In the Footsteps of Newton
Hanover College

Lesson Plans - Secondary Science and Math

Grade Levels: 9-12

The following three lessons are appropriate for either the secondary science or math classroom. Lessons can be used independently or together as a unit.

Lesson 1 Newton's life

Lesson 2 The role of evidence: What is Science?

Lesson 3 Searching for Patterns

by Professor Deborah Hanson
Associate Professor of Education
Hanover College

Lesson 1 Newton's life

Objectives:

Create a timeline of the life of Isaac Newton and his accomplishments.

Analyze the impact of Newton's discoveries in math and science today

Observe and document how Newton generated his data and conclusions

Procedure (in a 5E format):

Engage: Have students view the documentary, In the Footsteps of Newton.
Students should observe and record various aspects of Newton's life and accomplishments.

Explore: Students should work together in groups to construct a timeline of the various aspects of Newton's work. Additional research may be needed.

Explain: Back together as a group the students should share their timeline.
Students should share why they thought each aspect was important to place on the timeline.

Elaborate/Evaluate: Students, still working in groups, should select one of Newton's major contributions to explore further.

How did Newton make this discovery or contribution to this particular field of science or math?
How did this discovery impact the further study of this area?

a. Reflecting telescope (mirrors to clarify image, prevent aberrations of lenses, greater magnification)

b. Nature of Light (white light into spectrum of colors)

c. Universal Law of Gravity (added relationship of gravity and mass)

d. Calculus

e. Motion (three laws of inertia, acceleration and action/reaction still form basic principles)

Students can present their findings in a variety of formats. Explicit follow-up may be needed to pull out key Nature of Science (NOS) aspects. Newton was constantly observing the natural world around him, asking questions and recording his observations or results of his experiments in journals. This evidence was important as he was somewhat reluctant to publish his ideas without substantial evidence. With this data, Newton had to use his creativity and imagination to search for patterns to develop mathematical formulas and/or discoveries.

References:

- Tyson, Peter. Newton's Legacy. NOVA website. http://www.pbs.org/wgbh/nova/physics/newton-legacy.html
- Isaac Newton, by Michael Fowler. University of Virginia. http://galileoandeinstein.physics.virginia.edu/lectures/newton.html

---

Lesson 2 The role of evidence: What is Science?

Objectives:

Explain how science differs from other ways of knowing and pseudoscience explain how nature of science aspects were illustrated in an activity.

Materials: Closed boxes with one or more objects inside hidden from view.
(Author uses a pencil box covered with duct tape with gobstoppers candy inside.
Original source for this activity is unknown.)

Engage: What do scientists do?
Have students brainstorm terms they know (or think they know) about a scientist and their work.
Record students' responses.

Explore:

1. Give each student or pair of students a mystery box. It is important that the boxes are identical with the same hidden object.
2. Students should make and record observations of the box. Remind students that observations are based on the five senses and only those things that they can actually experience may be written down.
3. Have the students share what they think is inside the box. Generate a class list of the various predictions. Ask students how they developed their prediction. How do they know?
4. After hearing the other predictions, have the students make more observations about their box. Ask the students if their original prediction has changed and, if so, why.

Explain: What you just did is like a scientist.

a. You made observations based on your senses and developed inferences/predictions based on your observations (variety of methods).
b. Your observations became your evidence as they guided you to your final answer (role of evidence).
c. You creatively synthesized your evidence to formulate your prediction (role of creativity).
d. You were also influenced by your previous knowledge of various objects and the objects you were familiar from your own experiences and culture (socio-cultural infliuences).
e. You then shared and collaborated with other scientists and based on new evidence or a different view of existing evidence, you may have changed your views (tentative).

Teachers note: It is recommended NOT to reveal what is in the box. This represents science as often we are guided only by inferences generated by evidence, without actually observing or testing the true object, like in many topics in astronomy and geology. It is important to ask and emphasize the question-how do they know-and the role of evidence in determining their response.

Elaborate: What similarities do you see in this activity and with Newton's work? What differences? Did you see examples in Newton's life that were not scientific or based on evidence?

Background information: Newton was a very complicated man. Although he advanced the study of math and science in many ways, many aspects of Newton's life and journals were not scientifically based. For instance, Newton documented many experiments in alchemy, trying to find the philosopher's stone, and his faith. Students may question this, and this discussion may provide an opportunity to present what science is and what it can or cannot do-another aspect of the nature of science. Science is one way of knowing; it is based on evidence. It is what separates it from other ways of knowing, such as faith. One is not better than the other; they are simply different ways of viewing the world. One is not exclusive of the other as many scientists also have a strong faith.

