NOS Resource Cards by Rebecca Vieyra, Cary-Grove High School, used with permission.

Title: The Real Prize Inside: Learning about Science and Spectra from Cereal Boxes

Content Area:

- Aspects of Nature of Science
    - Observation versus Inference
- Knowledge of Inquiry
    - Explanations are developed from a combination of collected data and what is already known.

Source: Kustusch, M. B, Gaffney, J. D. H., & Beichner, R. (2009). The real prize inside: Learning about science and spectra from cereal boxes. *The Physics Teacher*, *47*, 451-453.

Target Grade / Course Level: 9-12 / Science (any science content area would be appropriate).

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

Idea: Student look for patterns in UPC barcodes that have been separated from their products using **observation**. Students make hypotheses about the meaning of the patterns via **inferences**, and then predict the products associated with various barcodes using **collected data** and **what is already known**.

Use:

This activity would most likely be appropriate at the outset of a science class. Students are split into small groups and given four UPC labels that have been separated from their product (the authors of the article use four different cereals, two of which are *Quaker* brand). Students are asked to find as many patterns as possible. After time for small group discussion, the instructor helps the entire class to synthesize their findings. The teacher explicitly describes the patterns seen from the UPC labels as **observation**. The groups then develop hypotheses about the meanings of the patterns. The instructor presents the small groups with the products attached to the UPC's that may disprove the old hypotheses and result in new hypotheses. The class' hypotheses then are revised. The instructor helps students to directly reflect on knowledge development from **collected data** and **what is already known** by asking them what would be required to disprove their hypotheses. Finally, the instructors gives the small groups unmarked UPC's, and asks students to develop predictions for the unmarked UPC's for the products to which they belong. The instructor explicitly describes the process of applying observed patterns to as-of-yet unobserved phenomena as **inference**.

Materials: The following materials are needed per small group of 3-5 students:

- UPC barcodes (either from various groupings of similar products or photocopied out of the journal article.)
- Right and left side codes for UPC (photocopied out of the journal article or found online).
- Whiteboards / place to display group information.

Modifications:

- The journal article uses particular brand cereals, but any brand could be used for these purposes. If food products are not available, UPC labels from textbooks could work just as well.
- For younger students, number or color patterns representing UPC labels could be used. A preliminary activity could be to simply decode the labels, and then look for patterns in the data.
- For the visually impaired, instead of decoding with numbers, the UPC labels could be translated into Braille.

Title: "Oops, I Did It Again: Errors in Measurement"

Content Area:
- Measurement and error
- Knowledge of Inquiry
    - All scientists performing the same procedure may not get the same results.

Source: Jones, M. G., Taylor, A. R., & Falvo, M. R. (2009). Chapter 3: Oops, I did it again: Errors in Measurement. Excerpt published in *NSTA Reports* (2009), 24.

Target Grade / Course Level: 5-8 / Physical Science

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

Idea: Students are asked to make basic measurements. After sharing their data with the class, students compare their data by reflecting on their collection procedures and possible sources of error. In all likelihood, students who **followed the same procedure may not get the same results.**

Use: Students are split into small groups of 3-5 students. The group is given one thermometer and simply asked to measure the temperature of the room and to report their data to the teacher after they are done. The teacher collects the data and displays it for the class to see. The teacher prompts a discussion about any differences observed between the data, and asks the small groups to come up with possible reasons for the differences. If students performed significantly different procedures, the students are asked to collaborate and collect more data using the same procedure. Still, data is very unlikely to be totally consistent, and the teacher explicitly helps students to see that **scientists performing the same procedure may not get the same results** as a result of unforeseen differences. Sometimes this is a result of error, but often it is a result of differing circumstances unknown to the researcher.

Materials: Each group of 3-5 students will need the following:
- 1 thermometer
- 1 metric measuring tape or meter stick
- Balance for measuring mass
- Shoe box
- Egg (hard-boiled)
- Yarn

Modifications:
- Almost any form of measurement could be substituted for this activity. Students could be asked to measure the height of their desk, for example.
- Students can learn about precision even without "formal" measuring instruments. Students may be asked to measure objects in terms of the lengths of popsicle sticks or paper clips.
- To make this activity a bit more difficult and to include other possible variables in the situation, high school students might be asked to measure the outdoor temperature. Students will be confronted with problems such as, "Do I put the thermometer in the sun or in the shade? How high off of the ground should it be? Should I shield it from wind?"

