

SYNOPSIS	Students manipulate sealed "mystery" boxes and attempt to determine the inner structure of the boxes which contain a moving ball and a fixed barrier or two. The nature and sources of uncertainty inherent in the process of problem-solving are experienced. The uncertainty of the conclusions is reduced by student collaboration and scientific argumentation.
PRINCIPAL CONCEPT	Scientific knowledge is fundamentally uncertain.
ASSOCIATED CONCEPTS	<ol style="list-style-type: none">1. Science is uncertain because it is a human activity.2. Science explanations seem less certain when they are based on indirect information3. Scientific uncertainty can be reduced through collaboration.4. Scientific argumentation is based on justified evidence.
ASSESSABLE OBJECTIVES Students will.....	<ol style="list-style-type: none">1. Distinguish between observations and interpretations.2. Recognize and/or demonstrate two causes of uncertainty in science.3. Illustrate how information can be obtained by using non-visual sensory data.4. Demonstrate that science is a collaborative enterprise.5. Recognize the elements of scientific problem solving as encountered in the activity.6. Recognize elements of scientific argumentation.
MATERIALS	<p>Each "Mystery Box" is a rigid, permanently sealed, opaque, rectangular box with one or two glued-in partitions, ramps, etc., and a rolling sphere (e.g. a marble or steel ball). A class set of boxes should have groups of 4 to 6 boxes with the same interior contents and arrangement, with common labels or colors. Keep barrier layouts simple. It's OK if a barrier here and there comes loose (these are "mutations").</p> <p>The original model was plastic boxes for 24 glass microscope slides) with wooden barriers glued in and glass marbles. Wooden replicas of this size are the author's favorite, but they are not available commercially.</p> <p>Smaller, 1" x 1" x 2" plastic boxes with plastic and wood barriers and ball bearings were used quite successfully in ENSI and SENSI demonstration lessons. The boxes were obtained from a plastics store in Northern California. There are 8 colors available, but that is no longer the case. The only opaque boxes available from this source are black and white, which isn't fully opaque to bright light. (Let us know at ENSIweb if you find an acceptable box source.)</p>
TIME	Full 45-55 min. period.
STUDENT HANDOUTS	none

TEACHING STRATEGY

Because this lesson provides an excellent opportunity to understand important elements of the **Nature of Science**, be sure to read our [Teaching the Nature of Science](#), with our Rationale, our Approach, and tips for Presenting the lessons for maximum effect and Dispelling some of the popular myths about science. Also, see the [Index to Useful Overviews of the ENSI NOS Lessons](#), and information on [Scientific Argumentation](#) for strategies for doing that. SA is an important component of the NGSS and CCS.

Ideally, the teacher will not know the inner contents and/or arrangements inside the boxes, and, in any case, will never divulge any knowledge of the contents. To be totally honest, someone else should prepare the boxes; two teachers can prepare the boxes for each other, and not share the content information.

Chalk boards / white boards should be erased, so that students will have room to draw their pictures of the contents of their boxes.

PROCEDURES

1. Hand a box to each student. If possible, do this as soon as the bell rings, before taking roll. Scatter the types of boxes randomly in each area of the room. Make it clear that the boxes are to remain closed.

STUDENTS: will look at boxes, pick them up, shake them, and look for a way to get inside. They will ask questions of the teacher (don't answer)...lots of noise!

ENSI 92 Teachers "Doing" the Mystery Boxes
Tom Atkins, Ralph Peterson, Ray Potts, Cheryl Garcia's back, Brian Stanley,
Bonnie Romono



2. After a minute or two, get the class' attention. Ask students to describe what you have given them.

STUDENTS: will volunteer information, e.g. box shape, size, material, ball inside, obstructions inside, color, etc.

3. After the class reaches general agreement about the similarities (size, shape, opaqueness, moving interior object) assign that each box be analyzed to determine its interior configuration (contents, arrangements). Ignore comments about differences to focus them on the task at hand. Indicate that A "report" for each box's insides is to be drawn on the chalk board. Don't encourage sharing at this time.

4. While they are working, draw enough rectangles on the white board so there is one for each box. Walk around the room. Encourage them to report by completing a drawing of the insides in their rectangle on the board. Insist that scientists identify their work by placing their names under their "reports". Early "reporters" can continue to refine their interpretations at their desks.

5. When all drawings are complete get the class' attention again. Ask the students to scan the array of illustrations on the board referring to the drawings as data. First, ask for any statements which they can make about the total set of drawings. (e.g. "They are not all alike.") Then ask if they have any questions for any of the 'reporters.' This may elicit more complete drawings or labels. Then, ask for

suggested evidence of patterns which seem to exist.

