Presenter Notes for K-12 VA SOL Institutes

This document contains the talking points to the Nature of Science workshop given at the Fall 2010 K-12 VA Science SOL Institutes around the state of Virginia. The PowerPoint and other presentation materials that accompany these talking points can be accessed at http://mason.gmu.edu/~lpetersn/nos/index.html). ALL the materials should be used together for maximum impact.

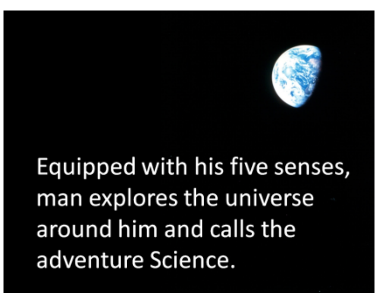
Please refer to the VA State Nature of Science Workshop PLANNER for slide-by-slide particulars for presenting this workshop.

Prior to starting this PPT, participants should have completed an Anticipation-Reaction Guide and discussed their ideas with a shoulder partner.

They should have also received (1) a blank sheet of paper or several post-it notes for note taking and (2) pencils and/or pens

OPENING SLIDE

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide.



SLIDE 2

- Equipped with his five senses, man explores the universe around him and calls the adventure Science.

Presenter – please read the information below to participants to set the purpose for the NOS workshop.

However, you do not need to read the sources for the information or quotes as that will break the flow of the narrative.

INTRODUCTION -*To Accompany Slide 2*
The scientific enterprise is organized around several tenets which comprise what is called "the nature of science" (NOS). These tenets serve to standardize and guide scientific inquiry around the globe. Understanding the nature of science helps to promote scientific literacy.

A scientifically literate person has the knowledge and habits of mind needed to make informed personal decisions and contribute to society. If we are to produce scientifically literate citizens who are fully able to “take part in our country's political discourse” (Hazen & Trefil, 1991, p. xi) and compete in a competitive global economy we must explicitly teach the nature of science.

The recent changes in the Virginia Science Standards of Learning provide an opportunity for science educators to thoughtfully incorporate a discussion of the nature of science into the work they currently do with their students. In this way students will come to understand that that nature of science is much more than mere “experimental design” as has often been presented in the past.

The purpose of this presentation is to (1) explain the seven key concepts related to the nature of science and (2) to provide a model to help students “make connections between the components of the nature of science and their investigations and the greater body of scientific knowledge and research” (VA SOL Curriculum Framework, Physical Science, p. 4).

The quote comes from Edwin Powell Hubble, *The Nature of Science*, 1954; the graphic comes from NASA

INSTRUCTIONS FOR PARTICIPANTS -*To Accompany Slide 2*

Presenter: Please read the information below to participants. There is no accompanying PPT slide.

In this interactive workshop, you will view a PowerPoint presentation while listening to information which will serve to build your background understanding of the seven main components of the Nature of Science (NOS).

You have been provided with a sheet of paper on which to take some notes as you are listening.

After viewing the PPT presentation you will use your notes by working independently or in pairs to fill in a graphic organizer with a drawing and a catchy phrase that captures your understanding of each of the seven NOS components.

After your graphic is completed you will work collaboratively in groups to check your understanding by analyzing eight science-related scenarios and determine which NOS components apply.

Groups will share their analysis with other groups to process their learning and come to consensus.

Finally, you will use the back of your graphic which contains Discussion Questions to plan how you will use classroom hands-on science investigations to help your students understand NOS.

To recap, you will -
1. Listen and take notes
2. Create a picture and catchy phrase for each NOS component
3. Analyze NOS scenarios
4. Plan how you will use NOS with students

SLIDE 3

The Natural World is Understandable

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 4

The Natural World is Understandable

- The natural world is understandable through the careful collection and critical analysis of empirical evidence.
- Every discipline in modern science has derived its principles and paradigms through this process.

Presenter: Slowly read the information below. You do not need to read the sources for the information or quotes as that will break the narrative. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.

Perhaps the most foundational component of the nature of science is the universal belief that the natural world is understandable through the careful collection and critical analysis of empirical evidence (American Association for the Advancement of Science, 1993).

Every discipline in modern science has derived its principles and paradigms through this process.

Knowing that scientific conclusions are formed in this manner, allows the public "to react thoughtfully to scientific claims and [makes them] less likely to reject them out of hand or accept them uncritically" (AAAS, 1993).

Most importantly, this way of thinking precludes the actions of supernatural beings as causative agents of natural phenomena and helps to focus research on testable questions.