Title: Kinoki Foot Pad Commercial (As Seen on TV)

Content Area:

- Aspects of Nature of Science
    - Empirically Based

Source: Kinoki Foot Pad commercial. *Can You Find the BS?* Retrieved 12 October 2009 from YouTube.com <<http://www.youtube.com/watch?v=exmEGrNqgcA>>.

Target Grade / Course Level: 6-12 / Science

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students observe a brief commercial about Kinoki Foot Pads and discuss the reasonableness of the scientific claims based on evidence provided. Students will determine that because science is **empirically based**, a critical thinker might challenge some of the claims on the commercial.

Use: The teacher plays the commercial once, and then asks the students to discuss their general impression with regard to the commercial (Are they convinced? Would they buy the product? Why nor why not?) The teacher then plays the commercial a second time, and asks the students to list all of the claims made by the commercial. The teacher directs a discussion by explicitly stating that "**science is empirically-based**," meaning that it relies upon evidence. The students then watch the commercial a third time, and make note of the "evidence" provided on the commercial, and judge the evidence with regard to credibility. Finally, the students are asked to respond to the question, "Do the claims made by the Kinoki Foot Pad advertisers rely on legitimate science? Why or why not?"

Materials: The class needs the following:

- Internet access
- Lap top computer
- LCD projector

Modifications:

- If internet access is problematic, a VHS or DVD could be used to pre-record the commercial.
- So long as the official website still exists, students could also perform a web-quest to do their own research regarding claims made about Kinoki foot pads or another "scam" product.
- Note: The title for finding the commercial on YouTube is called "Can you Find the BS." Teachers may want to only project the video once it is in full-screen mode so that the title is not viewed by the students.

Title: “Sun” Magazine

Content Area:

- Knowledge of Inquiry
    - Scientific data are not the same as scientific evidence.

Source: “Sun” Magazine. Available in most grocery stores in the check-out aisle.

Target Grade / Course Level: 9-12 / Science

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

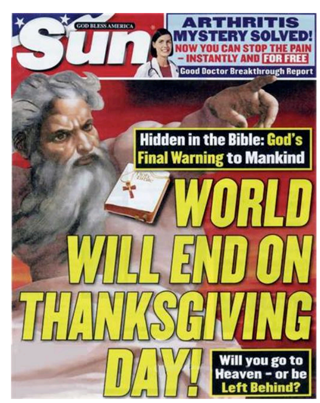
NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students choose an article from the “Sun” magazine and compare data and claims of scientific evidence by the authors. Students should identify **data** as quantitative or qualitative measurements, and **evidence** as interpretations imposed by scientists.

Use: The teacher places a magazine for each small group before they come into the classroom. The teacher should allow the small groups to browse through the magazine and discuss the contents. Students should be encouraged to find what they view as the most interesting article – the article must contain some form of data and a claim about that data. In their small groups, students should use a whiteboard to display (1) one or two claims from the article, (2) examples of the raw **data**, and (3) an example of the “**evidence**” provided by the authors supporting their claims. Students should present these whiteboards to the class, and the teacher can engage presenting students and the “audience” with the following questions: “What data did the authors provide?” “What evidence did the authors provide to support their claim?” “**What is the difference between the data and the evidence**?” “Do the statements regarding evidence actually reflect the nature of the data?” “Why or why not?” This can be extended even further to determine whether the research claims actually correspond to the evidence.

Materials: For each small group of two to four students:

- One copy of “Sun”



Modifications:

- Any non-reputable magazine may be used in place of “Sun” magazine.
- For lower level students, specific articles may be chosen instead of allowing students to choose from the magazine. However, the opportunity for students to search for “data” and “evidence” is quite valuable!
- Credible articles may also be used for the same purpose (i.e. research articles).

Title: Woman of the Enlightenment: Emilie du Chatelet

Content Area:

- Kinetic Energy
- Aspects of Nature of Science
  - o Socially and Culturally Embedded

Source: Hakim, J. (2006). *Story of Science: Newton at the Center.* Smithsonian Press. / PBS's "Einstein's Big idea" video clip.

