Critical reflection of my teaching practices:

1) **Scientific Investigations Use a Variety of Methods** – This tenet is addressed in my classroom whenever we do an experiment where the students need to design their own protocol (which doesn't happen that often, to be honest). One example is a laboratory activity where students are working with Alka-Seltzer to change their package instructions to maximize product efficiency by increasing the efficiency/rate of dissolving. That's the storyline I present. Each group chooses their own variable and how they are going to collect data. One of my favorite class lessons addresses replicability of results and honest and ethical reporting of findings. We start by reading a small news article about Haruko Obokata and the stem cell research scandal. We then watch a rather comical clip from Shark Tank, where a veterinary doctor is trying to pitch a line of pet food that "prevents all cancer" and "increases the life expectancy of pets by 50%." We record the claims made the doctor and then students design the protocol for experiments to test one of the claims. I think that I reference the importance of making valid scientific claims often throughout the year. I do not often cover new technologies. I think that this is a flaw of my curriculum- I don't cover current events or what's happening today in science often enough.
2) **Scientific Knowledge is Based on Empirical Evidence** – Perhaps I cover this best when we get to evolution and explore lines of evidence that support evolution. We often do lab activities that look for multiple lines of evidence to come up with a final conclusion.
3) **Scientific Knowledge is Open to Revision in Light of New Evidence** – This tenet is often incorporated into my exams. I add questions that use the theme of the unit content but are really asking about the nature of science. The NYS Regents actually has a decent selection of these questions. In terms of teaching, I address this tenet best during our unit of evolution. The recent discovery that dinosaurs had feathers and are more closely related to birds drives this concept home with my students. Students literally have to reimagine what has been reinforced by Hollywood and their childhood toys- and that's ok, because it is the nature of science! During remote learning, after evolution, as a reflection I asked students to share with me something that they found interesting during the unit. I was really quite surprised how many of them wrote about dinosaurs having feathers. It was a great opportunity to address this tenet of the NOS.
4) **Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena**- I do not address this explicitly in my teaching. I throw around the terms and I guess that I just expect that the students catch on. If a student ever challenges me with the "well it's just a theory!" then I will take the time to explicitly teach and explain how these words are used by scientists.
5) **Science is a Way of Knowing**- I think that this tenet has some overlaps with the second tenet. I may address this tenet best in our unit of genetics. We really focus on the timeline of genetics, from our understanding of patterns of inheritance for thousands of years, to how recently we discovered DNA, what has happened since then, and what we are hoping for in the future. I emphasize that what we are learning and teaching in school today was not part of their parents' curriculum, and certainly not part of their grandparents'. I also love telling my students that my friend is a tennis instructor who taught James Watson tennis just a few summers ago! They are shocked to find out that the person that discovered DNA is still alive. This is the one unit where I do get into recent work in the field, and even discuss the Human Genome Project.
6) **Scientific Knowledge Assumes an Order and Consistency in Natural Systems**- I can say that I very often refer to diffusion throughout the year… It seems to be an ongoing theme. We cover it explicitly in our cell biology unit. It then reappears in photosynthesis and cellular respiration in regard to how organisms exchange reactants and products. It becomes the theme of the respiratory, circulatory, and digestive system. When I teach photosynthesis, cellular respiration, and energy transfer in ecosystem, I really try to put a huge emphasize on the different forms of energy. I definitely address the first law of thermodynamics many times. However, I do not think my students would leave my class with a deep understanding that these repeating themes are of the nature of science. This is something that I can address in the future.

7) **Science is a Human Endeavor**- I can admit that I almost never address specific scientists and historical experiments. I address their findings indirectly, but I rarely cover the human endeavor, storyline, or history of experimentation.
8) **Science Addresses Questions About the Natural and Material World-** I address this tenet, and probably most biology teachers do, in our unit of genetics. Often, we talk about what we *can* do with genetics (mostly in terms of genetic engineering) vs. what we actually do because of our human values and ethics.

