

Stan Feighny
Methods of STEM Education
Winter 2020, 2/22/2020

Nature of STEM

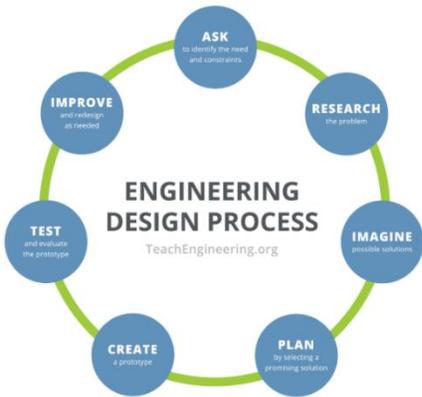
In choosing my “nature of” exploration, I completed a short literature study to better understand the “nature of” requirement. In this review, the Nature of Science (NOS) had the richest resources and the clearest definitions; engineering was next. I found math was covered by mostly philosophical discussions, and technology had only minimal coverage. NOS is reviewed here and used to provide background on the Nature of Engineering (NOE) selection. The NOS definition from *Learners’ Responses* (Clough, 2006) provided material for student discussion: “[what] science is, how it works, the epistemological and ontological foundations of science, how scientists work as a social group and how society itself both influences and reacts to scientific endeavors.”

Nature of Engineering

What is engineering... (Pleasant and Olsen, 2018) is a reference rich article that built the definition of the NOE from the same construct as the NOS definition in *Learners’ Responses* (Clough, 2006): “What engineering is, how it works, how engineers conduct their work, the relationship between engineering and other fields of study such as science, and how engineering influences and is influenced by society.” The *What is engineering...* article continues and provides the following nine points of discussion for the NOE:

<i>What is Engineering? Elaborating the nature of engineering for K-12 Education (Pleasant and Olson, 2018) referred to as the NOE list of nine.</i>
5.1) Engineering is focused on the practical design of technologies.
5.2) Engineers create specifications, constraints, and design goals to design products and processes.
5.3) Engineers utilize knowledge from science and engineering [and a] knowledge base of its own.
5.4) Engineering science is a key source of creating knowledge used in the design of technologies.
5.5) Engineers solve problems.
5.6) Engineers have a flexible design process.
5.7) Engineering designs are affected by the cultural norms of society.
5.8) Engineering has an internal culture.
5.9) Engineering’s use of science separates modern engineering from the craftsman approach of the past.

In Texas, Texas Essential Knowledge and Skills (TEKS) are guidelines for course curriculum development. This class is described in the section for Engineering Design and Problem Solving (Chapter 130,2015). The NOE list of nine is not specifically covered as such, but the ideas are woven throughout the course. Most of the list is covered in the general requirements section and not specifically called out in TEKS. For example, in the TEKS section b), Introduction paragraph (3), “the course is a creative process of solving problems by identifying needs and devising solutions.” The TEKS calls out “The student creates justifiable solutions to open-ended real-world problems using engineering design practices and processes” however, creativity is not mentioned.”



My current focus is more on the engineering design process rather than the NOE. We use the circular model (Engineering Design Process), but students soon find out that it does not go in a step-by-step fashion. This is stretch for the students as many of them want the engineering design process to be more like the elementary model of the scientific method (fixed with an end point). Any design with complexity requires crossing over the center (early and often) so the process looks more like a nine-point star than a circle. The specifications and constraints are provided, but the students create their own design goals. As starting engineers, the specifications and constraints will be provided. Regrettably, I do not cover much on the cultural

norms of society as this is an important aspect that needs to be covered. The internal culture of engineering is covered in the Professionalism Standards (Chapter 130, 2015) grading area for the class. Students receive a grade every three weeks on how they have contributed to the class. Leadership and the support of a professional environment is rewarded. This is not a participation grade.

To enhance the teaching of NOE, I plan coach the students through the same the path I have covered the past weeks. NOS is an excellent model to help students understand how to talk about the nature of anything. A possible activity is to break the class in to groups and have them develop one handwritten poster that shows their interpretation of *Revising Instruction...*(Lederman and Lederman). I start with science because engineering is based on science, and the students already have two or three years of high school science to draw on. This is also a useful review as to the difference between observation and inference, as well as, difference between laws and theories, terms we use often in engineering.

At the start of the year, all the students find a degree plan at a university they are interested in pursuing and have a good chance of acceptance. They are often surprised by the number of science courses that an engineering student takes. The study of the NOS is a good way to help the students understand how employers expect them to think, not just the facts and procedures they need to know.