Target Grade / Course Level: 11-12 / Physics

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES History and Nature of Science: Science as a human endeavor. Nature of scientific knowledge. Historical perspectives.

Idea: Students read a chapter from *Story of Science: Newton at the Center* and watch a video clip (*"2" is for squared*) from PBS' "Einstein's Big Idea" and then **reflect upon how society and culture influenced the development of scientific understanding**.

Use: Students read the chapter on their own, followed by the video clip. They are then asked to respond individually, and then in groups, to the following questions:

Emilie was not widely regarded publicly by scientists until only about 20 years ago. "What **social and cultural** factors <u>prevented</u> Emilie from being able to successfully share what she learned about energy?"

Example answers may include the following:

Females in France during her century were not accepted as legitimate scientists – they weren't allowed into some "science parlors" or organizations.

Emilie challenged Newton, who was perceived by most reputable scientists to be "god-like" and irrefutable.

This discussion should be extended to even modern day influences:

"If Emilie were alive today, how would society and culture possibly have influenced her work? Explain why."

"What kind of social and cultural influences (not just gender) do you think are present today in science?"

"Is social and cultural embeddedness a good or a bad thing, in your view? Elaborate."

Materials:

DVD – PBS "Einstein's Big Idea"

Photocopy of Chapter 22 from *Newton at the Center* for each student.

Modifications:

- This activity can be accomplished with either the DVD or the reading – I prefer to do both because it seems to "enrich" the historical perspective of the students.
- Many scientists in history have been overlooked or disregarded – students could alternatively read a science autobiography.

Title: Barbie Bungee Jumping Lab

Content Area:
- Nature of Science
    - Observation versus Inference
- Physics/Math
    - Developing mathematical models for a set of data.

Source: Illinois State University GK12 NSF Grant Fellows, summer workshop 2005

Target Grade / Course Level: 11-12 / Physics

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

Idea: Students perform a laboratory activity in which they collect data (through **observation** of Barbie falling 0 to 1 meter from a bungee cord of rubber bands) and make predictions (**inferences**) about how many rubber bands would be needed to release Barbie from the top of a stairwell and drop Barbie as close to the floor as possible without hitting her head. The students use this activity to **reflect upon what parts of their experimentation included observations and inferences**.

Use: The students are asked to complete the Barbie Bungee Jumping laboratory activity. Following the activity, students are asked to reflect upon two questions.
- **What parts of the activity included observations**?
    - What observations did you think were important?
    - How did you record your observations? (Data table, chart, graph, etc.)
- **What parts of the activity included inferences**?
    - What was your prediction?
    - How did you make your prediction?
    - How sure were you of your prediction?

After reflecting upon their specific laboratory experience, the teacher could generalize the discussion.
- What kinds of observations do scientists make?
- What is required for something to be considered an observation?
- Are all observations “correct”?
- How do scientists know that what they are observing really reflects reality?
- What kinds of inferences do scientists make?
- How is inference different from “faith,” in the religious sense?
- How certain are scientists about their own inferences?
- What might affect the validity of an inference?

Materials: For each pair of students:
- 50 identical rubber bands
- Barbie, GI-Joe, or small doll.
- Meter stick
- Graph paper

Calculator
Straight-edge
Pencil

Modifications:
- For greater complexity, students can be given a combination of different types of rubber bands.
- Any laboratory activity using predictions can be used in the same way.

Title: Table Talk

Content Area:

- Nature of Science
  - Tentativeness
- Knowledge of Inquiry
  - There is no single scientific method

Source: Personal Communication with Thomas Holbrook (my high school physics teacher).

Target Grade / Course Level: 11 – 12 / Science

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

Idea: Students go home and explicitly discuss with their parents about the **tentative nature of science** and how **there is no single scientific method**. Students and their parents must come up with one or two clear example of each of these aspects of science.

Use: Following a unit on the nature of science and knowledge of scientific inquiry, students are given a small sheet with two prompts about tentativeness and scientific methods. The students are to discuss with their parents the following two questions: "What is one example of how science changes?" and "Give two examples of scientific discoveries, and explain how their methods of discovery were different." The students must write a paragraph response to each question, and a parent signature must be obtained to ensure that the students actually discussed the topics. The teacher will evaluate the responses by the student to determine if they truly understand the concepts – or, perhaps students, parents, and teachers disagree! If so, follow-up lessons can be used to provide even more examples of the nature of science and science inquiry.

