Were You There?

<u>Theme</u>: Process and Nature of Scientific Inquiry

<u>Problem</u>: Scientific Inference: How can we apply what we learn from studying the natural world today to events and processes that occurred in the past when there was no one to observe it or record the events?

<u>Concept</u>: Application of scientific laws, theories, hypotheses, and investigations.

<u>Background</u>: "Seeing is believing"; everyone knows that phrase … and it makes sense. When we have experienced something ourselves or seen it with "our own eyes", we are much more confident about our knowledge about it. The second best thing is to hear about it from a trusted friend—which is why so many persistent urban legends begin with a report from a close personal friend or other "reliable source".

Can we, in fact, know *anything* that we have not seen or experienced ourselves?

Can we say *anything* about things that happened in the distant past when there were no eyewitnesses?

Science says we can: If our observations provide us with a reliable understanding of the way Nature works in the present, then we can use those observations to understand natural events both in the past and in other places in the universe.

Of course, each application of this knowledge is essentially a hypothesis to be tested … and if/then prediction of what we *should* observe in the past if our understanding of the present is correct.

The basic principle behind this approach is referred to in general as *uniformitarianism*: the expectation that natural laws and processes that are at work in the present were fundamentally the same in the past.

"Were you there?" is a creationist challenge to our modern scientific understanding of earth history and the history and diversity of life on earth (http://www.answersingenesis.org/e-mail/archive/AnswersWeekly/2011/0716.html). It rejects uniformitarian approaches to understanding what we cannot observe directly and argues that because there were no human eyewitnesses to these events, we cannot have any confidence in the validity of the current scientific understanding of prehistory.

This set of activities promotes uniformitarian modeling: the main goal is for students to apply observations that they can make in the present to events that occurred in the past.

Note to Teachers: The material presented here is intended as a foundation. In all cases, they should be adapted to the resources available to you and your students.

Regardless of the activity or material—or how you modify it to make it workable in your classroom or lab—the essential question remains the same: How do we apply the laws of Nature to events and processes that we cannot observe directly? How can we use those laws to identify and understand when something out-of-the-ordinary occurs, for example, the impact of an asteroid?

I. Preparatory Activities

1. Pick some activity familiar to students, such as bounding a ball off a wall, rolling a ball down a ramp, swinging a pendulum, floating a piece of wood in a bucket of water, and so on.
   (a) Ask students to make observations about what happens when they do this activity.
2. Now, ask students to tell you what would happen if they did this same activity somewhere else.
   (a) Would they expect to see roughly the same results in the next classroom or in the school gymnasium or cafeteria, etc. (or, if outdoors, in a forest, instead of a parking lot, for example).
      i. Record their answers on a blackboard, overhead, etc.
   (b) Repeat the question, this time for a different place, farther away (for example, a different school in a different location; or a different community or part of the country).
      i. Record their answers on a blackboard, overhead, etc.
3. Discuss these answers.
   (a) Most will tell you that they expect the same or very similar results, but regardless of what they answers, be sure to ask them why they made that inference.
      i. Separate the reasons behind the inferences into different levels of explanation:
         A. For example, some will refer to proximate variables and events: if in the gym, the floors or walls may be made of materials that affect the ways that a ball bounces; or if outside, there may be a gust of wind affecting the results.
         B. Others will refer to underlying properties and principles; for example, force, mass, acceleration, gravity, buoyancy, and so on.
      ii. Place these on the board where students can see them and ask *them* to judge which of these are principles that will apply regardless of where we observe the event and which of these are local variables that will affect how the effects of the general principles appear to us.
      iii. Then ask: "Is there a way to separate the two?"
         A. The obvious answer, of course, is direct observation, but there is also experimentation (for example, simulate a gust of wind using a fan; bouncing balls of different mass or composition, and so on).
         B. In either case, we can make predictions—as they just did— based on the general principles and then identify the differences between our predictions and our observations.
         C. Then, we can ask the question: "When the predictions and the observations do not match *exactly*, can we tell what part of our observations are different due to these local variables and what part are due to the underlying principles (such as mass, gravity, etc.)?
4. Finally, ask the culminating question: "If another person in a country on the other side of the earth did the same thing you just did, how confident are you that you could describe the result, even if you could not see it?
   (a) Answer the same questions, but instead of another country, what if your grandparents did the same activity in the same grade in school all those years ago?
   (b) And what about some student 100 years in the future?