[clarification note for presenters from Linda P: this is meant to say that the motion of a ball rolling down a ramp is governed by natural laws rather than the actions of ghosts, fairies, or sprites].

"Science is a way of knowing about the natural world. It is limited to explaining the natural world through natural causes." (AAAS, 1993). For further reference presenters may find the following site helpful.
http://www.project2061.org/publications/sfaa/online/chap1.htm?txtRef=&txtURIOld=%2Ftools%2Fsfaaol%2Fchap1.htm

SLIDE 5 ***Example/Illustration to accompany the Natural World is Understandable***

*Presenter: **This is a hidden slide**. Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

Each year billions of dollars are spent by business, political, and other interests to find out what people believe to be true about a given topic. Rather than asking what people believe to be true, it might be more informative to ask ***how*** they arrived at this decision and ***what*** criteria were involved.

In fact, people use a variety of “truth filters” (Toffler, 2006, p. 123) to guide them in making decisions in their personal and professional lives. For example, when deciding which movie to see or book to purchase, a person might use a “consensus” filter.

“Authority” is another often used “truth filter” and relates to the importance bestowed upon the opinions and beliefs of influential people. Whether earned or not - we tend to place more weight on the viewpoints of people and institutions which represent authority. National newscasters, successful entrepreneurs, political leaders, respected print and news media, and movie stars are just a few of the authorities people currently look to for truth.

SLIDE 6 ***Example/Illustration (cont'd) to accompany the Natural World is Understandable***

*Presenter: **This is also a hidden slide**. Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner*

Truth can also be inherited. If a fact, story, or opinion has been around for a long time then it is more likely to be believed because it has withstood the rigors of time. “For most of us today it is hard to appreciate just how important inherited truth was before the Enlightenment and the industrial revolution” (Toffler, 2006, p. 126).

This brings us to science as a “truth filter. “Of all these various criteria [for determining truth], science is probably the one we rely on least in our daily lives yet … none in recent centuries has had a greater impact on [societal] wealth” (Toffler, 2006, p. 126).

“The invention of scientific thinking [has been] … a powerful meta-tool for probing the unknown and … for spurring technological change and economic progress” (Toffler, 2006, 127).

By its very nature, science is a unique truth filter. It is predicated upon the premise that the natural world is understandable and that the universe is “knowable” and is governed by natural factors that can be discerned through observation or experimentation.

The major difference between science and other "truth filters" is that rather than relying on external sources for validation such as group consensus, authority, or durability over time, science relies on internal processes of validation through data collection, objective analysis, and evaluation.

SLIDE 7

Science Demands Evidence

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS...

SLIDE 8

Science Demands Evidence

- Scientific knowledge involves a combination of observations and inferences.
- Scientists use data to make inferences and formulate explanations of phenomena.
- Data can be obtained through experimentation or observation.

Presenters: Please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

Scientists use data to make inferences and formulate explanations about phenomena.

Scientists use the data they collect to make inferences and formulate mental constructs around which disciplines are organized. These data can be obtained through observation or experimentation. Both types of data are equally useful and valuable in the scientific endeavor.

For example, data about the efficacy of a new cancer treatment drug would require a formal **experiment** protocol using a control and levels of the independent variable, but a modern astronomer would use **observations** collected from space telescopes to look for patterns from which to formulate inferences and conclusions.

Unfortunately, there is a mistaken belief that all scientific knowledge has been experimentally derived Chen (2006). It is, therefore, important to point out that constructs such as biological classification, plate tectonics, or the current model of the atom were not experimentally derived. These represent "theoretical rather than experimentally derived constructs" (Chen, 2006).

One can assume that students hold similar misconceptions that must be addressed if they are to accurately understand the nature of science. Thus, it's important to call to students' attention the fact that the data they collect through observation or experimentation are equally useful in helping them formulate scientific conclusions.

SLIDE 9

The myth of the scientific method

- Scientists apply various methods in doing research.
- There is no universally accepted scientific method agreed upon by the scientific community.
- Science does demand that evidence be empirically collected and analyzed.

Presenters please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

It often comes as a surprise to science teachers (and others) when they learn that, contrary to what is presented in most science textbooks, there is no universally accepted scientific method agreed upon by the scientific community.

In reality, scientists apply various methods in doing research (Chen, 2006; Hanuscin et al., 2006) and no clear and consistent definition concerning what constitutes a scientific investigation exists.

Although no set "scientific method" exists, science does demand that evidence (observational or experimental) be empirically collected and analyzed (National Science Teachers Association, 2000).