Materials:

- Table Talk prompt sheet
- Paper
- Pencil
-

Modifications:

- For students who do not live with parents, a guardian, teacher, or another responsible adult (age 21 or older!) may be substituted.
- Alternative questions about any of the aspects of nature of science or knowledge of inquiry may be substituted for whatever is most appropriate to the classroom.
- Students may be given an article or talking point about a specific aspects of science (i.e. the atomic model) if there is concern that the parent or student may be unable to discuss the ideas independently. (Fortunately, I have run this activity before, and have found that most of my parents are more than competent when it comes to discussing science!)

Title: *Evolution of Physics*

Content Area:

- Physics
  - Nature of light
- Aspects of Nature of Science
  - Tentativeness
  - Functions and relationships of theory and law.

Source: "The Decline of the Mechanical View" chapter from Einstein, A. (1967). *The evolution of physics.* Touchstone: New York.

Target Grade / Course Level: 11-12 / Physics

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students read a chapter on the evolution of the models of light from Einstein's *Evolution of Physics*. Students comment on how the conception of light has been and still is **tentative**. Students complete a notes sheet and label appropriate information from the text as **theory** or **law**.

Use: Students should be introduced to light and traditional beliefs about its make-up. Aristotle through Newton believed that light must be a "particle" of some sort. However, as can be easily demonstrated in the classroom, light displays properties of both particles and waves (i.e. interference patterns, polarization, straight-line travel, etc.). After a discussion about how these very ingrained Aristotelian beliefs were challenged and eventually changed, demonstrating the **tentative** nature of science, students read "The Decline of the Mechanical View" from *The Evolution of Physics*. After completing the activity, students fill out the "Competing Theories of Light" worksheet and seek supporting evidence for each **theory** of light. Students discuss which aspects of their observations constitute **laws**. (Students should be able to come up with the **Law of Reflection** and **Law of Refraction** as prime examples). Students should be explicitly given the definition of a law as a description of the relationship between two variables, with theories and the explanation for the relationship.

Materials: For each student the following materials are needed:

- Copy of "Decline of the Mechanical View" chapter from *Evolution of Physics*.
- "Comparison of Theories of Light" document
- Demonstration materials for each of the pieces of "evidence" as listed by Einstein (optional). See the inquiry lesson plan for more information about this.

Modifications:

- Students may read the excerpts in class (or outside of class) depending upon time constraints.
- Excerpts may be enlarged or read aloud for students who have visual difficulties or prefer to learn audially. (Parts of the excerpt may even be role-played).
- Instead of reading the article, the teacher may demonstrate each of the observations scientists have made about light, or, alternatively, students may make their observations in small groups via a stations lab.

Title: Pendulum Lab

Content Area:

- Physics
  - Oscillatory motion
- Knowledge of Inquiry
  - All scientists performing the same procedures do not always get the same results.

Source: Chicago ITQ Cohort 3: Modeling Method of Instruction. Held at Dominican University in June 2007.

Target Grade / Course Level: Physics / 11^{th} – 12^{th} grade

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

Idea: Students perform a laboratory experiment to determine the relationship between the length of a pendulum and the time for one cycle. Each group is given a specific range in which to work. Students will see that although they had the same question as likely used a similar procedure, the resulting data may **not get the same results** because they may only be viewing a small portion of the whole range of possible data.

Use: The teacher demonstrates a swinging pendulum, and prompts students to brainstorm the possible variables that may account for the length of time of a full cycle of the pendulum. After students have determined that only length significantly affects the cycle time, the teacher asks students to develop a graph showing the relationship between the length and the time of a full cycle. Half of the class is asked to study only lengths between 5 cm and 30 cm, and the other half is asked to study lengths between 30 cm and 60 m. Students can plot a general sketch of their graphs on a whiteboard and present their findings to the group. Students who worked within the 5cm to 30 cm range will determine that the relationship is non-linear, with the greatest change in the time of one cycle occurring at the shortest lengths. The groups working between 30 cm and 60 cm may determine the relationship to be almost or entirely linear. During the whiteboarding session, students should also share their procedures. Inevitably, most of the groups will have followed the same procedure, yet the class is not likely to come to a consensus. The teacher should draw the discussion to a close, asking students to reflect on the reasons why **scientists performing the same procedures do not always get the same results**. In this case, this was a result of the range of data (and should lead into a discussion about the importance of testing a wide range of data), but it can also be a result of lack of precision or differing interpretations of the same data.

