

My state, Ohio, held onto the same standards for science from 2010 through 2018. The 2018 standards will not be adopted by my district until this coming school year. Ohio's 2018 standards are based on the NGSS, but with some variations, some subtle, some glaring, including the Nature of Science tenets. As a result, we have not yet begun to teach with any tenets in mind. With no tenets for practice or crosscutting concepts to ground us, much of our current curriculum has been strictly content coverage based, often jumping from topic to topic with no clear through line for the students to follow aside from what we call our "bars." I did try this past year, however, to create a through line; one that could be referred back to again and again. That is following the quote from physicist Richard Feynman's book, *Six Easy Pieces* (1963):

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the *atomic hypothesis* (or the *atomic fact*, what whatever you wish to call it) that *all things are made of atoms - little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another*. In that one sentence, you will see, there is an *enormous* amount of information about the world, if just a little imagination and thinking are applied. (p.4)

Because my students are only in the 6<sup>th</sup> grade, I did not, of course, word it that way. In fact it was never stated explicitly at all. I simply started the year with physical science, covering the topics of matter, atomic structure, and energy (esp. thermal), then referring back throughout the year to the fact that *all phenomena we experience are the result of atoms* ("these little dots" we'd call them) coming together, moving apart, and jiggling back and forth constantly. This was an effective unifying concept all year long, throughout not only our physical science units, but through our life science and Earth science units as well.

As a science teaching team, the closest thing resembling the tenets we followed the past two years were the "bars" set in our Professional Learning Community meetings. For 6<sup>th</sup> grade, our bars were:

- 100% of students will be able to read and annotate a scientific text, extracting the main as well as supporting ideas.
- 100% of students will be able to read and interpret scientific diagrams, graphs, and tables in order to describe an object (i.e. a plant cell) or what takes place during an event (i.e. a ball rolling down a ramp).
- 100% of students will be able to use the steps of the scientific method and follow prewritten directions in lab activities in order to answer a question or solve a problem.

These bars were skills that students were to practice throughout the year regardless of the content we were studying. As a PLC team, we were instructed to give students occasional formatives on these skills, study the data gleaned, and then, in

our weekly meetings, brainstorm improvements for helping students continue to build these skills.

Unit planning for this coming year, including how we will work the NOS tenets into our curriculum, is currently up in the air. This is, of course, due to COVID-19 and the question of whether we will be working virtually, in brick and mortar, or some sort of blended model. I am also not sure as to how the tenets will blend with our bars, which is something our building administration is committed to. That said, I believe there are a number of ways the tenets can be woven into the everyday experience of my science class regardless of how or if they are an explicit part of our lessons or units.

In Ohio, the closest direct comparison to the NGSS Nature of Science tenets can be found in the category, Science is a Human Endeavor, in which three of the four bullet points for middle schools are duplicated. One bullet point, *“Men and women from different social, cultural, and ethnic backgrounds work as scientists and engineers,”* would be especially effective in many of my lessons.

One thing I have noticed in the two years I’ve been in my current position is that there is rarely, if ever, any mention of the men and women who have contributed to our vast body of scientific knowledge over the past four hundred years (several thousand if you count indigenous cultures). It is as if all of the content we cover simply exists in a vacuum and has always been self-evident throughout human history. Some of this, I believe, has to do with the traditional whitewashing, both literally and figuratively, of the history of science in American classrooms and the more recent effort in response to tone down the veneration of “dead white men” in lieu of our ever growing diversity of students in American schools. This, while well intentioned, is somewhat short sighted in that humans are storytellers. Dry facts are not enough for student engagement. Even the NGSS calls sequences of their lessons, Storylines knowing full well that content must be wrapped in the context of events and problems to be solved in order to have relevance.

The Ohio tenet, Science is a Human Endeavor along with the NGSS connection, *“Science knowledge is cumulative, and many people from many generations and nations have contributed to science knowledge,”* found under the tenet, Science is a Way of Knowing (not adopted by Ohio) can bring back the stories and the people so important to the history of science to my classroom. While we can still celebrate the accomplishments of known white scientists and inventors such as Darwin, Newton, and Galileo, we have a marvelous opportunity to weave the stories of women and minorities into our content as well.

My school [population](#) is 50% white, 33.4% African American, 7.5% Hispanic, and 6.6% Asian/Pacific Islander. Along with this, 43% of the total population are economically disadvantaged. Many of my male minority students feel their only career options are to become ball players or rappers. My female minority students I’ve spoken with are somewhat more motivated in that there are some who want to be pediatricians and veterinarians. Unfortunately, none of these students have heard, in my class, the stories of anyone who looks like them, especially the boys, to inspire them toward more STEM oriented opportunities and futures.

With only a little effort, students could learn about the composition and interaction of various molecules or the life cycles of plants while hearing the story of George Washington Carver who saved countless lives in the American South using only the barest of scientific equipment, what he called “cook stove chemistry.” Students could also learn about more recent figures, such as physician and astronaut Mae Jamison in a possible unit discussing what it takes to provide proper healthcare to people in developing nations. To teach science without the stories of the people who have made and continue to make it happen is to undermine our next generation’s chances of contributing their own chapter. This is especially so for our minority and at risk populations.

Another valuable aspect of including the stories of these scientists and inventors in our classes is demonstrating how the natural laws they worked with and the technologies either available to them at the time (Carver) or that they invented (Jamison) overlap. Science is the act of investigating and understanding the phenomena of the natural world, while technology is the act of taking those understandings and the human problems they reveal, and working to solve those problems, thus improving our lives and environments. That said, there are a number of common understandings that are crucial to both.

First, there is the understanding of systems and how they work. Systems can be naturally occurring, such as a forest or pond ecosystem, or human made such as an artificial heart. Each system is composed of individual parts and each part has a specific role to play in the system’s overall function. Without each individual part, the system is impacted, sometimes in a minor way, other times resulting in the system’s shut down or destruction. Additionally, individual parts of some systems may be interchangeable and utilized for the understanding or the improvement of other systems.

Second, advancement in both science and technology are only possible by way of the work of people who came before them and the progress they have made. Newton’s quote regarding “standing on the shoulders of giants,” is not hyperbole. Again, the knowledge we have gained has not simply sat around in a vacuum simply waiting to be reasoned out. It has been accomplished in slow, gradual steps by the efforts of a number of people working in diverse fields over countless years. In order to build the Space X rocket, you first had to have the Apollo missions, and before that, the research of Wernher von Braun and his experiments in basic rocket technology during and after World War II. Of course none of this would have been possible without the thought experiments of Arthur C. Clarke regarding the possibilities of satellite technology and Isaac Newton regarding his fictional cannon able to fire a ball that circled the Earth.

Finally, and arguably most importantly, both science and technology use mathematics as their common language. Understanding the amount of thrust needed to escape Earth’s gravity and then building a rocket that will allow men and women to do so safely and then return to Earth requires an understanding

velocities, tolerances, trajectories, materials, acceleration of gravity, and countless other concepts all communicated through the language of math.