II. Classroom Activity

1. Understanding Sediments and Strata

How can we use our knowledge of current process of depositing sediments and interpreting strata?

a. Newspaper Sedimentology

1. Over a period of weeks, ask your students to bring from home newsprint items.
2. These can be daily newspapers, weeklies, or even the advertising supplements that arrive in the mail.
3. Ask your students to deposit them in one of 3 or 4 large cardboard boxes around the classroom.
   (a) It is best to ask your local appliance store for a box from a stove, dishwasher, washing machine, or other waist-high appliance, but if you are adventurous and have students with lots of materials, a refrigerator box would be more challenging.
   (b) Do not be more specific than that; students can deposit them in any of the boxes, *as long as* they add newer items on top of older ones.
4. In addition, *you* should add items occasionally to the top of the pile; these can be any items on paper that you receive in the course of a day.
5. After the pile has filled the boxes, cut down one of the sides to expose the whole "column" of papers.

Before you begin any analysis, ask the students to predict what they will find in each boxes.

For example:

How will the papers at the bottom compare to those at the top? (They will have been placed there earlier, so they will be older).

How will the columns in different boxes relate to each other? (In general, there will be concordance but the dates on the papers at, say, 15 cm from the bottom in one box may not be the same as those 15 cm from the bottom in another box).

How can we explain the similarities and the differences? (The general rule of superposition —newer layers form on top of older ones—applies to all cases, but local conditions can produce variations; for example, thickness of the papers forming each layer, the number of papers forming each layer; and so on.)

6. Now divide the students into teams to begin "excavations"—first recording the depth of each paper and its characteristics, then carefully removing layers of papers, one at a time.
   (a) You should attach some scale to the side of the box; either a low-cost paper tape measure or a photocopy of a meter stick or a tape measure.
   (b) Students should create a data sheet to record anything that seems relevant to them.
      i. You can suggest, for example, thickness of each paper that they remove; something aspects of the paper itself (is it a daily, a weekly, an advertising supplement or mailer; etc.); is there anything in the paper to indicate its connection to a specific time or

event (examples are back-to-school and holiday-related sales; sports contests; elections; unique photographs; natural disasters or weather events; community celebrations or festivals; or even printed dates, whether of publication or some future event).

ii. And, of course, the school-related items that you have deposited intermittently will serve as checks on the data.

7. After each team has completed its "excavation" it will be time to compare results.
   (a) First of all, each team should draw a representation of its "paperologic" column: what is the time span of the whole column and how "tall" are the strata representing specific time periods (either by the calendar dates or by the appearance of specific events that only occurred once during the period of "deposition").
      i. Second, ask the students to report on the locations of a few "landmark" events (something in 6.b.i, for example; or the occasional special event; for example, the Labor-Day-to-Vernal-Equinox Period is 12.5 cm tall).
   (b) Then, ask each team to describe its results and how well their observations fit their predictions.
   (c) Now, ask the students to compare the results from their columns.
      i. Do they match exactly? (Probably not)
      ii. Are they concordant? (that is, do the papers represent their events in the same general sequence; probably so)
      iii. Are there any places where the layers between events are not the same? (Probably)
      iv. Can student explain why? (most likely explanations are 2-fold: (1) the papers deposited in one pile are smaller or fewer over the interval; for example, one column is made up of a lot of daily papers, whereas another is made up mostly of weekly advertising supplements; (2) for one reason or another fewer items may have been deposited in one or more of the boxes over a period of time … or none at all)
      v. Which of these observations is due to local variation in the deposition of papers (rate, quality, quantity), and which to the fundamental process of superposition?
         A. How do we know that?
8. Going back to the geologic column that has been exposed by erosion in the Grand Canyon, what general principles from the "paperologic" experiment might we apply to the geologic strata.
   (a) How could we compare what we found here to the strata exposed in other places on the planet? (they should also show older layers on the bottom; younger on the top)
   (b) What local conditions might produce differences among the locations? (volcanic, earthquake, and sea-level differences might affect what is deposited at certain times in certain places, but major events affecting the whole planet would be recorded at all locations; see http://undsci.berkeley.edu/article/0_0_0/alvarez_01 for a discussion on how the identification of an Iridium-rich stratum marked the end of the Cretaceous.)