Materials: Students should work in small groups of three to four students. Each small group will need the following:

- Ring stand with clamp (or sturdy place to hang pendulum).
- String
- Scissors
- Pendulum bob
- Electronic timer
- Meter stick

Modifications:

- If pendulum bobs are not available, sets of washers can be tied on to the end of the string.
- Any kind of laboratory activity in which the data is not linear can be substituted for this lab (i.e. inverse, logarithmic, exponential).
- Instead of looking at the range of the experiment, students could be asked to collect no more than two data points – students quickly identify that this is insufficient data.

Title: Galileo's Thermometer

Content Area:

- Chemistry / Physics
    - Density, Buoyancy, Thermodynamics
- Knowledge of Inquiry
    - Explanations are developed from a combination of collected data and what is already known.

Source: Rebecca Vieyra

Target Grade / Course Level: 3rd – 12th / General Science

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students observe a Galileo's Thermometer and the changes that occur in it when moved from a cold to a warm environment, or vice versa. Students provide examples of **what they already know** about floating and sinking objects, and the effects of temperature on liquids. Students experiment with different temperatures to **collect data** to determine the relationship between temperature and the number of floating bulbs.

Use:

The teacher begins class by removing the Galileo's Thermometer from a cooler filled with ice – students should not see this! As the class goes on, students are asked to make observations about what is occurring with the bulbs inside of the thermometer. Students are asked to explain possibilities for the bulbs to begin sinking or floating by giving examples of experiences they have had with sinking and floating. Students may list experiences such as being in a boat, feeling buoyant in water, having dense objects sink and less dense objects float (**what they already know**). The teacher may opt to use a KWL chart at this point.

Students should be encourage to feel the Galileo's Thermometer and look closely at the bulbs. Seeing the "degree" symbol on the bulbs and feeling how cool it is, students should come to the conclusion that the bulbs sinking or floating are a function of temperature. Students may **collect data** by returning the thermometer to the cooler, or placing it in a beaker filled with luke-warm water. (Caution: The water should not be above 100 degrees Fahrenheit!) Observations may be recorded in the KWL chart.

Once the temperature dependence is determined, students should list on their KWL chart what they know about molecules of warm and cool fluids, and provide examples (hot air rises, etc.) This should be followed by an explicit discussion about science rarely being done in isolation of other ideas, be they personal experiences or research completed by other scientists. Students should be asked to provide examples of this – almost all scientists before the Scientific Revolution relied somewhat upon the observations of Aristotle, and many scientists after the revolution based their work off of the experimentation of Newton. In the words of Newton himself, "nanos gigantum humeris insidentes" – even the greatest of scientific scholars only go where they were by standing on the shoulders of giants.

Materials:

- Galileo's Thermometer
- Beaker
- Water
- Hot plate
- Ice
- Thermometer (alcohol)
- Balloon

- Cooler

Modifications:

- Instead of using a Galileo's Thermometer, a common "hand boiler" may also be used, and demonstrates similar properties about the expansion of fluids as a result of an increase in temperature.
- Instead of using a Galileo's Thermometer, a Cartesian diver may also be used, and demonstrates similar properties of floating and sinking as a result of changes in overall density of objects in a fluid.
- The Galileo's Thermometer may alternatively be placed in a refrigerator and allowed to warm up in the classroom as the class goes on. It may also be placed outside a classroom window and viewed by the students as it changes temperature.

Title: Filters Activity

Content Area:
- Physics
  - Absorption and transmission of light
- Nature of Science
  - Observation versus Inference

Source: Riendau, D. Workshop at the Chicago Section of the American Association of Physics Teachers Spring 2009 conference. Crystal Lake South High School.

Target Grade / Course Level: 9th – 12th / Physics

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students look at a set of projected colored dots on a PowerPoint slide, and are asked to predict how the colors will look different when **observed** through a filter held in front of their eyes. Students are then asked to **infer** the reason why the colors appear as they do through the filters. The teacher provides a definition of observations and inferences, and asks the students to reflect on the strength of observations and inferences as scientific evidence.

