to engage with their thinking. The trouble is, students have learned that school is about *doing exactly* as the instructions/rubrics/directions demand. Conversely, the wonder-related activities asked students to open up to their wonders and consider the resulting thinking that might bubble up to the surface. Because of the initial challenges in engaging in wondering, instructors should use scaffolding questions as a means to help students determine how they wish to represent their thinking. These often included: What is it you wonder about? Can you describe what you observed to come up with this wonder? What further questions do you have? What hypotheses can help you explain the observations of that phenomenon? How might you go about discovering more about your wonder? These questions are not exhaustive but were representative of how the first author scaffolded students and provided a measure of clarity. These efforts framed the parameters of the wonder-infused assignments (with efforts to not overly bound thinking) within the syllabus descriptions and weekly sessions, but ultimately students crafted what their engagement would entail. This required a great deal of trust between teacher and students. The teacher was looking for engagement, while students were worried about grades.

This concern was addressed in several ways: 1) by providing journal entries from prior students (see Figures 1 and 2 as examples); 2) presenting and discussing images of prior wonder fairs as well as providing examples of projects; 3) students who previously completed the course came back to take part in a panel discussion regarding the wonder project, which helped them better understand the structure of the sharing session; and 4) reducing the number of points associated with wonder activities (between 10%-20% of course total) so that there was less stress for the students while also allowing the instructor to provide a measure of leniency in grading, as the goal was mainly about completion. As an instructor, I collected journals early in the semester in order to provide ungraded feedback, which does seem to increase student engagement and can be used to deepen the engagement if some students' work appears to be superficial. For instance, the scaffolding questions (provided in the beginning of this section) were utilized as written feedback within their journals as a means to prompt deeper consideration of the topic addressed in their wonder. These approaches alleviated some of the resulting stresses for both parties.

Assessment will continue to be refined going forward. As for now, the goal was to prompt future teachers' noticing, writing and thinking about science and the observations of the natural world (Atkins & Salter, 2015). For us, getting the students writing, thinking and sharing was an essential aspect of *wonder-infused pedagogy*, which ultimately led to the building of both content confidence and a strong community of classroom learners (See Gilbert and Byers (2017) for research based claims regarding impacts of wonder on interest and confidence within science content).

Students expressed how these assignments forced them to face the idea of open-ended problems, typified by comments from exit tickets, where students remarked needing to be “less rigid” (Figure 5) and that it “was hard not having structure at first but I loved it in the end” (Figure 4). Ultimately, the challenges of enacting this approach were minimal when compared with the positive experiences expressed by these future teachers and their resulting engagement with science.

Figure 4 (Click on image to enlarge). Sample exit ticket – wonder fair.


Exit Ticket: Wonder Presentations

Overall reaction to the wonder presentations (and why):

I loved it, it was an opportunity for me to dive deeper into my interests & share my interest w/ my class

Tell us anything that stands out to you about your journey with wonder this semester.

It was hard not having structure at first but I loved it in the end & it was so good for me

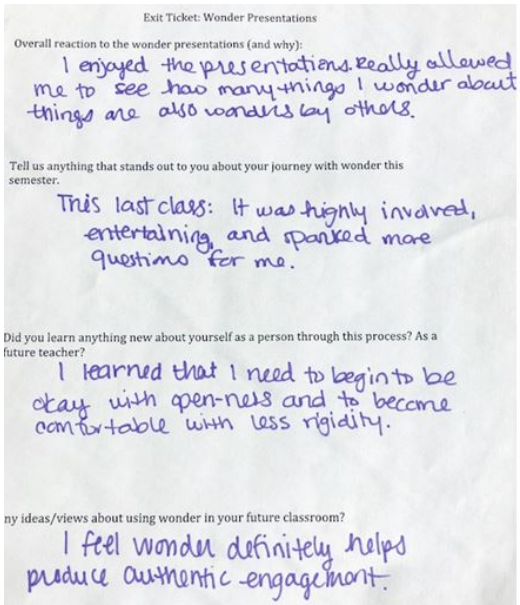
Did you learn anything new about yourself as a person through this process? As a future teacher?

I learned to follow my wonders and encourage my wondering thoughts & I should do that w/ my students as well.

Any ideas/ views about using wonder in your future classroom?

I want to encourage wondering & curiosity and not squish it.