b. Aquarium/Terrarium Sedimentology

1. Set up an aquarium or terrarium in the classroom.
2. Over a period of weeks, ask your students to sprinkle some material onto the surface. Do not be more specific than that; students can deposit any of the available materials in any of the containers, as long as they add newer items on top of older ones.
   (a) Over the course of the experiment, you will provide materials of different qualities … size, shape, buoyancy, color, texture, etc.
   (b) Something like colored play sand or the decorative pebbles used in aquaria are quite suitable.
3. You will provide quantities of different materials in sequence.
   (a) You will keep track of the availability of the materials, so you will know which was available first, second, etc.
   (b) You may add a new material to the pile even if the older material is not completely used up; this will result in layers of mixed characteristics.
   (c) You may also repeat the use of one or more materials, introducing it for a second or third time.
4. When you have completed the deposition of the "sedimentary" materials, ask your students to observe the layers from the outside of the containers (through the glass).
5. First, you should attach some scale to the side of the box; either a low-cost paper tape measure or a photocopy of a meter stick or a tape measure.
6. Then, students should record the depth of each layer and its characteristics.
   (a) Students should create a data sheet to record anything that seems relevant to them.
      i. You can suggest, for example, color, texture, size …. any features that will identify the nature of the materials in the deposits.
7. If you have time and feel more adventurous, you can have students perform "excavations" within the containers (be sure to drain water carefully from the aquarium *first*).
   (a) Before students begin this process, have them predict whether the layers that they excavate will match what they see through the glass on the edges (probably not).
   (b) Remind them that the depth of the layers on the edges is a clue to the depth of the layers in the middle; so if a layer is 0.5 cm deep on the edge, they should be removing *very* small amounts of material with each "scoop" if they want to extract individual layers.
8. After each team has completed its "excavation" it will be time to compare results.
   (a) First of all, each team should draw a representation of its "sedimentary" column: what is the sequence of layers in the whole column and how "tall" is each stratum in each of the containers?
   (b) Then, ask the teams to compare their columns; are the layers in the same order; are they the same thickness; is it easy to see where one layer begins and the other ends?
      i. Do they match exactly? (Probably not)
      ii. Are they concordant? (that is, do the layers form the same general sequence; probably so)
      iii. Are there any places where the layers between events are not exactly the same? (Probably)

iv. Can student explain why? (most likely explanations are 2-fold: (1) the sediments deposited in one container are smaller or fewer over the interval; for example, one column is made up of a lot of larger, coarser particles, whereas another is made up mostly of smaller, finer particles.(2) for one reason or another fewer items may have been deposited in one or more of the containers over each period of time … or none at all)

v. Which of these observations is due to local variation in the deposition of particles (rate, quality, quantity), and which to the fundamental process of superposition?

A. How do we know that?

9. Going back to the geologic column that has been exposed by erosion in the Grand Canyon, what general principles from the "sedimentation" experiment might we apply to the geologic strata.

(a) How could we compare what we found here to the strata exposed in other places on the planet? (they should also show older layers on the bottom; younger on the top)

10. What local conditions might produce differences among the locations? (volcanic, earthquake, and sea-level differences might affect what is deposited at certain times in certain places, but major events affecting the whole planet would be recorded at all locations; see http://undsci.berkeley.edu/article/0_0_0/alvarez_01 for a discussion on how the identification of an Iridium-rich stratum marked the end of the Cretaceous.)them in one of 3 or 4 large cardboard boxes around the classroom.

III Classroom/Lab Activity

Waves and Currents

How does the movement of water re-shape the surface of the earth?

A. Beaches and Waves

This activity will create a simulated beach environment that you can use for various experiments and explorations. Of course, if you have a beach nearby, it is always good to confirm your lab observations with what happens on an actual beach—for example, after a heavy storm or a very windy day.