Use:
The teacher creates a PowerPoint slide with a white background and three large dots, each in red, green, and blue (matching the filter colors as closely as possible). The students are asked to make **observations** of the colors. The teacher asks the students if all of their observations are the same – this may lead into a unique discussion about how "your blue" may not be perceived in exactly the same way as "my blue." The students then predict how each of the colors will change when viewed through a red filter, and then provide a tentative hypothesis about why they think the colored dots might look differently. After students make their observations, they share their **inferences** about what is happening to light as it passes through a filter. Many students will **infer** that white light is getting "colored" or "mixed" with the color of the filter. Other students will **infer** that the filter only allows its own color through, while blocking or absorbing the other colors. Students will perform the same **observations** with blue and green filters, and then with filters that let through the secondary colors of light. Students should revise their **inferences** based on their new observations. Following this activity, the teacher should provide an explicit definition of observation and inference by asking the following:

What were your observations? Did you all agree?

Is it ever possible that scientists do not make the same observations of the same phenomenon?

What were your inferences given your observations? Did you all agree?

Is it ever possible that scientists do not make the same inferences despite similar observations?

Materials:
- PPT Presentation "Colors Activity"
- Worksheet "Colors Activity"
- Colored pencils, markers, or crayons
- Colored filters (red, blue, green, magenta, cyan, yellow)

Modifications:
- If an LCD projector is not available to present the PowerPoint, consider using a colorful, bright object. The flag of South Africa works very well, as it includes all of the primary colors of light as well as black, yellow, and white.

Title: *A New Twist on "Mystery Boxes"*

Content Area:

- Nature of Science
  - Observation versus Inference
- Knowledge of Inquiry
  - There is no single scientific method.

Source: Rau, G. (2009). A new twist on "mystery boxes." *The science teacher*. *No. 11*, 30-35.

Target Grade / Course Level: 5th – 12th/General Science

Standard:
ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students use all of their senses to identify various objects inside of "mystery boxes" into which students cannot initially see. Students record their **observations** (anything they can sense), as well as their **inferences** (the meaning they make of their observations). Students will identify this activity as an **investigation**, and discuss that it is as valuable a part of science as **experimentation**, because scientists do not all follow a "scientific method" to learn about the natural world.

Use:

Provide each small group of 3-4 students with two mystery boxes (or one box with a divider). Students may shake the boxes and place their hands into a small opening in the boxes to feel or smell the item. (Caution: Do not place any items in the box that are sharp or may potentially scare students, such as dead insects. Beware of objects that may be allergen-producing). Ask students to individually make a list of all observations – explicitly state **observations** are things that can be sensed with vision, touch, smell, taste (not in the laboratory!), or heard. Beneath the list of observations, the student should make an **inference** – a statement that makes meaning out of the observations. For example, observations for a pine cone might include "bristly," "hard," "spiny," and "rough." An inference would be the following: "I think that the mystery item is a type of pine cone." Students should be asked to compare their observations, and remove any items from the list that are not simple observations. The students may then open the box and continue to make visual observations and refine their inference. For a pine cone, this might include "brown," "has grooves," etc.

This activity should be followed up with a question about if the activity was "scientific." Undoubtedly, most students will say yes. In biology, identification and categorization is a large component of the body of knowledge. The teacher should also ask students if this was an **experiment**. If students say that it is an experiment, the teacher should follow up this activity with a true experiment that includes manipulation of variables, to help demonstrate the difference. The teacher should help students to recognize that the mystery box activity is an **investigation** because it did not deal with looking at cause-and-effect relationships. Scientists can study the world in many ways – they do not all use a single **scientific method**.

Materials: Each small group of 3-4 students will need the following:

- Medium-sized box with a divider *or* two small boxes (with a hole cut in the top large enough to insert a hand).
- Paper or fabric (to cover the hole in the box).
- Two items per box – preferably "natural" artifacts that have a variety of smells, shapes, and textures.
- Paper and pencil.
- Rubric (from *The Science Teacher* article).

Modifications:

- This activity is ideal for students who have visual difficulties – consider choosing items with more obvious aromas and textures.
-
- Specially made boxes are not absolutely necessary – this activity can be accomplished just as easily with black plastic or fabric bags.
- Boxes aren't even necessary – observations and inferences can also be made only on visual evidence.