Figure 5 (Click on image to enlarge). Sample exit ticket – wonder fair.


Exit Ticket: Wonder Presentations

Overall reaction to the wonder presentations (and why):

I enjoyed the presentations. Really allowed me to see how many things I wonder about things are also wonders by others.

Tell us anything that stands out to you about your journey with wonder this semester.

This last class: It was highly invovled, entertaining and sparked more questions for me.

Did you learn anything new about yourself as a person through this process? As a future teacher?

I learned that I need to begin to be okay with open-ness and to become comfortable with less rigidity.

ny ideas/views about using wonder in your future classroom?

I feel wonder definitely helps produce authentic engagement.

Conclusions

> *“The most worrying part about a lack of wonder in the classroom is that we don’t just ignore its potential, we often actively discourage it” (Piersol, 2014, p. 17).*

It is no surprise that modern schools, which are predicated on test scores as the key measure of quality, would openly discourage wonderings that ask students to slow down and ponder questions that may fall outside the realm of scripted curriculum and pacing guides. However, we cannot discount that wonder, as a pedagogical tool, draws from a long history and tradition of science and pondering about the natural world. Wonder places the human experience at the center of the inquiry process. We can and should utilize abstract ideas to elicit and evoke emotional connections to science itself (Hadzigeorgiou, 2016). We do not wish to discount the role of standards-based learning in schools; however, we wish to also point to the role that wonder-infused pedagogy can play in interesting future teachers (and their future elementary students) in science and the associated state mandated standards. There exist numerous anecdotal examples of the connections that program graduates shared over the last few years. In one such case, a former student carried out an action research project regarding wonder in her class where she claimed, “Working with a wonder wall is interesting because I can choose to highlight wonders from the children that also connect to standards we need to address.” In this case, a wonder wall where children posted their wonders regarding content became a vehicle for the teacher to introduce and address science standards. Wonder-infused approaches can become the entry point into science by building interest, which we contend will create greater willingness and commitment to make sense of the content within those standards in their future classrooms.

Cobb (1977) reminded us that there is power in individuals creating their own meanings and connections to the natural world because there exists a “genetically motivated process of learning” (p. 18) that impacts people in a far more meaningful fashion than memorizing someone else’s interpretation of that world. It was this spirit that both drove and sustained the science methods course. We feel this approach has remarkable potential for engaging preservice elementary teachers as well as other students in K-16 contexts. A *wonder-infused pedagogy* provides at least one pathway to address the current crisis of interest impacting preservice elementary education (Tytler, 2007). These affective connections between scientific content and individual cognitive structures helped class participants make sense of scientific phenomena by connecting emotion and imagination as a conduit into scientific thinking (Egan, 2005; Trotman, 2014; Whitin & Whitin, 1997). Ultimately, *wonder-infused pedagogy* provided a productive opportunity for preservice elementary teachers to engage with their own vexing questions as a means to excite them about both learning science content and their future science teaching practice. The first author has received numerous communications from program graduates, over the last few years, articulating ways new teachers have engaged with science and wonder in their classrooms (wonder walls, student wonder projects, wonder centers, wonder journaling, etc.). One of the most powerful examples comes from a recent graduate who was offered a position at a local school as the lead science teacher on a fourth grade team. She was apprehensive about the science lead role, but took the position. Utilizing elements of wonder and inquiry ultimately led to her team being recognized with a district-wide award for their excellence in science teaching during

her first year. Our contention is not that wonder alone created these conditions, but it is indeed a driver to build the courage necessary to try innovative approaches and even take on science leadership positions early in our graduate's careers.

Cobb (1977) argued that the "genesis of knowledge" (p. 32) begins with wonder. We agree wholeheartedly with this statement, as it was on display with these preservice teachers rekindling their connection to wonder. Importantly, methods course instructors using this approach need to exhibit the same courage and trust they wish their preservice teachers to embody in their future classrooms. We cannot tell them where to take these ideas or how to get there. The goal was the wondering, the traipsing, the getting lost and eventually finding their way. This process could lead to a single finding, a series of new inquiries, or a testable question, and in many cases even more wonders. This ultimately was the goal, to reconnect and rekindle what has typically been lost during schooling.

Supplemental Files

Appendix-A.pdf
Appendix-B.pdf

References

Akerson, V., Morrison. J, & McDuffie, A. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching,* 43, 194–213.