This activity takes long class period. Next, I give them the sections of the *What is engineering* (Pleasants and Olsen, 2018) article and have them create a chart that shows the differences between science and engineering. From there, the class develops a combined chart to be posted on the wall and referred to during the year. Fundamentally, the way to improve student understanding of the NOE is to teach it **explicitly** as explained in *Tips and Strategies...*(UC Berkley, 2008) and to refer to the NOE explicitly during the course. I know it is very easy for me to get caught up in the details of making something work and not to continue to teach the more overriding concepts.

In the following table I have extracted the “nature of” elements from current thinking about the nature of science and the nature of engineering. To classify the overlap, I generalized the concept and created a list at the next higher level to better show the relationship of the “nature of” elements. I started with the McComas list of nine, as it seemed more comprehensive and tried to match the other NOS/NOE to this list. Surprisingly, the Change element is missing in the NOE. Specifications, constraints, and goals are missing from the NOS lists, but this is an engineering unique requirement.

Overlap in the NOS and NOE			
Nature of _____ Concept	<i>Keys to Teaching the Nature of Science (McComas, 2004)</i> (List of nine) *	<i>Revising Instruction to Teach the Nature of Science (Lederman and Lederman, 2004)</i> (List of seven) *	<i>What is Engineering? Elaborating the nature of engineering for K-12 Education (Pleasant and Olson, 2018)</i> (List of nine) *
Source of Knowledge	Demands and relies on empirical evidence [1]	Based on observations of the natural world [3]	Engineers utilize knowledge from science and engineering [and a] knowledge base of its own. [5.3]
Knowledge Production	Knowledge production includes common features, ... [but] no single method [2]	...is empirically based and involves the invention of explanations and this requires a great deal of creativity. [4]	The methods used [for knowledge production] are extremely similar [to science] ...[however] produced knowledge is only a means to be used for the purposes of designing technologies [5.4]
Change	Scientific knowledge is tentative [3]	Scientific knowledge is subject to change [7]	<i>Not explicitly in the NOE list of nine.</i>
Use of mathematics	Laws are patterns in nature [4]	Laws are descriptions of relationships of observable phenomena [2]	Engineers solve problems [5.5]
Use of theory to explain phenomena	Theories are explanations for why such laws hold [4]	Theories are inferred explanations for observable phenomena [2]	Theories are used by engineers for practical purposes of design [5.3]
Creativity	Science is highly creative endeavor [5]	Involves imagination and creativity [4]	Engineers solve problems (5.5) using a design process [5.6]
Impact of subjective and cultural norms	Contains a subjective component [6]. There are historical, cultural, and social influences on science [7]	Scientific knowledge is partially subjective and socially and culturally embedded [6]	Engineering designs are affected by the cultural norms of society. [5.7]
Core characteristic	Science and technology impact each other. ...Pure science aims at basic understanding of the nature of reality [8]		Distinguishing characteristic is its concern with the practical design of technologies. [5.1]
	Science methods do not answer all questions [9]		Engineers solve problems [5.5] from the scope of engineering.
			Engineers use specifications, constraints and [design] goals. [5.2]
* [] number from the article			

References

- Chapter 130 Texas Essential Knowledge and Skills for Career and Technical Education. Subchapter O. Science, Technology Engineering and Mathematics. §130.142. Engineering Design and Problem Solving.
<http://ritter.tea.state.tx.us/rules/tac/chapter130/ch130o.html>
- Clough, M.P. Learners' Responses to the Demands of Conceptual Change: Considerations for Effective Nature of Science Instruction. *Science Education* 15, 463–494 (2006).
<https://doi.org/10.1007/s11191-005-4846-7>
- “Engineering Design Process.” TeachEngineering.org.
CU Engineering, University of Colorado Boulder
<https://www.teachengineering.org/k12engineering/designprocess>
- Koen, B. V. (2003). *Discussion of the method: Conducting the engineer's approach to problem solving*. Oxford, UK: Oxford University Press.
- Lederman, N.G., and J.S. Lederman. Revising Instruction to Teach Nature of Science. *The Science Teacher* 71(9):36-39. (2004).
<https://www.nsta.org/publications/news/story.aspx?id=49932>
- Pleasant, J, Olson, JK. What is engineering? Elaborating the nature of engineering for K-12 education. *Science Education*. 2019; 103: 145–166.
<https://doi.org/10.1002/sce.21483>.
- “Tips and strategies for teaching the nature and process of science.” Understanding Science. University of California Museum of Paleontology.
<https://undsci.berkeley.edu/teaching/tips.php>