Title: Atomic Bomb Scientist and Government Panel

Content Area:

- Physics
  - Radioactivity
- Nature of Science
  - Socially and culturally embedded

Source: Dannen, G. (9 August 2003). *Atomic Bomb: Decision.* Retrieved 8 November 2009 from <<http://www.dannen.com/decision/index.html>>.

Target Grade / Course Level: Physics

Standard:
NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students do some preliminary research to understand the historical and political atmosphere surrounding the developing and use of the atomic bomb on Hiroshima. Students will hold a panel discussion via role-playing of major scientists and government officials involved in the decision making surrounding the Manhattan project. Through this activity, students recognize that science can be helped or hindered by the **social** and **cultural** atmosphere of a country.

Use:

This activity should be carried out only after an introduction to ionizing radiation and its effects – movies such as *The Manhattan Project* or *Barefoot Gen*(Caution: This is a *very* graphic manga-style movie) do a superb job of showing both the cultural climate in the United States and Japan as well as the biology effects. Students will review original source documents (including some then-confidential government papers) from the above listed source link to research the varying positions of scientists and government officials regarding the ethics and legality involved in the research and use of the bomb.

Following some preliminary research, students should be assigned various roles, such as General Groves, President Truman, Oppenheimer, Szilard, Fermi, Compton, Lawrence, etc. Students should research the position of their chosen character, then re-enact a committee meeting at which they decide the fate of the bomb. A moderator (teacher) should be present to facilitate the discussion.

Following the activity, the teacher should de-brief the students with the following discussion questions:

- What kinds of global or national influences encouraged the development of the Manhattan Project?
- What were the "winning" arguments for the use of the atomic bomb in Japan? Whose stance did they reflect?
- What was the global effect of using the atomic bomb immediately after its use?
- What was the global effect of using the atomic bomb on today's politics?
- What are some other examples in science in which **society** and **culture** have affected the outcome of a scientific project or scientific research?

Materials: Students must complete on-line research in preparation for the panel:

- Computers
- Internet Access
- Atomic Bomb Web Quest

Modifications:

- For classes that do not have internet access, the original source documents may be printed out in hard copy for students to use and return.
- Instead of re-enacting an entire committee meeting, students may simple be asked to read and reflect upon the articles and follow-up questions in an essay.

Title: Emilie's Kinetic Energy Experiment

Content Area:

- Physics
  - Kinetic Energy
  - Kinematics
- Knowledge of Inquiry
  - Research conclusions must be consistent with the data collected.

Source: Center for Applied Research in Education. (1994). *Hands-on physics activities with real-life applications*.

Target Grade / Course Level: 11^{th} – 12^{th} / Physics

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

Idea: In this experiment, students modify the speed of a ball bearing as it collides with clay. By graphing the depth of the "crater" (energy) versus the final velocity of the ball, students see that Newton's claims were overthrown because his **conclusions** were not **consistent with the data**, and this consistency is fundamental in science.

Use:

Newton served as an authority figure for many scientists, who did not dare to contradict his theoretical or experimental work. Newton believed that kinetic energy (*vis viva*) was proportional to the velocity of a falling object. The Dutch s'Gravesande as well as French du Chatelet experimentally found that Newton's **conclusions** were inaccurate.

Students are given a single ball-bearing and asked to determine if Newton's statement about kinetic energy being directly proportional to velocity is correct. Students should be able to calculate the final velocity of dropped ball bearings using knowledge from kinematics. After the ball is dropped into clay, the energy making the hole ("work done" by the ball) can be measured in the droplets of soap water it takes to fill it up (the soap decreases the surface tension). The data for energy and final velocity can be plotted on a graph. Students will see that the curve is parabolic, not linear, as predicted by Newton.

The teacher should convene the class to compare data. The teacher should ask the students what to do – should Newton's claim remain authoritative given the evidence? Students should resoundingly answer "no," and attempt to create a new statement that is **consistent with the data**. The teacher should address the class with the following questions:

- Have there been other cases in which **conclusions** were not **consistent with the data**?
- Why might a scientist make **conclusions** that are not **consistent with the data**? (This is a great time to discuss the concept of scientific ethics!)

