Kelli Kinlen
Nature of STEM Assignment

STEM is a unique field, as it encompasses four different disciplines - science, technology, engineering, and math - and highlights how these four pillars work together to uncover new information about the world around us. As a science teacher, my outlook on STEM starts with the nature of science. Lederman (1992) and McComas & Olson (1998) defined the nature of science as “inherent guidelines that scientists follow in order to cultivate valid ideas about the natural world” (as cited in Peters-Burton, 2014). This nature of science definition ties into the “nature of” the other STEM disciplines and can be used to build a strong foundation for STEM education and STEM careers.

(a). The nature of science is the basis for the NGSS standards. The goal of these standards and new pedagogy of teaching science is to help students become “scientifically literate” (NGSS Release, 2013). There are eight “basic understandings”, or tenets, about the nature of science that become the foundation for the NGSS standards. Of these eight tenets, there are many that I hit in my Science Research classroom. The first understanding, “scientific investigations use a variety of methods” is naturally present in this course. The Science Research course allows students to perform individual projects with the help of their mentor. More than one student could be studying something similar, but their methodology could be completely different. Students also need to study published research to see if their project has already been done, and how other scientists have studied the same or a similar topic. Students can then use the published methodology, and make changes based on their specific question and hypothesis, and access to materials. The changes to the methodology invites discourse between the students, mentor and teacher, to determine how best to perform the experiment. This directly demonstrates that “science investigations use diverse methods and do not always use the same set of procedures to obtain data” (NGSS Release, 2013). Another understanding that is present in my Science Research classroom is “scientific knowledge is based on empirical evidence”. Students practice this understanding in their results, discussion and conclusion sections of their projects. After collecting and analyzing their data, students discuss how the patterns of their results fit into the current theory of their topic. For example, I had a student who was studying butterfly migration based on compounds found in the butterflies’ tissues. After analyzing the data, the student was able to conclude the path that butterflies took to migrate, which was the same path as previous research had concluded. In this project, the student participated in the “process of coordination patterns of evidence with current theory” and “strengthened” a scientific argument by finding evidence that supported a single, previously published, explanation (NGSS Release, 2013). My Science Research classroom also hits on the understanding that “scientific knowledge is open to revision in light of new evidence”. This understanding is also naturally present in Science Research. Students often complete multiple trials or even multiple different tests to answer a question/support a hypothesis. The results from one test may be different from the results from the second test. Initially, the results from one test may support an explanation, but the results from the second test may refute the initial explanation, and require “logical discourse” between the student, mentor and teacher to determine a new course of action, whether that be repeating the methodology or revising the concluded explanation. Another understanding that I hit upon is “science is a way of knowing”, specifically the idea that “science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review” (NGSS Release, 2013). The Science Research course highlights the need for empirical standards by requiring students to collect and analyze data in order to develop a conclusion. The course also requires students to include statistical analysis, which the students use to strengthen their conclusion to create a “logical argument” that is backed by their results. We also talk extensively about “skeptical review”, in the form of judges at competitions and peer reviewers. This helps students understand that knowing science is “unique” and the way they perform and present their findings matters. I also highlight the understanding that “science is a human endeavor”. At the beginning of the year, I have students pair up with a classmate in a different grade to do a research project on their favorite scientist. This project helps students get to know each other to help build relationships between grade levels and students get to practice their presentation skills by presenting their projects. More importantly, students get to explore the scientists throughout history that have contributed to our scientific knowledge. Students choose scientists from different time periods, cultures and backgrounds, and it creates a beautiful compilation of all of the incredible and different people who influenced the progression of our scientific knowledge. The last understanding that is supported in Science Research is “science addresses questions about the natural and material world”. At the start of their project development, students must devise a research question that they want to study. Every year, I have students who write questions that cannot be answered by science. I work extensively with those students to revise their question to remove any semblance of ethics or values, which would not be answerable through the nature of science. This helps students have a better understanding of the nature of science, and how we can use experimentation to understand specific things about the natural world.