STUDENTS: will notice that the boxes aren't all alike, and that some boxes that look alike *might* be the same inside. They may also want to add the color or label of each box to the diagrams on the board, and when they do, may see some correlation between that ID and the insides. Permit modifications of drawings while the discussion continues.

ENSI 92 Teachers Discussing "Published Boxes"
Leslie Hays, Sandi Watson, Eric Kuwada



6. Ask how they would suggest testing the patterns.

STUDENTS: will usually decide that all people with boxes of same color (or label) should compare information and boxes.

7. Based on their suggestion, get them into groups for further information gathering, comparisons, and analysis. Ask the group to improve the data report(s) if possible.

8. Again, watch the groups. Note interactions. Encourage them to improve or modify the diagrams on the board (their own reports). If there is apparent agreement ask them to make a single drawing with all names associated, and get them to erase the drawings they have replaced..

STUDENTS: will make new drawings or perfect their earlier ones, and remove redundant or incorrect illustrations.

ANALYSIS - ARGUMENTATION:

9. When the groups have generally agreed on the arrangement of contents, again get the class' attention. Have someone from each group describe the process that their group went through to arrive at its report; what they DID, not what they decided. This will not be easy for them. Start with a group that concurred on one drawing fairly quickly and save the still conflicted groups for last. Learn about effective persuasion first. Note heroic people who would not be persuaded to give up to group pressure.

--- a. What did people do?

STUDENTS: traded boxes, compared impressions, told and showed others how to investigate a box and what to look/listen for (persuasive techniques), or developed new tests; ask "how were some people convinced to change interpretations?"

---b. Ask for examples of observations made.

STUDENTS: call out examples of their **observations**.

---c. Ask students to identify any “**observations**” (what was actually perceived) that were actually **inferences** (what was subconsciously inferred directly from those observations).

STUDENTS: point out examples of “observations” that were actually inferences. Examples: “I heard the marble roll...” (inferring it was a marble; could be wooden ball). “Rolling object hit a wall...” (wall inferred; could be a pit or groove).

--- d. Discuss the role of common human traits, as it might affect problem-solving: egos, preferences, experiences, and biases; ask students to share their experiences with this.

STUDENTS: should refer to their experiences with interactions in reaching conclusions. (You may want to describe several interactions you observed while they were working.) They will probably try to **justify** what they did, which enhances the discussion.

--- e. Discuss the impact of these factors on objectivity. How does this affect one's confidence in the final explanation? Does this happen to real scientists doing real science? [yes]. Consider possible safeguards against excessive bias or domination. [The relative objectivity of measurement, publishing one's research (so others can repeat the work), and peer review, **all reduce the influence of bias or domination.**]

--f. Point out that students have essentially engaged in **scientific argumentation**. Did they notice that they made **claims**, pointed out the **evidence** for those claims, and **justified** that evidence as making the case for their claim? Did they also see **rebuttals**? Did others challenge the claims (offering evidence that countered the other evidence)? This is **SCIENTIFIC ARGUMENTATION**, something that goes on in all good science. The NGSS and Common Core include scientific argumentation in their expectations. Several articles in the NSTA journal *The Science Teacher* (Summer 2013) describe various effective strategies for using scientific argumentation. [Click Here](#) for an extended review of those articles, plus links to ENSI lessons that use or accommodate scientific argumentation.

--g. Ask how this is different from arguing with parents.

STUDENTS: May recognize that arguing with parents, friends, etc. is when claims are usually based on feelings or opinions, seldom on empirical evidence that justify the claims.

SEE THE **EXTENSION AND VARIATIONS** BELOW, ESPECIALLY THE MYSTERY BOXES ACTIVITY BY GERALD RAU – **ITEM F**, WHERE DIRECTIONS AND MATERIALS ARE PROVIDED TO DO HIS VERSION OF THE MYSTERY BOXES EXPERIENCE.

10. **Collect the boxes** when the discussion about their investigative techniques and their relationship to the way that scientists work is apparently complete.

STUDENTS will ask about the correctness of their reports, in the form of 'did we get it right?'

11. Re-inquire about their confidence in the information that they have reported. Were they giving you a story, didn't they do their best work - - what's the problem?

STUDENTS will admit to uncertainties about indirect information (something they couldn't see).

12. Find out what other non-invasive tests they might do with more time and better equipment (balances, magnets). Ask if this would make them more comfortable with their answers.