Materials

Either a wave or ripple tank or …

A large plastic bin, tub, or aquarium

Sand and pebbles (varying coarseness; beach sand tends to be fine grained)

A household fan

A block of wood about the width of the tank or tub for manually creating waves; (or a motorized cam mechanism that can produce a reciprocating action at the water's surface; for example, *http://www.enasco.com/product/SB47491M*).

1. Place sand to a uniform depth in the tank or tub
2. Place the tank or tub at an angle with one end up on a sturdy support (for example, a 2× 4 or 4× 4 block of wood.
3. ***Gently and slowly*** add water to the lower end of the tank until it fills about ½ to ¾ of the tank.
   (a) Let the water settle for a bit.
4. While the water is settling, ask students to brainstorm the qualities of the waves that might affect the physical features of the beach[1].
   (a) The most common are the height of the waves, the speed of the waves, the interval between the waves, and the slope of the shore.
   (b) *Have students create a data sheet for collecting this information*.
      i. *You will need to have handy tape measures, stop watches, erasable or water-soluble markers.*
      ii. *It may help to mark the outside of the container (if it is translucent or transparent) with a grid of 1-cm intervals (alternatively you can create this on your computer and print or copy it onto acetate film to attach to the side of the tank; acetate, of course can also go inside the tank).*

1 As students brainstorm these qualities of the water, have them also think about how they will use the materials and equipment available to them to generate these differences in the waves. If possible, involve them in the design and construction of the materials.

5. Now you are ready to generate waves on the beach.
6. Using the block of wood or a motorized kit, begin to generate waves of different heights (amplitudes) and at different intervals (frequencies).
   (a) These explorations should follow the qualities of the waves that students identified in their brainstorming sessions.
7. Students should examine the “beach” after the trial, and record the changes they observe in the features or distribution of the sand (for example, ripples on the surface, erosion patterns, pooling of water, and so on).
8. After each trial, the sand on the beach should be smoothed out and returned to its original depth as well as possible.
9. Students should repeat these trials varying at least one of the features in each set, and recording the changes in the beach.
10. After generating the waves with a mechanical device, students may also explore the effects of wind by using a variable speed household fan.
   (a) The process is the same, except the only force on the water is that of the fan.
      i. *Note: the fan should be directed only at the water as much as possible; the effects of the wind on sand are interesting, but these explorations are focused only on the effects of the water.*

Sample Data Sheet

Water Depth: ______ cm	**Beach Composition: Sand/Pebble/Mix; Fine/Medium/Coarse**				
Trial Number	**Wave Speed (cm/sec)**	**Wave Height (cm)**	**Wave Frequency (n/sec)**	**Distance “Up Beach” (cm)**	**Changes in Beach Sand**
1					
2					
3					
4					

Of course, your data sheet will reflect the variables that your students are exploring.

This can be repeated with different depths of water or different beach materials (fine or coarse pebbles; coarser sand or sand mixtures, etc.). Before proceeding return to Step 4 and have students make predictions about what they expect to see.

In the end, students should compare their observations to their predictions.

They should also answer the question: If the events that occurred in this experiment happened at another place and time, would the changes in the landforms be the same, mostly the same, mostly different, or completely different? Explain why.

Would the nature of these changes be different if there were no eyewitnesses? Why or why not?

B. Sudden, Short-term Flooding

This activity will explore the effects on landforms of sudden, short-term flooding. The wave set-up in the previous activity will simulate flooding onto land from a body of water, such as a lake or sea. The procedure in the Tsunami Lesson Plan (http://www.niehs.nih.gov/health/assets/docs_a_e/ehp_student_edition_lesson_tsunami_simulation_experiment.pdf) shows the effects of a very large wave of this type.

For an example of flooding due to rain, melt water, or other sudden, large change in the volume of water on a landform, you will need to create a mini-habitat that allows some "outflow". Old picnic coolers may work; or a plastic bin or tub with one or more holes at one end to allow water to flow out (these can be "subterranean" to represent aquifers or they can be at the level of the surface of the soil in the tub to represent river drainage.