While controlled experiments can offer compelling evidence to support a hypothesis or theory, it is a myth to believe that the most credible scientific theories are supported by controlled experiments (Chiapetta & Koballa, 2004).

SLIDE 10

Example/Illustration: Spontaneous Generation

Presenter: This is a hidden slide. Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.

We may laugh at the notion now but, before microscopes were invented people generally believed that life sprang from inanimate matter - that life could spontaneously be generated from inanimate matter.

This view had first been introduced by Aristotle who said that some animals could grow spontaneously and that such animals need not come from others of their own kind. Earlier philosophers believed that the earliest men must have sprung up, fully formed, from the soil in adult form because they never could have survived otherwise.

Before we laugh too hard at these ideas we should note that many scientists – even up to the 1800's – held these same views. In fact, recipe books for making animals were written and one such recipe for making a scorpion called for basil to be layered between two bricks and then placed in the sunlight.

Real science, however, relies on empirical evidence and replicable results. Thankfully, the myth of spontaneous generation was finally put to rest in 1859 by Louis Pasteur.

SLIDE 11

Science is a Blend of Logic and Imagination

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 12

Science is a Blend of Logic and Imagination

- ❖ Scientific knowledge involves human imagination, creativity, and inference.
- ❖ Much of the scientific enterprise is governed by the ability and creativity of scientists to visualize different situations and predict outcomes.

Presenters: Please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

Albert Einstein once said “logic will get you from A to B. Imagination will take you everywhere.”

Scientific knowledge involves human imagination, creativity, and inference (Sterling, Greene, & Lewis, 2002).

Scientists and children alike use science process skills to gather data about the natural world. Whereas children use their five senses, scientists use more sophisticated instruments (Llewellyn, 2002). To determine which data constitutes evidence, and what that evidence means, are not entirely based upon logic, however.

Much of the scientific enterprise is governed by the ability and creativity of scientists to visualize different situations and predict outcomes. Einstein’s “thought experiments” about Special Relativity and Schrodinger’s “cat” are two examples of how visualization and creativity can be used to help in formulating and conveying science concepts.

SLIDE 13

Presenter: ***This is a hidden slide.*** *Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

Example/Illustration: **The Structure of Benzene**

Since its discovery in 1825, the molecule benzene was known to contain carbon atoms and hydrogen atoms. However, their exact arrangement was a mystery for decades and eluded the scrutiny of many scientists.

About 40 years after its discovery, a young chemist by the name of August Kekule devised the hexagonal structure of the now familiar molecule. According to Kekule, the idea came to him in a dream during an afternoon nap. In his dream, the atoms were moving about in front of him in "long rows, sometimes more closely fitted together, all twining and twisting in snake-like motion."

He was amazed to see that "one of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes." Thus the ring-like structure of benzene was discovered during a chemist's afternoon nap.

SLIDE 14

Scientific Knowledge is Durable

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 15

Scientific Knowledge is Durable

- Scientific ideas are continually tested.

- Ideas that are able to withstand the scrutiny of the scientific community form the foundations of our current understandings of the natural world and how it functions.

Those scientific ideas and explanations that are able to withstand the scrutiny of the scientific community form the backbone of our current understandings of the natural world and how it functions (Kuhn, 1996).

For example, our understanding of planetary motion is derived from the work of Ptolemy, Copernicus, Galileo, and Newton - each contributing a bit of information to the planetary puzzle.

Sharing scientific ideas and explanations is a critical component of the scientific enterprise. This practice not only disseminates new information, it also ensures that explanations will be exposed to the scrutiny of others.

Continually tested in this way, scientific ideas are revised when new, compelling data become available (AAAS, 1993; Sterling, Greene, & Lewis, 2002).

SLIDE 16

Theories and laws.

- Theories and laws are two different types of knowledge used by scientists to describe natural phenomena. They are equal in terms of scientific validity.
- Theories are generally used to explain complex pattern or phenomenon.
- Laws use mathematical formulas to show relationships and make predictions about the natural world.

Presenters; Please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

A major misconception exists with respect to scientific theories and laws. Theories and laws are two different types of knowledge used by scientists to describe natural phenomena and, within the scientific community, slight distinction is made between the two.

Both theories and laws have substantial supporting evidence and it is false to believe that "hypotheses become theories and theories become laws" (Colburn, 2008).

Theories combine many facts, concepts, and laws to form scientific understandings around which disciplines are organized. A good example of this is atomic theory which includes the law of conversation of mass, Avogadro's Law, Boyle's Law, Periodic Law, etc." (Chen, 2006; Chiapetta & Koballa, 2004, Hanuscin et al., 2006). From this example it is clear that the theory provides the framework for more detailed explanations of phenomena which are represented by laws.