STUDENTS will usually admit that they expect confirmation of their answers from teachers.

TEACHER REPLY: If you have used these boxes before assure your students that their reports are similar to earlier ones you have seen. Point out that scientists don't have a place to check their

answers. Make the case for the importance of reporting to others so that tests can be run by others.

14. Discuss the precise sensory information gathered, and alternative interpretations one might derive from those observations. Distinguish perceptions (sensory experiences) from inferences (what our brain automatically interpreted from those experiences).

15. Discuss: consistency, predictability, tentativeness of the interpretations (generalizations). Ask how certain are they that their particular interpretations are the correct ones? Did they notice the variations in diagrams of what might be identical boxes?

16. IN SUMMARY, ask students to clearly but briefly state two different reasons why science is uncertain.

STUDENTS: should point out two causes of uncertainty: 1) normal human activity, with its biases and different perspectives, and 2) indirect information and inability to directly observe a situation.

17. IN SUMMARY, ask students to clearly but briefly suggest how uncertainty could be reduced.

STUDENTS: should include in their response that communication and cooperation can help reduce uncertainty.

18. At this point (if not done earlier), collect the boxes **without** revealing their contents.

19. OPTIONAL: Have students describe the scientific processes that were used by their groups.

STUDENTS: should express a clear statement of the **problem**, **hypotheses** (possible inner configurations that would explain their perceptions), **predicting** and experimental **testing** (tilting, while listening, feeling for expected movements), **argumentation** (dialog between students about claims and evidence), and **reporting/publishing** (showing diagram on board), etc.

20. Note the purpose of the boxes: to illustrate knowledge that could be gained from unseen information. Real examples: atomic model, Earth's interior, composition of stars, etc..

21. If asked, explain what you DO and do NOT know about the insides of the boxes. Hopefully you won't know too much, and can explain why that makes them better examples of scientific problems. Discuss the pitfalls of countering student information with "the right answer." Note the comparability of student information, and probable sources of discrepancies. Get students to realize that we will never know the totally real answer to any scientific question, but we often come close enough for practical purposes and future exploration. Encourage students to look for similar data for other boxes, exchange boxes for further checking and fine tuning, then be reasonably satisfied with the most probable description of the insides: their best hypotheses.

ASSESSMENT

1. Observe that all students are engaged and take turns in handling the boxes, exchanging dialogue, and sketching their interpretations on paper.

2. Develop tests that address the assessable objectives listed for this lesson.

EXTENSIONS AND VARIATIONS:

A. Ask students to suggest what aspects of the natural world are most like a mystery box. [Alternatively, or even as an assessment, project the following list on your screen, and ask students to select which items are most like the mystery box exercise, and explain why:]

1. Making a map of Yosemite National Park	6. Learning the structure of an atom.
2. Making a map of the Earth's interior	7. Finding out how DNA works.
3. Exploring the surface of the Moon.	8. Learning what causes a new disease.
4. Exploring the surface of Venus.	9. How do we remember things?
5. Studying a cancer cell.	

B. CHECKS LAB: Try this other excellent and very popular lesson which, as presented here, embodies many of the same elements as the Mystery Boxes. Makes a good alternative to the Mystery Boxes.

C. PAPER BAG MYSTERY: Here is another alternative to the **Mystery Box** lesson, using objects in a paper bag, with a consideration of the characteristics of life incorporated: "I begin the year with an exploration in which my students are given brown paper bags with various objects in them in which they have to determine the contents of the bag as living, once living (now dead), or never living, without opening the bag itself. This leads into the discussion of testable and observable and knowing without seeing. It is a great discussion opener for understanding 'what is science?'"

I have used any object that I can grab. Some of the following have been used: berry branches, rocks, birds nest remains, sulfur, mushroom, fossils, bark.... really it is just anything that I can find the weekend before around the house and local park. I will make several bags, typically at least 4-5 bags (label bags of A,B,C,D etc to promote organization), for each group. I do try for a group size of 3 and use group roles as materials manager, reporter/recorder, time manager to introduce the importance of working together."
Jennifer Berry, PhD

D. Another teacher adds this variation: "One time I did the bags with one of them containing a "slam" toy. You know---the toys that make a noise or say something if you slam them down? It was so funny to have kids be working along and then suddenly hear their bag say "ouch!" (I told them to include sound, so they may want to see what it sounds like when they drop it from a short distance to the table. I, of course, did not have anything breakable in any of the bags.)"
Shirley Greene

E. WHAT'S IN THE BAG! Still another variation, focusing on hypothesis-building and testing, collaborative efforts, and associated terminology, using **ONE** sealed bag. Kindly provided by Candace Lutzow-Felling. [Click HERE for the narrative for this.](#)

F. MYSTERY BOXES - A NEW TWIST

by Gerald Rau in *The Science Teacher*, November 2009, pp. 30-35. Click on title (above) for more detailed description and materials to do this excellent version of Mystery Boxes.

