The Use of Storytelling to Model NGSS Science and Engineering Practices

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An important strand of three-dimensional learning in the Next Generation Science Standards is science and engineering practices (SEPs; NGSS Lead States 2013). The SEPs also are one of four critical attributes of sensemaking (NSTA, n.d.). These practices replace the oversimplified “scientific method” often presented in science textbooks that bears little resemblance to actual scientific research (Windschitl et al. 2008). To effectively communicate SEPs to students, teachers must describe what they know about science (science content) in the context of how we know it (science practices). Few elementary or secondary teachers have engaged in scientific research, so this presents an obvious challenge. In their study based on surveys of science teachers, Kite and colleagues (2021) observed that educators generally lack a nuanced comprehension of how science is done, and underscored the importance of teaching the teachers how to effectively integrate science practices into classroom lessons.

The NGSS SEPs are listed in Table 1 (see Online Connections). The identification of a collection of practices rather than...
a series of steps allows students to understand that the SEPs are part of an iterative process of scientific discovery (Windschitl 2008). Also, the practices more closely align with actual scientific research. For example, one of the steps in the scientific method is to carry out an experiment. However, much scientific research is analytical or observational rather than experimental. The practice of “carrying out investigations” better describes all types of research that might be done.

We propose an approach using storytelling that we employed in upper-level biology and freshman Earth science classrooms under the banner of People to Ponder; our approach can be modified to use in elementary and middle-school classrooms. To engage students in science content and illustrate SEPs, we shared stories about historical scientists, modern-day professionals, and citizen scientists who modeled the practices as they sought to understand natural phenomena. Each story explicitly illustrated the SEPs and was linked to the disciplinary core ideas (DCIs) students were learning at the time. More important, the stories often directly related to classroom activities in which students embraced the practices. Our results are empirical and anecdotal; however, this approach engaged students, enhanced their comprehension of science content, and increased their understanding of the nature of science.

**An example of a person to ponder: Joanna Haigh**

Joanna Haigh (left) is a British atmospheric physicist, born in 1954. From a young age, she had an interest in weather; she created her own weather station as a child, recording observations of clouds, wind, rain, and temperature over the years. After graduating from Oxford with a physics degree, she traveled around the Middle East for a year visiting archeological sites. Joanna was fascinated by weather in Morocco and returned home to do a master’s degree in meteorology at Imperial College. In 1980 at Oxford, she earned a PhD in atmospheric physics to better understand climate change and then did a postdoctoral fellowship. In 1994, she moved to Imperial College, where she spent the rest of her career. Joanna was the head of the Department of Physics from 2009 to 2014. From 2014 to 2019, she was co-director of the Grantham Institute – Climate Change and the Environment (Humans of Science 2017).

Joanna is known for her research on solar variability. She wondered whether solar variation could be responsible for the changes in climate on Earth that were being observed. Her approach was different from previous workers, because she studied variations in ultraviolet (UV) radiation rather than visible light, using data from satellites. An increase in emission of UV radiation by the Sun heats the stratosphere preferentially (because it contains ozone) and affects winds in the troposphere because it changes temperature gradients across the tropopause. Heating of the lower stratosphere causes jet streams to be moved toward the poles, affecting climate (Ball et al. 2016; Climate Assembly UK 2020; McSweeney 2019).

Joanna’s work was important in helping scientists establish the role of solar variation in climate change on Earth. Her paper in the journal *Science* had a big impact, prompting climate modelers to think about the effects of UV on heating the stratosphere. Her expertise in modeling atmospheric heat transfer allowed her to develop fast but accurate computer models now used by climate scientists around the world. Though her own research focused on variations in solar radiation, Joanna recognized the role of human activities in the increase in global temperatures. She has been a vocal advocate for government policies aimed at reducing emissions. During her career, Joanna published dozens of papers related to climate, including landmark papers in *Nature* and *Science*. She was the lead author on the *Third Assessment Report of Intergovernmental Panel on Climate Change*. Joanna also has been interviewed numerous times for podcasts, books, print and online articles, and she has given dozens of talks. Even though she retired in 2019, Joanna remains an active science communicator (Dunning 2019).

