Black Boxes: Using the practices of Science to investigate a phenomenon

Summary: In this investigation, students make multisensory observations of sealed black boxes to determine what is inside and then develop conceptual models to show what they think is inside of the box. This simulates something scientists are faced with all the time -- how do we learn about things that can't be seen or touched like very small objects such as cells and atoms, or very large or distant things like solar systems? Making careful observations and building models we can test our ideas about what might be happening in places we cannot see.

Students will

- understand why scientists use models to help them explain phenomena of things that can't be seen directly, e.g. due to their very small size (atoms, organelles) or far away distance (other galaxies, stars), or blocked view (a living brain inside a skull).
- experience how to propose a model of something that can't be seen, based on indirect information gathered from observations and experimentation.

Grades 3-6

Time ~1 hour

Vocabulary
"Black Box": Any system that cannot be directly observed and easily understood is called a black box.

Model: A representation that explains how something is built or how it works.
Conceptual model: explanations expressed in drawings, words or math
Physical model: 3-D construction designed to explain or represent how something works
Phenomenon: something observable (with any of the senses) in the world/nature that you want to explain or make sense of

Materials
black boxes: In this activity we will use black boxes that are rigid, permanently closed, non-transparent boxes with one or two glued-in partitions, ramps, etc., and a rolling sphere (e.g. a marble or steel ball) inside. 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. Partition layouts inside the boxes should be simple. (In the 5th grade Mixtures and Solutions FOSS kit there 4 sets of 8 boxes, each with one of 4 different internal configurations, labelled A, B, C and D. You can also make your own boxes using petri dishes or square plastic boxes -painted so that they are opaque- with pieces of cardboard or popsicle sticks glued into the bottom).
drawing templates: a blank page with a square drawn on it; this helps to normalize diagrams for posting and comparing
markers: dark colors for good visibility on posted drawings of model
tape (optional): small pieces of tape or non-permanent stickers can be used to aid the observations

Procedures
1) Introduce the boxes and present the challenge:
Hold up box-
Today we are going to investigate these black boxes.
Shake the box-
Something is going on inside but I don't know what it is because the boxes can't be opened.
We will investigate and observe these boxes to try to figure out just what is going on inside.
Our challenge is to figure out what the inside of the box looks like, what we would see if we were able to open the box.

2) Establish guidelines

- Students work in pairs or small groups to explore one box (<u>without looking inside</u>.)
- The boxes remain closed!
- No violent shaking or hard pressure – boxes can break

3) Exploring the boxes

a) Students will work in groups of two.
b) Distribute one box, labelled with a letter, to each pair of students (you want to have at least two groups for each different letter)
c) The challenge: Figure out what the box would look like inside if you opened it and looked down on it from above (birds eye perspective).
d) Students gently tilt box and listen as marble moves -- they should take turns conducting experiments by observing and shifting box to explore the way the marble moves within the box.
e) Students write notes and draw diagrams in their notebooks (or on scratch paper) to record their ideas and observations. Emphasize that they should include the evidence for their ideas.
f) After 5 minutes or so, pass out templates, one per group. Have each pair come to agreement and draw a model on the provided template. Remind them to draw what they would see if they looked down on the opened box.
g) Poll: How confident are you in your model?
h) Have students post their models on the board, grouped by letter (A, B, C, D)
i) Discuss - What do you notice?

Regrouping (What can scientists can do when they want more information? Talk to other scientists)

a) Make new, larger groups by combining pairs that have the same type of black box (all the "A" groups together, "B" groups together, etc.). Within the larger groups, students should discuss and compare ideas. The goal is to work together to come up with a model for the black box which can be agreed on. Encourage students to talk about their experiments, ideas about what the interior of the box looks like, and evidence for their ideas. They may also conduct further explorations to try to refine and come to consensus as to how the interior of their box looks
b) Come to consensus and redraw your model on a new template.
c) Each group presents their revised consensus model to the class. Encourage students to include observations that led them to their ideas/model. Also, encourage the audience to ask questions of each other's models and how they came to their conclusions.
d) Poll -- How confident are you in your revised model?

4) Wrap-up / discussion

A model is a representation of the world. Models are often based on evidence from experiments. A model allows scientists to make predictions, and design further experiments to test the validity of the model. Often these new experiments and the evidence that comes from them lead to refinement of the model – much as when groups came together, students incorporated the data (and interpretations) of others, and thereby refined their model. This process of refinement, through evidence and discussion/argument, is critical for the advancement of scientific knowledge.

a. How does this activity reflect the way scientists work?
b. How were the models useful?
c. What kind of evidence did you base your model on?
d. Where else might models be useful in helping to understand phenomena?

