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Teaching the Nature of Science

Abstract

Contained in this paper are activities designed to teach the nature of science through the topic of evolution in a unit plan. The activities are designed for students above the fifth grade level and promote learning about evolution as well as the basic tenants of science. Science is a process and framework for how we consider the world, it is more than a body of knowledge. These activities are designed to teach students how scientists examine the world around them and reconcile background knowledge with collected data to make meaningful, critical interpretations about the world. By using the specific content topic of evolution, students will gain an understanding that it is through this process that scientists have proven and continue to support the theory of evolution.

Rationale

The study of science is more than following the steps of the scientific method from observing to concluding, and it is because of this and many other misconceptions that science teachers have the duty and responsibility to teach the nature of science. Science, through the process of inquiry, is a framework for how we study and examine the world. Here, inquiry is an integral part of how scientific knowledge is acquired and the process by which theories and laws are created (Bybee et al., 2008). Students need to have explicit exposure to the process of inquiry as well as the idea that learning in science is "play." This idea of play has been one which is related to science before through the idea that as children, we come to know and understand the world through the process of play, and scientists who are learning about the world employ the same tenants of the play process, or as they call it, experimentation, to come to understanding.

Furthermore, one of the central themes to science is the theory of Evolution. Although called a theory, science teachers have the responsibility to teach students that evolution is the accepted underlying theory for all biological sciences. This will allow students to more successfully engage in science as a body of knowledge of all levels of interactions. Inquiry is also important in this process because through this process, students will be able to understand their surroundings are part of a long history of changes (National Academy of Science, 1998).

Students can apply methods of inquiry and observation about their world as a skill beyond the content of science, where scientific thinking becomes a framework for how they view, process, and problem solve in the world.

But teaching evolution in the classroom through the process of inquiry is not possible without science content. The content of science further elucidates the theory of evolution as a central fixture for how we construct scientific knowledge. Teachers have a responsibility to demonstrate to their students through science education that certain viewpoints fall under the realm of science while others may not. Science concerns itself with natural methods and explanations and precludes supernatural explanation in the production of scientific knowledge (NSTA Position Statement, 2000).

The nature of science can be reasonably defined as the idea that there are multiple ways to create scientific knowledge and science deals with natural patterns and explanations. This tenant also acknowledges that there is a tentative nature to science, as evidences are accepted to challenge and inform scientific theory over time. Historically science has shifted and changed as new information is continually evaluated to inform scientific practice and theory because testing of scientific ideas means trying to disprove those ideas instead of prove them. When knowledge survives repeated testing, it is strengthened. Additionally, it is the nature of all knowledge to contain bias, but the rule of science are geared to minimize biases. Students will be able to understand through this unit on evolution that scientific knowledge is empirical in nature, requires background information, creativity, and flexibility to interpret and inform scientific practice.

Established Goals:

Students will be able to understand and describe that there are multiple ways to create scientific knowledge, that scientific knowledge is tentative, changing, and creative based on empirical evidence. Students will be able to clarify that rules of knowledge of science differ than knowledge in other domains. Students will learn to value the highly tested evidences of evolution as a scientific framework for understanding the world around them.

Understandings:

Students will understand and know that...

1. The theory of evolution has been rigorously tested and is consistent with all current information.
2. Scientific inquiry involves creativity, background information, collaboration, and flexibility.

3. Science is tentative and can changing over time based on evidence and new information.
4. Objectively there are specific characteristics of scientific knowledge and evolution as a scientific theory and be able to discriminate between interpretations which are included in science and interpretations outside of the realm of science.

Unit Activities

Activity 1: Forming Hypothesis Which are Subject to Tests

A closed box is shown to the class. It can be seen that 3 wires run through the box lengthwise and 3 more run through it widthwise, creating a grid of 6 crossed wires. The class is told that there is a metal washer somewhere on one or two of the wires inside the box. The challenge is to propose a series of "tests" (pulling out the wires, one at a time, listening for the washer to drop) in such a way that the washer's location can be ascertained. (Adapted from Indiana University ENSI, 1999).

i. Students will formulate a number of hypotheses and test their predictions.
ii. Students will recognize why scientific knowledge is tentative and uncertain.
iii. Students will use this exercise as an illustration of uncertainty in science.