**Digesting the stories**

While listening to the stories in Earth science classes, students were expected to take notes on handouts with sections labeled with Who, What, Where, When, and How (Figure 2). After listening to each story about a person to ponder, freshmen students were shown a list of the SEPs (see slide 14 of Figure 1; see Online Connections). They were asked to choose one and describe what the subject did that illustrated the specific prac-
Assessing student learning

Ninth-grade students were informed early on that they would have a People to Ponder test (Appendix I; see Online Connections) at the end of each semester. The test required written answers, and students were given time in class to complete it (although they also could work on it outside class). Students were expected to use their notes, but they also could do research online as long as they cited any sources that they used. The test required, for each person pondered, that students identify one SEP that the subject engaged in and explain what they did specifically that aligned with that SEP. Students could not use an SEP more than twice. The beauty, and challenge, of this approach was that there were many possible correct answers, and students should not all have the same answers on their individual tests.

Selected responses from students’ tests are listed in Appendix II (see Online Connections). It is clear from these responses that students had learned and understood the material. Their answers were in their own words, rather than rote repetition of content. It’s notable that some of the answers in Appendix II were from non-native English speakers. The stories helped them access content and develop understanding that might be difficult in a traditional lesson. Individual subjects were seen as practitioners of different SEPs, depending on the student. Some students identified links between practices and activities that they had researched on their own and were not discussed in class, a true indication of learning. Others referenced the predictive power of models. Many made connections between the SEPs and the phenomena the subjects were working to understand and that were discussed in class: continental drift, apparent shifts in the positions of stars, the shapes of planetary orbits, or the relationship between the masses and properties of individual elements.

Another measure of the impact of storytelling included two simple unscheduled student surveys at the beginning and end of the school year. Each time, students were asked to list the names of every scientist they could think of and, if possible, something of note that person had done. At the beginning of the year in which 148 students saw 16 People to Ponder presentations, students named an average of 4.2 scientists (range 2–16) and 3.8 accomplishments (range 1–10). By the end of the year, the list of names given by each student was longer; they named an average of 13.6 scientists (range 10–28) and 21.3 accomplishments (range 13–31). In some cases, students could not remember the names of scientists but could remember what they had done. For example, some students responded with “the priest who calculated the Big Bang [sic]” (Georges Lemaître) or “the guy who figured out climate cycles” (Milutin Milankovic).

A final indication of the impact of storytelling was evidenced by students talking about the practices while participating in classroom activities. In one case, students were engaged in a group activity and one member of the group had run into an obstacle that stopped them in their tracks. Another group member encouraged them to “design a solution” for their problem. The students brainstormed together, found a workaround, and continued with their project. Another time a student said “I have to communicate my information with you” to classmates who were instructed to compare their calculations with others in class. By feeling comfortable with their understanding of the practices, students were more likely to use academic language to communicate ideas.
Integrating stories into science classes

It requires time and effort (although little direct cost) to research and prepare accounts about people who model SEPs. In addition to creating a valuable resource to assist students in understanding science practices, compiling the stories enables teachers to learn more about the nature of science and gain confidence in their own ability to teach the practices. Students would ask when we’d be doing another People to Ponder and even suggest people about whom they would like to learn more. We found that our broader knowledge of science increased through researching the lives of our subjects. Sharing this fact with our students modeled lifelong learning and showed them that we could be co-passengers on a voyage of discovery.

ONLINE CONNECTIONS

Table 1. Connecting to the Next Generation Science Standards: https://tinyurl.com/5n9a3j3n
Figure 1. PowerPoint biography of Joanna Haigh: https://tinyurl.com/2sa42wzjc
Appendix I. People to Ponder test: https://tinyurl.com/uhfb5zkj
Appendix II. Student responses: https://tinyurl.com/3bzuwvk

REFERENCES


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