

## What I Have Learned About the Nature of Science, Its Presence in My Teaching and Its Connections to the Nature of Engineering

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There are many myths and misconceptions about the nature of science. Some people think that the nature of science is simply a series of steps known as the scientific method. Others view science as a set of unchangeable facts that must be memorized, while still others view science as secondary to other subjects and not even necessary to be taught. Yet, the truth pervades that science is a necessary and important part of education that seeks to not only teach children about the natural world but to actively involve them in the process of inquiring into the world around them and to participate in investigations and discourse that leads to a deeper understanding of the way the world works. According to the NGSS Executive Summary, science learning should be three-dimensional, focusing on disciplinary core ideas, cross-cutting concepts, and practices. Additionally, students need to learn about the nature of science, in other words, the tenets that make science what it is (Peters-Burton, 2014); and research has found that science should not be taught in isolation, but should be integrated with technology, engineering, and math to maximize student learning and deepen students understanding (Nadelson & Seifert, 2017). Therefore, through this paper, I will examine the nature of science, its presence in my own teaching and how it can be integrated with engineering.

A lot of research has been done to define the nature of science, and the authors of the Next Generation Science Standards in Appendix H have outlined eight tenets specifically. The tenets are as follows:

- Scientific Investigations Use a Variety of Methods
- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence
- Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

In terms of the first tenet, that scientific investigations use a variety of methods, there isn't one way to do science. This debunks the common misconception that science is simply guiding students through the scientific method. Renee Schwartz does a good job of explaining this in her article, "What's in a Word?". As she states, "Learners should understand that scientific knowledge is developed through a variety of approaches, and not one 'scientific method'. Scientific knowledge is developed through creative and inferential processes of collecting and making meaning from observations..." (Schwartz, 2007). In my own classroom, this tenet can be seen through the backward design of many of my lessons where students are actively exploring ideas, participating in inquiry and project-based activities and asking questions.

As for the second tenet, that scientific knowledge is based on empirical evidence, this can be seen in my class through the investigations my students participate in. One such example, is a "Sailing Car Lab" that my students conducted while learning about the power of air. The question arose as to which shape sail will catch the most wind, so my students researched different shapes of sails, designed sails of their own, and tested them by attaching them to Lego cars and blowing them with fans. Through this experience, the students collected empirical evidence to determine that larger sails worked better than smaller ones and ones without holes worked better than ones with holes, etcetera. This activity also sheds light on the third tenet, that scientific knowledge is open to revision in light of new evidence, because as students shared their results from the lab the students had to constantly evaluate the new data their peers shared to draw conclusions, and this is what real scientists must do. As the Science Learning Hub explains, science is tentative because there are no absolute truths in science - it is constantly evolving and building on itself as scientists acquire new knowledge.

The fourth tenet that science models, laws, mechanisms, and theories explain natural phenomena, can be seen in my fifth graders exploration of catastrophic events. To introduce the students to the concept of convection I demonstrated the phenomena to them by dropping hot water dyed red on one side of a large tank of room temperature water and by dropping cold water dyed blue on the other side of the tank and letting them observe what happens. Then, we were able to refer to this throughout the unit as the students learned about convection in the Earth's mantle and convection currents in the air. This example also illustrates the fifth and sixth tenets of science in that it displays how science is a way of knowing about the Earth's systems and that there are patterns, like the pattern of heat rising and cold sinking, that are consistent within the natural world.

My students' study of catastrophic events can also be used to represent the seventh and eighth tenets because the students broke into groups to learn more about a disaster of their choice. They had to work together as a team to determine how the negative effects of the natural disaster they chose could be reduced or prevented, and their working together points to the fact that science is a human endeavor. The students also had to determine answers to their questions about the causes of the natural disaster they chose, which points to the eighth tenet, that science addresses questions about the natural and material world.

While illustrations of each of the tenets can be seen in my teaching, what I have become aware of after learning about each of the tenets is that I have never referred to them specifically as representations of the nature of science. This is something I would like to do in the future and *need* to do. To help my students recognize the nature of science and to enhance my teaching, I would also like to give my students more time to reflect. The Appendix H states, "students must have the opportunity to stand back and reflect on how the practices contribute to the accumulation of scientific knowledge." - giving my students time to reflect is something that will greatly benefit their overall understanding of science. I was also struck in Renee Schwartz's article, "What's in a Word?", by the effects our word choice has and how easy it is to reinforce misconceptions about the nature of science with our language. Moving forward I want to be more aware of the words I use by following her suggestion of coming up with a list of dead words that my students and I avoid. For example, avoiding the word proof since

that perpetuates the idea that there are absolutes in science - which is another thing on which I need to reorient my thinking. The fact that science is fluid is something I rarely think of, and is something that I need to remind my students of as well. A final step I would like to take to further my own understanding of the nature of science and that of my students is by learning more about science as a human endeavor to better understand how our biases influence our interpretations of evidence and conclusions.

Now that an understanding of the nature of science and the role it plays in my teaching has been established as well as the ways it can be enhanced, it is important to evaluate the nature of another STEM subject and the ways it overlaps/connects with the nature of science, as the whole premise of STEM education is based on the value behind the integration of two or more disciplines. To do so, I will focus on the nature of engineering.

The nature of engineering is not nearly as researched as the nature of science since engineering learning standards have yet to be developed and adopted by a majority of states. However, in 2006 the Committee on K-12 Engineering Education was developed and they laid out the nature of engineering in the following three principles (Katehi, Pearson, & Feder): (1) K-12 engineering education should emphasize engineering design, (2) K-12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills, and (3) K-12 engineering education should promote engineering habits of mind. These principles overlap with the nature of science and can be used to enhance science education in several ways.

One way the nature of engineering overlaps with the nature of science is through inquiry. Katehi, Pearson, and Feder state in the executive summary of Engineering in K-12 Education that, "Certain science concepts as well as the use of scientific inquiry methods can support engineering design activities." As students are actively inquiring into the natural world, the science concepts can provide a rich context for students to apply the engineering design process. Another way the two overlap is through the use of testing methodologies and measurement tools since many of the tools scientists use to collect data are the same tools engineers use (Katehi, Pearson, & Feder). A final overlap can be seen in the 21st Century Learning Skills that both disciplines develop, particularly creativity. As mentioned above, creativity plays an important role in science as scientists have to creatively gather observations/data, while engineers must creatively design solutions to solve problems.

In all, it is my hope that this paper has highlighted the nature of science education through the ways it is visible in my classroom and can be enhanced in my teaching, as well as the ways it overlaps with the nature of engineering to deepen students' understanding.

## **Works Cited**

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