Therefore, "we should not think of scientific theories as ideas built on shaky facts and flimsy evidence because many of the major theories of science have held up to considerable scrutiny and have shown to be durable" over time (Chiapetta & Koballa, 2004).

SLIDE 17 ***Scientific Ideas Are Subject to Change***

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 18

Scientific Ideas are subject to Change

- The drive to elucidate the finer points of a commonly held scientific paradigm is what "normal science" is all about.
- The sensitive instruments developed to elucidate the finer points of a paradigm help to uncover ambiguities in the expected data. These may lead to changes in our understanding.
- Although subject to gradual refinement, "the main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually."

Presenters: Please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

Normal science is predicated upon a system of collectively held beliefs (called paradigms) about the natural world and how it works. The drive to examine and explain the finer points of a paradigm is what drives "normal science" (Kuhn, 1996).

To this end, new instruments are developed for the purpose of collecting extremely precise measurements in order to "match fact with theory" (Kuhn, 1996) related to a paradigm.

Paradoxically, the sensitive instruments developed to explain these finer points help to uncover ambiguities in the expected data.

Only by having an idea of what to expect are scientists able to recognize when it does not occur. New paradigms often arise from researchers who are able to view discrepant data with fresh eyes.

Science strives to continually test and refine our understanding of the natural world. Although subject to gradual refinement, "the main body of scientific knowledge is very stable and grows by being gradually being corrected" (AAAS, 1993) over time.

SLIDE 19

Example/Illustration: Theory of Plate Tectonics

*Presenter: **This is a hidden slide.** Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

In 1912 Alfred Wegener noticed that the world's continents seemed to fit together like a giant jigsaw puzzle and proposed that the continents were once compressed into a single protocontinent which he called Pangaea. According to Wegener, the continents had drifted apart over time into their current locations.

A strength of Wegener's theory was that it could explain the formation of mountain ranges at the leading edge (Andes) and interior of continents (Himalayas). It also explained the similarities among fossilized plants and animals from the same time period in South America and Africa and North America and Europe.

However, a major drawback to his theory was that it offered no plausible mechanism to explain how or why the continents moved in the first place. Wegener suggested the movement could be caused by centrifugal force as the Earth spun on its axis or was caused by the pull of the Sun and the moon.

All of these ideas were rejected and his hypothesis fell out of favor with the scientific community.

SLIDE 20

Example/Illustration: Plate Tectonics (cont'd)

*Presenter: **This is a hidden slide.** Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

However, in 1929, Arthur Holmes proposed that continental drift was caused by thermal convection currents in the Earth's mantle. He explained that these convection currents acted as giant conveyor belt moving continents from one place on the Earth to another.

Holmes' idea was largely ignored until the 1960's when marine geologists reported the existence of deep sea trenches and mid-ocean ridges on the ocean floor – all perfectly explained by Wegener and Holmes' ideas.

Today, the theory of plate tectonics is derived from Wegener's "continental drift" and is universally accepted to explain the motion of the Earth's crust. Strangely enough, some data do support the effects of gravitational pull of the Sun and moon as well as Earth's rotation as secondary forces at work in continental movement. Thus, the example provided by the work of Alfred Wegener demonstrates that scientific knowledge is durable yet subject to refinement as new instrumentation and data become available.

SLIDE 21 ***Scientists Attempt to Avoid Bias***

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 22

Scientists Try to Identify and Avoid Bias

- Since scientists within the same field tend to share common methodologies and views, their objectivity must continually be challenged to ensure validity of results.
- Within the scientific community there are ethical practices which guarantee that scientific endeavors are carried out under universally accepted standards around the world.

Presenters please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

Within the scientific community there are ethical practices, such as the accurate and truthful reporting of data and peer and public review, which guarantee that scientific endeavors are carried out under universally accepted standards around the world (National Research Council, 1996)

The world's public trusts and believes in the results of scientific research only because of the professional rigor imposed by the community in an effort to identify and avoid personal bias (Balzer, 2010).

Because scientists within the same field tend to share common methodologies and views (Kuhn, 1996), their objectivity must continually be challenged to ensure validity of results (AAAS, 1993).
Although scientists strive for objectivity in their data analysis they nonetheless rely on a healthy skepticism within the scientific community to replicate and verify their results.

The scientific community self-regulates and will not tolerate those who falsify or misrepresent their data. In addition to ensuring professional credibility, such scrutiny helps to protect the public from the impact of poor science.