1. Set up the mini-habitat in the tub by using a coarse-grained pebble layer at the bottom; with finer materials on top.
    (a) In some set-ups you might want to vary the ground cover—from bare ground to leaf litter to grass and so on.
        i. You should decide if there will be a river in the system.
    (b) Before introducing the set-up to students, determine how much water the system can accommodate without saturation and how fast the water is removed from the mini-habitat.
    (c) A reasonably priced water flow meter that attaches to a garden hose is available from http://www.cleanairgardening.com/water-usage-meter.html; with a stop watch and the reading from the meter, you can calculate the volume of water per time interval.
2. Now have students brainstorm again; some possible variables are the volume of water, the velocity of the water (whether it is due to a heavy soaking rain or to a sudden burst of flooding as from a burst dam), the time interval, and so on.
    (a) They can use news reports of recent flooding from hurricanes and storm surges to guide their thinking and to form their explorations.
3. Students should design experimental trials to collect data based on these variables.
    (a) Use a small sprinkler to simulate a soaking rain; vary the intensity and the duration; and record the changes in the land surface.
        i. Be sure to "reset" the mini-habitat to the starting conditions before beginning a new trial.
    (b) Use a hose to simulate a water current.

After the trials, have students summarize the observations.

Based on these observations, what evidence of flooding would they expect to find recorded in the flooded area?

Based on these observations, could they reliably tell the difference between the flooding due to heavy rain and the flooding due to a sudden, fast-moving current?

Would the nature of these observations be different if there were no eyewitnesses?

C. Water Currents on a Larger Scale

This activity is essentially the same as the previous one, but it uses larger areas for the study. If you have an area on or adjacent to the school yard where you can conduct this experiment, repeat the explorations in Activity B in this outdoor location.

If you have already done Activity B in the classroom or lab, ask students to brainstorm how their observations might be different in this exploration compared to the others and why.

IV. Film Follow-Up Questions

For use after one or more of the "lab" or field activities.

1. When scientists examine geologic formations that were produced millions of years ago, how can they be confident that they know the way that the formations were produced?
   (a) How would a scientist tell when a geologic formation that was produced by an unusual, catastrophic event, such as a flood, tsunami, or earthquake, for example?
2. In your explorations of the effects of water on landforms, which of them produced a result most like the formation of the Grand Canyon—the movement of a single water current over time, the effects of a large "burst" of water over a short time, or the exposure to an extended period of "rainfall" in your mini-habitat?
3. Which of your explorations is most similar to recent flooding events in the news: the 2011 Tsunami in Japan, the flooding from Hurricane Irene on the east coast in the summer 2011, the flooding in the Dakotas in spring 2011 … or some other flooding event you learned about in your research?
4. Now that you have completed this study, what general predictions would you make about what alterations of landforms you would expect to find after these different types of flooding events?
   (a) A strong current of water;
   (b) A sudden surge of water (from an ocean or large lake; or from the destruction of a natural or artificial dam);
   (c) A build-up of water due to an abundance of water only (such as long periods of heavy rain), but not associated with a storm surge or strong current)?
5. From watching and listening to scientists studying formations like the ones in the Grand Canyon, do they use a single formation or location in the Canyon to draw their conclusions?
   (a) How many different types of evidence did they use to reconstruct the geologic history of the Canyon?
   (b) How do they respond to unusual or inconsistent data when they find them (for example "unconformities")?
      i. What part do these responses play in the process of scientific inquiry?
6. After viewing the film and completing these activities, how confident are you that …
   (a) scientists can understand and explain events in the past that no one witnessed or recorded directly?
   (b) your understanding of the process that scientists use to study these past events will allow you to accept the conclusions of these scientific studies?
   (c) your understanding of the process that scientists use to study these past events will allow you to accept the conclusions of *other* scientific studies?

V. Extension Activity

A. Webquest

With the recent landfall of several hurricanes and tropical storms in the eastern part of the US, we have an opportunity to observe how flooding over very large areas produce geographic and geologic changes in land forms.

These sorts of events are often referred to as "natural experiments" since they allow us to make direct observations of the effects of specific events and forces on the terrain in a specific area.