Here's an interesting alternative to consider. The focus here is for students to clearly distinguish **evidence** from **inference**, and how to construct **scientific arguments**. It also shows **how scientific evidence gradually accumulates over time**, so they understand why **scientific knowledge changes over time**. In the process, curiosity is stimulated, and questions are asked about the objects that will be answered later in the year.

This approach also helps to **refute the misconception that science follows a single universal method**. It has been used effectively (with minor changes) from **middle school** through **college**, and would also probably work at the **elementary** levels. It was developed as a **Biology** activity, but with different objects, could also be used in **Earth and Physical Science classes**.

Students experience **observation**, **interpretation** and **argumentation**. They are led through several alternating stages of **observation and inference** about an unknown object, during which they learn the value of representations and **collaboration**. They are then asked to **construct an argument about the identity of the object and the process of its formation**. Each object is something not easily recognized by the students, but has identifiable characteristics. For Biology or Life Science, it should be "produced by a once-living organism and modified in some way, either by human or natural activity." Examples are given. Detailed steps for presentation are provided, along with a grading rubric for the written report.

ALTERNATIVE LESSONS (All interactive demos by the teacher):

1. [Find the Washer](#).

2. The Great Volume Exchanger.

3. The [Magic Hooey Stick lesson](#).

4. Do the "**Phantom Tube**" demo, as described in [Teaching About Evolution and the Nature of Science](#). Unfortunately, this one doesn't work too well, so get the detailed instructions for making and demonstrating a [Phantom Tube that works](#).. This is a **Flinn's Chem Fax**, a 4-page version of their puzzle tube. You pull on the strings and the students watch the other strings move up and down in surprising ways. You can walk through the entire process of science using the Phantom Tube - OR... decorate your **Phantom Tube** with mystical figures and present it with flourish as real "MAGIC" (see example at left) - then "reluctantly" let students get skeptical and critique that idea and seek a NATURAL explanation. **MOST IMPORTANT:** do **NOT** allow the students to see the inside of the tube, nor explain how it works, or even give cues. As in the Mystery Boxes, get students to use drawings to show their hypotheses (or models) of what they think the inner workings are most likely to be, and figure out ways to test those hypotheses. If anyone hits on the its essential mechanism, do NOT say "that's it!", Just ask "does it work?" If it does, it's the "Best Hypothesis so far." It's important for them to see that in science we typically never get to **see** the "answer." It's always tentative - the explanation that works best - so far. [Click Here for Special Instructions](#).

5. For another type of **Mystery Tube** to add to your NOS Tool Kit, take a look at the **3-D Molecular Design** version. They are about 18 cm (7 in.) long. They come with presentation directions and discussion questions. Specific ways these tubes meet the NGSS are pointed out. Prices and contact information are provided for ordering (use their phone number).

6. Also, consider getting [The Data Dilemma](#) lesson from **3-D Molecular Design**. This engaging lesson models how **scientific models** are developed, tested and modified with new information. It uses **Tangram** pieces as examples of "information" used to build a particular shape, as a metaphor for how science works. Instructions are provided along with sample questions for class discussions. Specific ways this lesson meets the NGSS are pointed out. Prices and contact information are provided for ordering (use their phone number). Enough material in one kit for 12 teams.

ATTRIBUTIONS

Some of the ideas in this lesson may have been adapted from earlier, unacknowledged sources without our knowledge. If the reader believes this to be the case, please let us know, and appropriate corrections will be made. Thanks.

1. Original Source: Use of slide boxes with wood barriers and glass marbles to investigate the unseen from trial versions of SCIS unit on atoms. Lawrence Hall of Science, Berkeley, CA
 2. Modified for demonstration of science processes.by: Jean Beard
 3. ENSI / SENSI original using small plastic boxes developed by: Jean Beard
 4. Reviewed / Edited by: Martin Nickels, Craig Nelson, Jean Beard 9/98
 5. Edited / Revised for website by L. Flammer 9/98 ;
 6. Major revisions, updating, adding new alternative lesson links: Flammer July 2013.
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