Activity 2: The Formulation of Explanations: An Invitation to Inquiry on Natural Selection

This activity uses the concept of natural selection to introduce the idea of formulating and testing a scientific hypothesis. Through a focused discussion approach, the teacher provides information and allows students time to think, interact with peers, and propose explanations for observations described by the teacher. The teacher then provides more information, and the students continue their discussion based on the new information. This activity will help students in grades 5 through 8 develop abilities related to scientific inquiry and formulate understandings about the nature of science. (Adapted from the National Academy of Science, 1998)

i. Students will understand that, as new information becomes available, theories and the body of science knowledge changes.
ii. Students will be able to identify and apply the process of natural selection to predictions about pesticide resistance.
iii. Students will be able to use background information and problem solving to predict the mechanism of pesticide resistance.

Activity 3: Natural Selection: Best Beak

Students will model natural selection through the collection of 'seeds' with different 'beaks.' Students will be split into groups and each group will have a different type of beak (spoons, chopsticks, forks, etc.). Each group member will collect seeds (different types of beans) from one of several habitats (each has different concentrations of beans). An individual survives a generation only if he or she collects the allotted amount of beans per time frame. The last beak standing is the fittest individual. Students will write up conclusions in a lab report. (Adapted from the National Academy of Science, 1998).

i. Students will be able to explore the process of evolution through the use of inquiry elements such as creativity and problem solving in order to survive the most generations.
ii. Students will use apply natural selection as a tenet of evolution to explain the development of beak types in birds.
iii. Students will view the development of beaks in birds as a tangible example of evolution.

Activity 4: Evolution vs. Intelligent design

Students working in small groups will be given a series of cartoons regarding evolution and intelligent design and asked to discuss the influence of religion and politics on science. Students will be asked to draft a definition of science and decide which tenets of the previous discussion fit into the drafted definition. As a class we will draft a definition of science together and choose the tenets of the evolution vs. intelligent design cartoon are described by the word science. (Adapted from an assignment for ED 398).

i. Students will be able to draft their own definition of science.
ii. Students will be able to explore aspects of the evolution debate and decide what is and is not science.
iii. Students will discriminate between objective observations and interpretations.
iv. Students will confront evolution as a scientific concept.

Activity 5: Web Quest

Students will complete the webquest by working in teams to gather evidence from different fields regarding evolution. After completion of students will discuss the validity of evolution as a theory. (http://www.pbs.org/wgbh/evolution/educators/lessons/lesson3/act2.html)

i. Students will be able to understand that the theory of evolution has been rigorously tested and is consistent with all current information.

Activity 6: Homologous Structures

Students will perform guided inquiry by exploring the bone structure of vertebrates. Students will research the bone structure of different vertebrates (include at least 1 winged

vertebrate) and come up with a testable hypothesis supporting bone strucutre as evidence for evolution.

i. Students will explore homologous structures as evidence of evolutionary history.
ii. Students will gain knowledge of the creativity and background knowledge that is necessary to construct hypotheses and theories in science.

Activity 7: Create your own Phylogenetic Tree

Students will create their own phylogentic trees based on DNA sequences using a free software. Students will choose 10 organisms and compare assess the relatedness of the organisms. Students will then predict the relatedness of 10 different organisms.

i. Students will be able to read a phylogenetic tree.
ii. Students will use genetic evidence to support the theory of evolution through the inquiry process.

Assessment

In addition to the assessments already structured within the unit plan, there will be space for students to conduct an independent project presented in a poster session exploring a topic in evolution of their choice. The intent of the project would be to allow for student driven learning to follow up on a particular topic presented in the overall unit which would reinforce their learning. For example, students could choose to conduct an investigation into the life of Charles Darwin, the mutation rate of bacteria and viruses like the common cold, etc.

Literature Cited

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