Through these observations, we can answer some questions about how sudden changes in wind, rainfall, river, ocean, and soil movement is recorded in the geologic record.

A webquest allows students to add to the information that they acquire in class by exploring a theme or an event through information available on line (more information, including model webquests and templates for students and teachers, can be found at http://webquest.org/).

Here are some guiding questions for the webquest:

A. What are the most common changes in landforms associated with wide-spread flooding?
    - I. Are these the same everywhere, or do they vary from place to place?
    - II. What are the conditions that may cause them to vary?

B. What differences can we observe between the material deposited by a flood or a fast-moving current of water and material deposited by waves or by simple sedimentation?
    - I. Are these differences always present; or mostly present?
    - II. How are these differences caused?
    - III. Are the causes more constant or more variable?
        - a. Is it easy or difficult to confuse the types of deposits produced by the two?

C. Based on these observations, which of the geologic deposits illustrated in the film are likely to have been caused by the actions of currents and which by sedimentation under calm conditions?

D. In comparing the after-effects of flooding and storm surges from the Atlantic hurricanes in summer 2011, would you conclude that the geologic deposits (*not* the erosion that exposed them!!) in the Grand Canyon are more similar to the effects of these widespread and sudden floods or to the gradual deposition of materials over a longer period of time?

Here are some sites to get you started:

American Geological Institute: http://www.agiweb.org/geoeducation.html

ELEMENTARY: http://www.k5geosource.org/index.html
Rivers and Land: http://www.k5geosource.org/2activities/1invest/rocks/pg5.html

MIDDLE SCHOOL: http://www.agiweb.org/education/ies/rocks/index.html
middle School Investigations 5 & 6

CUES: Chapter 3 Surface Processes
http://www.agiweb.org/education/cues/TeacherResources/geosphere/chapter3/index.html
(Teacher's Guide: http://www.agiweb.org/education/cues/teachers/index.html)

More Resources: http://www.agiweb.org/education/ies/rocks/research.html

HIGH SCHOOL: Watersheds and Rivers Investigations:
http://www.agiweb.org/education/es/units/2/ch6/index.html

US Geological Survey: Storm Surge video:
mms://video.wr.usgs.gov/movies/exploring_storm_surge.wmv

Geology.com (Geologic Society of America): http://geology.com/teacher/

Images of sediments after flooding: http://www.google.com/search?q=flooding+sediment&um=1&hl=en&biw=1260&bih=863&tbm=isch&ei=J4pKTuOpD-mgsQLe7sC6CA&sa=N&oq=flooding+sed&aq=6v&aqi=g-v10&aql=&gs_sm=c&gs_upl=7297l17734l0l21624l6l6l0l0l0l0l188l861l2.4l6l0

British Geological Service:
http://www.bgs.ac.uk/science/landUseAndDevelopment/shallow_geohazards/flooding.html

I**daho State U; Environmental Geology Lab**. (college lab needs to be modified)
http://wapi.isu.edu/envgeo/EG3_rivflood/eg3_rivers.htm

Additional Resources

Definitions and Discussions of Uniformitarian Concepts

http://geography.about.com/od/physicalgeography/a/uniformitarian.htm

http://www.enotes.com/earth-science/uniformitarianism (see also complementary page on catastrophism: http://www.enotes.com/earth-science/catastrophism)

http://evolution.berkeley.edu/evosite/history/uniformitar.shtml

http://abyss.uoregon.edu/~js/glossary/uniformitarianism.html (original text at http://www.britannica.com/EBchecked/topic/614600/uniformitarianism)

http://www.talkorigins.org/indexcc/CD/CD200.html

Examples from Research

Example of actualism (modern understanding of "uniformitarianism").:
http://undsci.berkeley.edu/article/0_0_0/alvarez_01

Other

Student worksheet in historical geology with resources:
http://www.sacstate.mobi/indiv/k/kusnickj/Geology12/Ch1&2.html

Phil Plait's essay on the power of science:
http://blogs.discovermagazine.com/badastronomy/2005/05/09/science-fare/

Simulating a Tsunami:
http://www.niehs.nih.gov/health/assets/docs_a_e/ehp_student_edition_lesson_tsunami_simulation_experiment.pdf