Materials: The following materials are needed for each lab group of 3-4 students:

- Ball-bearings of various sizes (from 10 g to 200 g)
- Soft modeling clay – non-porous, non-drying
- Meter stick
- Eye dropper
- Beaker / cup
- Soap water

Modifications:

- For younger students, the final velocities before impact can be pre-calculated and already placed into a column for the students – they can just be instructed to drop the balls from a pre-determined height.

- For younger students, only two trials are necessary, and no graphing is needed – just drop two balls, with one at twice the final speed as the other. Young student should easily be able to see that the ball with twice the speed required four times as many water droplets to fill it up.
- If modeling clay is not available, use *Crisco*, *Manteca*, or another form of soft lard.
- If the clay is porous but soft, consider cutting the clay and measuring the depth, as opposed to filling it with droplets of water.
- For older students, a further experiment can be accomplished – perform the experiment by manipulating the mass of the ball bearing, while keeping the final velocity constant. Students will see a linear relationship. A simple application of conservation due to energy results in the modern derived formula for the energy of motion.

Title: Benjamin Franklin Letters about Electrostatics

Content Area:

- Physics
  - Electrostatics – capacitors.
- Knowledge of Inquiry
  - Inquiry procedures are guided by the question asked.

Source: Morse, R. "Benjamin Franklin as my Lab Partner." Workshop presented at the February 2009 national conference of the American Association of Physics Teachers. Chicago, IL.

Target Grade / Course Level: Physics/Physical Science / 8^{th} – 12^{th} grade

Standard:

ILS STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

NSES Science as Inquiry: Abilities necessary to do science inquiry. Understandings about science inquiry.

NSES History and Nature of Science: Nature of scientific knowledge.

Idea: Students read simple excerpts from letters written by Benjamin Franklin to his friends regarding his experiments in electrostatics. The students follow the experiments described by Franklin – each experiment clearly **proceeds from the question posed.** The students analyze how Franklin builds upon the early understandings of electricity using a combination of **what was known** previously and his **new experiments**.

Use:

Students should have some basic foundational interactions with static electricity. At this point, a large T-chart should be placed in the classroom that will remain until the end of the lesson. The T-chart should have a column for **what is known** and **what was learned** from each consecutive activity. The **what is known** should be filled in with any introductory information the students may have. Students build a small capacitor as instructed in the reading packet. The students experiment with how to properly charge a film canister capacitor (filled with water). Afterwards, they observe the effects of a charged capacitor "hook" on a pith ball. All observations should go into the **what was learned** part of the T-chart.

Students will be given a laboratory / reading packet, "Ben Franklin as My Lab Partner," (can be found online from Robert Morse's resources at the TUFTS Wright Center for Science Education http://www.tufts.edu/as/wright_center/personal_pages/bob_m/). The teacher will help lead the students through the introductory readings. Benjamin Franklin's interest was piqued by this "Leyden jar," and proceeded to ask himself the following question: "Where is the charge stored in a capacitor?" The students follow the thinking and proceeding questions from Benjamin Franklin to discover the following: "Is the charge in the hook?" "Is the charge in the water?" "Is the charge on the surface of the bottle?" "Must there be metal on the surface of the bottle?" Students complete the accompany activities for each question to test where the charge is located. All observations should be included in the **what was learned** section of the T-chart. The teacher should initiate a debriefing discussion to focus on how the questions directly **proceeded from the questions posed**, and that even though Franklin was ingenious in his views, that he used his own **prior knowledge** of statics (and Leyden's work with capacitors from Europe) along with his **new experiments** to result in our modern understandings of science.

Materials: Students should work in pairs. Each pair of students will need the following materials:

- Two film canisters with a lid
- Aluminum foil
- Glue
- Large paper clip
- Two empty cups with water

- Charging rod (amber rod with fur, glass rod with silk)
- "Benjamin Franklin as my Lab Partner" laboratory worksheets and letter readings.

Modifications:

- If film canisters are obsolete, two plastic cups stacked one inside of the other will also serve as a capacitor. The outside cup must be lined with aluminum foil on the outside and inside. An aluminum "tag" must protrude from the middle of the cups to allow for charging.
- If commercial charging rods are unavailable, PVC pipe with faux fur from a fabric store work nearly as well.
- Hair dryers can be used if humidity is slightly too high.
- Videos for making the film canisters and performing part of the experiment can be found online at the above listed source.