Enhancing my Teaching:

This was my first year teaching chemistry, but, it opened my eyes to so many important connections in biology. While I have actively been trying to incorporate more crosscutting concepts from chemistry into my biology course this year, I have many ideas for next year. By mentioning the laws of thermodynamics and energy conservation as they relate to topics in biology, it exposes students to the *idea* of laws. It doesn't mean that I necessarily have to assess them, but I'm realizing the importance of exposure when it comes to the nature of science.

Something explicitly stated in *Appendix H* is that "The use of case studies from the history of science provides contexts in which to develop students' understanding of the nature of science." I'm not sure why, but I have completely avoided this in my biology teaching. Mostly because it is not required by the state standards, so when I developed my first curriculum, I did not include any historical figures or experiments. Furthermore, from my own memories of school, I always found the historical part of science tedious and annoying to 'memorize,' since we were always assessed on it. It felt like a history lesson and was never exciting to me. My experience with chemistry this year had furthered pushed me away from a historical approach to teaching science, but in retrospect, it really just taught me the WRONG way to approach history. In chemistry, it is actually part of the state standards to address scientists and their contributions to the atomic theory- and I *hated* it, because I myself did not understand the nature of the experiments nor the tools used (I am not certified in chemistry- I was asked to cover one section by my administration..). For example, I needed to teach my students that JJ Thompson discovered the electron by using a cathode ray tube. The beams in the tube had a negative charge, and the electrons passing by were deflected. We even HAD a cathode ray tube that I demonstrated, but it was so meaningless to me (and my students) that I felt terrible. I really did not understand the device, and every time that I asked my colleagues questions, they would shrug me off and say that *'the students didn't need to know that.'* This was really how most of the year went, but I've slowly built confidence. In chemistry, I had no freedom over the lessons- I had to use what was handed to me. Luckily, in biology, I was able to design my own curriculum. I am extremely excited for how this course is preparing me to open conversations in my school regarding curriculum, the nature of science, and the impending transition to NGSS in our state. Even though I am by far the least knowledgeable about chemistry, I'm developing a really strong sense for how to teach it.
In biology, I am very strong in content, and I am confident that I can incorporate a historical approach to teaching. Appendix H has made me realize that it's about engaging the students in the process and getting students connected to the nature of science. In the first part of this paper, I mentioned my complete failure to address the human endeavor of science without reading the conclusion of Appendix H. Almost the entire conclusion is focused on the history of science and how it can be used to address almost all of the tenets of the NOS. I cover plenty of content in biology that I don't actually test my students on. I think that if I give this a chance, it could be an engaging and routine part of my science units. I think that opening each unit with a historical piece could be a great way to introduce the unit. I imagine that I could present the data from the experiments, and have students attempt to draw their own conclusions.

Overlaps with the Nature of Math:

After reading through the Nature of Math- several tenets stood out to me. I read in the first math practice, *CCSS.MATH.PRACTICE.MP1*, that "*Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, "Does this make sense*?" Often, for laboratory analysis, I ask my students to analyze their data with simple calculations. When students miscalculate, it amazes me that they don't catch their mistakes, especially when their conclusion makes little sense. For example, after a miscalculation, a student might determine that their average heart rate was 378 beats per minute. They continue on to include this in their analysis, without catching the mistake! So often, students do not pause to ask themselves "Does this make sense?" These completely avoidable errors happen all the time. It sounds silly, but just constantly asking the students to look at their data analysis, pause, and think- "Does this make sense?" could actually have a great impact on the way that they approach data analysis!

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others state that "*Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is*." My students often fail to draw valid conclusions from our class data. They struggle to understand when data is significant vs. insignificant and consistent vs. inconsistent. This often leads to productive class discussions, but I hope that my students develop a keener sense of how to make arguments from data.

CCSS.MATH.PRACTICE.MP4 Model with mathematics. Even if student won't remember a particular formula, it doesn't hurt to incorporate calculations from math and physics into labs. I do this in one particular nervous system lab where students calculate reaction time using the free-fall gravity formula. I also incorporate permutations into a small lesson about genetic variation in gametes. It makes the lessons more engaging and interdisciplinary, and while I have put some effort into this tenet, I would like expand in the future, because so far I have seen success.

References:

NGSS. (2013). APPENDIX H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards. Retrieved June 6, 2020 from https://www.nextgenscience.org/sites/default/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf

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