It is also important to realize the socio-cultural influence at the time. Although scientists try to remain objective, they are human and cannot block out the influence of their prior knowledge, their culture and their experiences. Newton was part of a new scientific paradigm. Scientific reasoning and

evidence were beginning to emerge as a new way to interpret the natural patterns that existed. Earlier scientists such as Galileo and Kepler, began to challenge the existing paradigm, centered around the church, and replaced the ancient ways of knowing with a radically different view promoted by scientific thinking and reasoning. In fact, Galileo lost his life as he was persecuted by the Catholic Church for challenging traditional views with his scientifically based heliocentric view of the solar system. Newton's work solidified many of ideas of this Scientific Revolution and led into the period of Enlightenment, a time

Teaching NOS resources: There are many excellent resources for teaching Nature of Science.

Many different Nature of Science activities: www.indiana.edu/~ensiweb/natsc.fs.html

Lederman, N.G., & Abd-El-Khalick, F. (1998). Avoiding De-Natured Science: Activities That Promote Understandings of the Nature of Science. In W.F. McComas (Ed), The nature of science in science education: Rationales and strategies, (83-126). Dordrecht: Kluwer.

Lesson 3 Searching for Patterns

Rationale: Newton worked with numerous data sets to search for patterns within each data set. In the process, he used creativity to see patterns emerge from seeming random numbers generated by his experiments and observations. His unique ability to search for trends, patterns and cycles within data, helped provide data and mathematical reasoning to events such as the revolutions of the planets in the solar system and the foundations of calculus. This idea can be demonstrated in one of the published lessons from the NCTM's Illuminations website, Determining Functions by using regression: what is the function? (grades 9-12)

Objective: To analyze a data set for different patterns that exist within the data
to compare this activity to the work of a real scientist/mathematician.

Lesson Overview: In this lesson plan, students do four different experiments to yield data, then look to see how the numbers are related (various functions-linear, sinusoidal, cubic, power function and exponential decay).

Additional question: How did this activity model the work of Newton?
Newton did many experiments. He collected data in many ways and by analyzing the data, searched for patterns. His work developing this patterns and relationships lead to the development of the study of variables in a state of constant change-calculus.

Resources:

- Determining Functions by using regression: What is the function? Illuminations for grades 9-12. NCTM. http://illuminations.nctm.org/Lesson.aspx?id=2551

Connections to Math Standards

According to the Principles and Standards for School Mathematics by the National Council for the Teachers of Mathematics (2000), some of the goals for math instruction, in addition to the content standards, is the development of mathematical thinking and reasoning skills and problem solving skills. Students should gain insights to the nature and beauty of mathematics. The study of problem-solving and reasoning should help students develop sound deductive arguments, see that mathematics has powerful uses in modeling and predicting real-world phenomena, and help processes and skills that support the quantitative literacy of students. (NCTM, 2000, page 15).

Newton models these skills in his work. As one looks at Newton's discoveries, it is evident that Newton possessed a "mathematical disposition" as he sought to "analyze situations carefully in mathematical terms and to pose problems based on situations they see " (NCTM, 2000, page 52).

Connections to Science Standards

A key aspect of science education in the A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas (NRC, 2012), and the Next Generation Science Standards and Benchmarks (2012) is teaching the nature of science. The nature of science aspects serve as a foundational piece explaining how scientists do their work and how scientific information is generated. Yet, this concept is often misunderstood and often not taught but is key for developing scientific literacy. From the literature on teaching nature of science, and the NGSS, some basic ideas of the nature of science are appropriate for the K-12 classroom and should be explicitly taught:

a. Science is a way of knowing based on evidence.
b. Scientific investigations use a variety of methods, including observations.
c. Scientific knowledge is tentative, and may change with new evidence or the re-examination of existing evidence.
d. Science is a creative endeavor when designing new experiments or analyzing data.
e. Science is a human endeavor; although scientists strive for objectivity, subjectivity may be present arising from socio-cultural influences. (Lederman, 1992; McComas, 1998, NGSS, 2013, Appendix H).

This documentary provides insight to Newton and with explicit instruction can help students envision many of the nature of science aspects and science as a human endeavor.

Resources:

Lederman, N.G. (1992). Students' and teachers' conceptions of nature of science: A Review of the research. Journal of Research in Science Teaching, 29, 331-359.

McComas, W.F. (1998). The principal elements of nature of science: Dispelling the myths. In W.F. McComas (Ed), The nature of science in science education: Rationales and Strategies, (53-72). Drdrecht: Kluwer.