(b). Although the Science Research course includes many of the tenets outlined in the NGSS standards, there are a few that I have not explicitly addressed. The first understanding being “science models, laws, mechanisms, and theories explain natural phenomena”. I have not spent an adequate amount of time teaching my students the difference between a law and a theory. We jump right into exploring topics of interest and developing a project. In order to make sure students understand this tenet, I need to highlight the difference between a theory, which is what the students are developing through their experiments, and a law, which is a known fact that is no longer refuted. In order to explicitly teach this, I can use an argument based activity, like the ones outlined by Tang (2023). I would jump into this lesson at the beginning of the year, to create a foundation before students begin developing their projects. I can ask the students whether gravity is a law or a theory. I would then have students, without doing any extra research, decide whether they believe it is a theory or law. Students are grouped based on their decision and would then research more about gravity (the history of gravity, how it was discovered, what it means, how it is observed, etc.). Students would then have the opportunity to change their decision on whether or not gravity is a law or theory. Based on their final belief, students would create an argument that would defend their thinking. Once arguments are made and scientific discourse is allowed, students would discuss and create a visual representation for the difference between a law and theory, and how each plays a role in scientific research and science knowledge. The second understanding that I do not explicitly hit upon is “scientific knowledge assumes an order and consistency in natural systems”. I think this understanding is similar to the tenet explained above, as both contain material that I assume students have already learned and mastered in earlier years. This is not the case for most students, and should still be taught at the higher levels. In science research, we spend a lot of time discussing and looking at control and experimental variables. What we do not discuss is the natural laws that we know to exist and assume will continue to “operate today as they did in the past” (NGSS Release, 2013). One way to drive this message home would be to invite community leaders from different backgrounds to talk about how their cultures explain observations of the natural world (Spang & Bang, n.d.). Different cultures will have different explanations, but they all will be rooted in the same “natural laws”. By inviting these community leaders, it can “transform learning experiences to make them more engaging and meaningful” (Bell & Bang, n.d.), as well as help students who share the same cultural background feel seen and safe. This will create a better learning environment for all students as well as strengthen their understanding of science. My understanding of the “nature of science” and how I implement that into my science classes changes based on the students that I have in front of me and the class that I am teaching. In my Science Research class, many of the tenets happen naturally, because each student is explicitly undergoing the scientific process within their own project. This also means that the tenets are happening at the individual level, and each student will be focusing on a different tenet and understanding on a different day. Some students will dive deeper into some tenets while others may not. To further enhance my teaching, I can spend time with the entire class to explicitly teach some of these understandings that I feel most students are not exposed to. For example, in some years not all students will spend a lot of time working through the understanding that “science addresses questions about the natural and material world”. Students may immediately come up with scientifically testable questions, and they will not have to work through questions that are not answerable by science. To ensure that all students in all years meet this tenet, I can create a lesson using the “small-group discussions” outlined by Tang (2023), where students are in groups and are given a set of questions. They can work together to determine which questions would be testable by science and which would not be. They then could create an outline for how to know if a question is testable by science. This would meet the NGSS tenet and strengthen the students’ understanding of what types of questions can be explained through science. This will also directly help them create their own questions for their projects. In other science classes, like Regents Chemistry, the introduction of these tenets would look very different. Specific lessons, labs and activities would need to be created in order to explicitly highlight the different NGSS understandings. Some would be focused on naturally (ex. “Scientific knowledge assumes an order and consistency in natural systems” will naturally be embedded in Regents Chemistry when we discuss that all atoms of the same element have the same number of protons. This is then assumed through the rest of the course as the content builds) while some would have to be strategically and explicitly taught (ex. “Scientific investigations use a variety of methods” - typically regents labs are based on a methodology and set of questions that are printed and given to every single student to ensure that they all meet the learning objectives. These traditional labs would not meet the NGSS understanding. Instead, each lab group could have a different methodology that ended in the same results. Not only are the learning objectives of the lab met, but it opens discussion for how experiments can have different methods but still end in the same results). How the understandings are taught also depends on the resources that are available to the teacher and students. Although the “nature of science” and NGSS understandings are defined for everyone, how they are demonstrated in classrooms and to students is dynamic and can be altered to ensure that all students are successful.

(c). The nature of science is not the only “nature of” that is included in the NGSS standards. NGSS standards also explicitly include engineering and technology practices. It is argued that “humans have a need to know and understand the world around them” and “to change their environment using technology in order to accommodate what they understand or desire” (NGSS Release, 2013). Without the addition of the engineering and technology standards, students would only be able to have a minimal understanding of the world, and would not be able to change their environment. Although math is not as explicitly written in the NGSS standards, it is equally as important. According to Schoenfeld (1992), the nature of math can be defined as “the cycle of inquiry that begins with the representation of quantities as abstract symbols, accounting for all possibilities through manipulation of the rules (although there is some flexibility), and validating the quality of solutions and models by understanding the differences between mistakes and reasonable choices that did not turn out to be successful” (as cited in Peters-Burton, 2014). There are many ways that the nature of math overlaps with the nature of science, especially in Science Research. The first and most profound overlap is through the use of math for statistical analysis. In order for a project to be valid, there needs to be some form of statistical analysis. This analysis validates the quality of solutions and models (as written in the “nature of math” statement) which allows students/scientists to develop “logical arguments” and withstand “skeptical review” (as stated in the “scientific knowledge assumes an order and consistency in natural systems” NGSS understanding). A second overlap comes through using math as a way to perform experimentation. I have had students perform theoretical projects where they develop and use mathematical equations to answer a scientific question. Math can be used to create theoretical models that answer questions about the natural world, which directly relates to the nature of science. A third overlap is in the *why* of teaching math and science. According to one of the tenets of the NGSS standards, “science is a human endeavor”, which highlights the importance of explicitly teaching about “scientists’ backgrounds, theoretical commitments, and fields of endeavor” and how they “influence the nature of their findings” (NGSS Release, 2013). In his blog, “Why Teach Mathematics”, Larson (2018) discusses the reasons why math should be taught. He highlights that one of the reasons should be “appreciation of mathematics as an element of culture”. This reason would give students the opportunity to study famous mathematicians throughout history from different backgrounds and cultures.

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Larson argues that "by teaching mathematics as part of cultural heritage means that we do not just emphasize culture and heritage" and "we cultivate and nurture student identities". This would work to empower all students, and aid in their motivation to learn and understand math. In both math and science, it is important to recognize that progress of knowledge is due to people all around the world, not just one dominant culture. This helps all students see themselves as math and science people, and empowers them to continue to grow and learn in the STEM field, which is ultimately our goal as STEM educators.

Works Cited

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