Extensions:

For younger students you may want to start by just having them observe the external features of the boxes as a warm up, depending on their observational skills.

To extend the activity, you can begin or follow by having students make their own black boxes that they use to challenge their fellow students. They can create simple mazes in an empty cardboard box (shoe boxes work well) or a petri dish or plastic box. Students use tape and cardboard to arrange one or two 1-2 inch "walls" standing up in the box so that when a marble is rolled it hits the wall and must change direction to continue moving.

A second extension of this lesson is to have the students build physical models of their conceptual models out of empty plastic boxes and pieces of cardboard. This provides a way for them to test their diagram/conceptual diagram by seeing if see if they can reproduce what they observe about their original black box. It also provides the opportunity to talk about refining the model and how, in science, experiments have to be repeated many times to make improvements on a model.

Teaching notes:

- Have students concentrate on what the shapes of things inside of the box rather than the material from which it is made.
- Make it clear that you want students to draw what the inside of the box would look like when viewed from the top.
- When students make observations and describe their ideas about what the inside of the box looks like, help them think about what kinds of experiments they can do to get information about what the inside of the box looks like. Also, help them talk about the evidence or observations they are basing their ideas on. For example:
  I think/claim it looks like ________ because _______.
  I think it looks like _______ because when I _______ the marble _______.
  I observe ________ and it tells me ________.
- Black boxes have been successfully used with third, fourth, and fifth grade students to introduce the nature and process of science. Teachers at these grade levels should **focus on students' understanding that science is uncertain and that scientists base their conclusions on available evidence**. Additional evidence may strengthen their explanations or cause revision of those explanations.
- When using Mystery Boxes with third, fourth or fifth grade students, teachers need to be aware of students' abilities to observe and describe objects. Third (or fourth or fifth) graders may have had experiences and practice using words to describe the size, shape, color, texture, etc. of an object. This should enable them to provide more accurate descriptions of the boxes. If the students have not had the opportunity to learn to use descriptive words, they will have difficulty verbalizing their observations. They may say the box is pretty, which is how they feel about it rather than a description of what they observe using their senses. Students need to be taught this foundational skill before working with Mystery Boxes.
- Third grade students seem to be more open to not looking inside the Mystery Boxes than fourth or fifth grade students. Third graders accept not knowing for sure. When the nature of science is discussed and students are given examples of scientists knowing about things (such as black holes and dinosaurs) without having actually seen them, they seem able to

understand that scientists make conclusions based on the evidence they have and scientists may revise their conclusions based on new evidence. The older the students, the more they want to know the one and only "right answer". For all, the emphasis is on deciding on their best idea based upon the evidence they have.

NGSS Science and Engineering Practices:

Asking Questions and Defining Problems:

- Ask questions about what would happen if a variable is changed.
- Identify scientific (testable) and nonscientific (non-testable) questions.
- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

Developing and Using Models

- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events
- Identify limitations of models

Planning and carrying out investigations:

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or to test a design solution.
- Make predictions about what would happen if a variable changes.

Analyzing and interpreting data:

- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.

Using mathematics and computational thinking

- Use counting and numbers to identify and describe patterns
- Use of logic and geometry
- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address questions

Constructing Explanations and Designing Solutions

- Construct an explanation of observed relationships
- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation
- Identify the evidence that supports particular points in an explanation.

Engage in argument from evidence

- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- Construct and/or support an argument with evidence, data, and/or a model.

Obtaining, evaluating, and communicating information

- Communicate information, evidence, and ideas; can be done in multiple ways such as using tables, diagrams, graphs, models, interactive displays, and equations as well as orally, in writing, and through extended discussions.

NGSS Crosscutting Concepts:

Cause and Effect - Events and phenomena have causes that generate observable patterns. Scientists identify and hypothesize potential causal relationships to explain phenomena, patterns and/or change. They design tests to gather evidence to support or refute their ideas about cause and effects.

Systems and system models - Scientists and engineers use systems and system models to investigate natural and designed systems. A system is a group of related parts that make up a whole. A system may be described in terms of its components and their interactions. The purpose of an investigation might be to explore how the system functions, what may be going wrong, or to make predictions.