SLIDE 23 ***Example/Illustration:*** The Cost of Falsifying Data

Presenter: ***This is a hidden slide.*** *Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

One recent case of scientific misconduct occurred in 2009 when the UCLA Office of Research Integrity reported that one of its cancer researchers falsified data in two scientific journal articles and had lied about experimental procedures and findings in NIH and other federal grant applications.

Alerted to the misconduct by a former assistant in the researcher's lab, the Office of Research Integrity initiated a probe which ultimately found the researcher guilty of misconduct.

As a result the researcher was ultimately asked to leave the faculty post and has since resumed work as an oncologist working with patients

The details of cases of scientific misconduct are less important than the swift and sure condemnation and ostracism of the perpetrator(s) by the scientific community.

SLIDE 24 ***Science is a Complex Social Activity***

Presenter: Pause here for about 10 seconds to let the words and graphic sink in. Proceed to the next slide where you will read the explanation of this component of NOS.

SLIDE 25

Science is a Complex Social Activity

- Scientific knowledge is tied to social and cultural factors.
- Scientific research is dependent upon financial support, and this can influence - both positively and negatively - which areas are investigated.

Presenters: Please slowly read the information below. Provide sources of the information if needed. See the step-by-step instructions for presenters in the VA State NOS Workshop Planner

Scientific research can take place in a laboratory or out in the "real" world in deep sea submersibles, space shuttles, field observations, etc. The one critical factor linking them all is that the data gathered will ultimately be shared with others for their review and critique.

Scientific research is dependent upon financial support and this can sometimes make it difficult for scientists to carry out the research that most interests them (AAAS, 1993) because funding can be influenced by religious, commercial, or political agendas.

There are also numerous examples where scientific research was scorned by the community at the time, only to be validated at a later date. Trying to convince a skeptical audience that your observations have led to new discoveries is often a difficult and complex social activity in and of itself.

For this reason it is important to recognize that scientific knowledge is tied to social and cultural factors (Sterling, Greene, & Lewis, 2002).

The dissemination of scientific findings is critical to the nature of science. Scientists share their findings with their peers through a wide variety of media such as print, electronic, and even video.

While these communications serve to inform others' of the work being done in a particular field, they also help to expose ideas to the scrutiny and criticism of the general science community. In this way, results are "peer reviewed" and challenged for its authenticity.

SLIDE 26 ***Example/Illustration:***

*Presenter: **This is a hidden slide.** Please read this information slowly to participants in a story telling fashion. Also, see the step-by-step instructions for presenters in the VA State NOS Workshop Planner.*

The history of Stem cell research provides an example of how scientific research has been influenced by social and political forces.

Stem cell research first began in the mid-1800's. By the early 1920's stem cells were being used in bone marrow transplants to produce red blood cells. However, in 1973, Congress stopped funding for stem cell research using human embryos. .

Fifteen years later, an NIH panel of scientists voted 19 to 2 in favor of government funding for stem cell research. The Stem cell research ping-pong-ball continued with the Congress voting in 1990 to allow funding of embryonic stem cell research only to reverse itself in 1995.

While President Clinton lifted the ban on Stem cell research in 2000, President Bush confined such research to include only existing lines of Stem cells.

Wanting to stay on a par with other researchers across the world, Californians in 1994 created a 3 billion dollar fund to promote stem cell research within the state.

Fearing that the U.S. was lagging other countries in the field of Stem cell research, Congress in 2004 asked President Bush to review his policy on stem cell research. However, no change occurred until 2009 when President Obama lifted the ban on using federal taxpayer dollars to fund stem cell research.

SLIDE 27 THE NATURE OF SCIENCE (SUMMARY SLIDE)

To summarize…

The natural world is understandable
Science demands evidence
Science is a blend of logic and imagination
Scientific knowledge is durable
Scientific knowledge is subject to change
Scientists attempt to identify and avoid bias
Science is a complex social activity

Presenter: Please see the VA State Nature of Science Workshop PLANNER for particulars. Participants will now color in the NOS graphic organizer and share their ideas with others at their table. Please pass out the graphic organizer and colored pencils and provide time for participants to *illustrate the graphic and write a catchy phrase for each of the components of NOS. You may want to leave this slide up for participants to reference if needed.*

Subsequently, pairs or groups will apply their understanding of NOS to a set of scenarios.

Finally, participants will use the NOS Discussion Questions sheet (on the back of the Graphic Organizer) to plan how to promote discussion of NOS among students using their hands on activities.

References

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