Atkins, L., & Salter, I. (2015). Engaging future teachers in having wonderful ideas. *In* C. Sandifer and E. Brewe (Eds.). *Recruiting and Educating Future Physics Teachers: Case Studies and Effective Practices* (pp. 199-213). College Park, MD: American Physical Society.

Bianchi, L. (2014). The keys to wonder-rich science learning. *In* K. Egan, A. Cant, & G. Judson (Eds.). *Wonder-Full education: The centrality of wonder in teaching, and learning across the curriculum* (pp. 190–203). New York, NY: Routledge.

Brand, B., & Wilkins, J. (2007). Using self-efficacy as a construct for evaluating science and mathematics methods courses. *Journal of Science Teacher Education*, *18*, 299–317. Retrieved from https://doi.org/10.1007/s10972-007-9038-7

Bybee, R. (2015). *The BSCS 5E instructional model: Creating teachable moments*. Arlington, VA: NSTA Press.

Bybee, R. (2002). Learning Science and the Science of Learning. Arlington, VA: National Science Teacher Association Press.

Carson, R. (1965). *The sense of wonder*. New York, NY: Harper and Row.

Cobb, E. (1977). *The ecology of imagination in childhood.* New York, NY. Columbia University Press.

Cox, B. (2011). *Wonders of the universe*. London, England: Harper Collins.

Egan, K. (2005). *An imaginative approach to teaching*. San Francisco, CA: Jossey-Bass.

Einstein, A. (1931). *Living philosophies*. New York, NY: Simon & Schuster.

Gilbert, A. (2009). Utilizing science philosophy statements to facilitate K-3 teacher candidate's development of inquiry-based science practice. *Early Childhood Education Journal,* 36(5), 431-438.

Gilbert, A. (2013). Using the notion of 'wonder' to develop positive conceptions of science with future primary teachers. *Science Education International,* 24(1), 6-32. Retrieved from: http://www.icaseonline.net/sei/march2013/p1.pdf

Gilbert, A. & Byers, C. (2017). Wonder as a tool to engage preservice elementary teachers in science learning and teaching. *Science Education*. 101(6), 907-928. Retrieved from https://doi.org/10.1002/sce.21300

Hadzigeorgiou, Y. (2012). Fostering a sense of wonder in the science classroom. *Research in Science Education*, *42*(5), 985–1005. Retrieved from https://doi.org/10.1007/s11165-011-9225-6

Hadzigeorgiou, Y. (2016). *Imaginative science education: The central role of imagination in science education*. Cham, Switzerland: Springer International.

Kenny, J. (2012). University-school partnerships: Preservice and in-service teachers working together to teach primary science. *Australian Journal of Teacher Education, 37*(3), 57-82.

Llewellyn, D. (2002). *Inquire Within: Implementing Inquiry Based Science Standards.* California, USA: Corwin Press.

Mangiaracina, M. (2017). When is melting not really melting? Building explanations through exploration using an engaging toy. *Science and Children*, 55(4), 61-66.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington DC: National Academies Press.

Piersol, (2014). Our hearts leap up: Awakening wonder within the classroom. *In* K. Egan, A. Cant, & G. Judson (Eds.). *Wonder-Full education: The centrality of wonder in teaching, and learning across the curriculum* (pp. 3-21). New York, NY: Routledge.

Schinkel, A. (2017). The educational importance of deep wonder. *Journal of Philosophy of Education*, *51*(2), 538–553. Retrieved from https://doi.org/10.1111/1467-9752.12233

Trotman, D. (2014). Wow! What if? So what?: Education and the imagination of wonder: Fascination, possibilities and opportunities missed. *In* K. Egan, A. Cant, & G. Judson (Eds.). *Wonder-Full education: The centrality of wonder in teaching, and learning across the curriculum* (pp. 22-39). New York, NY: Routledge.

Tytler, R. (2007). Re-imagining Science Education Engaging students in science for Australia's future. Camberwell, VIC: Australian Council for Educational Research.

Van Aalderen-Smeets, S., Walma Van Der Molen, J., & Asma, L. (2011). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education*, *96*, 158–182. Retrieved from https://doi.org/10.1002/sce.20467

Whitin, P., & Whitin, D. (1997). *Inquiry at the window: Pursuing the wonders of learners*. London: Heinemen.