Things Are Not Always What They Seem

Suggested Grade Level(s): 9-12
Estimated class time: 1 class period

Summary

Students explore a discrepant event by devising an experiment to try and determine either how a "come-back can" works or what makes UV beads change color.

Objectives

- Students will understand that science is a quest for new information to explain phenomena which may seem at first "unexplainable."
- Students will explore the process of careful scientific investigation and discover how it can change mystifying magic into clear concepts upon which new knowledge can be based.

National Science Standards

- NS.9-12.1 SCIENCE AS INQUIRY
  As a result of activities in grades 9-12, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.4 EARTH AND SPACE SCIENCE
  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Origin and evolution of the universe
- NS.9-12.7 HISTORY AND NATURE OF SCIENCE
  As a result of activities in grades 9-12, all students should develop understanding of
  - Nature of scientific knowledge

Knowledge Prerequisite

This activity should come either near the beginning or end of a unit on stars and galaxies. If used near the beginning, it can focus on the concept that we know what we have learned about deep space by studying information carried by the energy wavelengths of the electromagnetic spectrum. If used near the end it can focus on the realization that we have much to learn about the way the universe works and the present day mystery surrounding "dark matter" and "dark energy" will one day become clear through the process of scientific investigation. Students should be familiar with the progressive structure of the universe from our solar system orbiting our own star to the similarities and differences of stars in general and to the make-up of galaxies of millions of stars.

Materials

- "Come-back Can" – a small coffee can with snap-on plastic lid on both sides (to make it roll straight) or oatmeal canister with lid; sturdy rubber band; large steel nut or other weight with a hole in it; two small paper clips. Find directions for making a "come-back can" at http://www.msichicago.org/online-science/activities/activity-detail/activities/make-a-comeback-can/
- UV sensitive beads (5-10/student) strung on a heavy string bracelet. (Educational Innovations, www.teachersource.com)
- Various sunglasses
- Access to automobile windows or auto glass from front and passenger windows
- Various equipment to allow students to devise their own experiments such as thermometers, beakers, ice, warm water, desk or table lamps

Note to Teacher: The following lesson can be done using either the come-back can or the UV beads as the Engagement, then using the other for the Exploration. Narration for both is included so you can decide which will work better for your class. For example, if your students are already familiar with UV beads, you might use the bead's surprising color change as the Engagement to introduce the concept that things are not always what they seem and allow the students to Explore with the Come Back Can as a discrepant event.

Procedure:

I. Engagement

Option #1: Engagement using the come-back can
Ask your students to list all of the "facts" they have learned about gravity (possible answers might be all objects in the universe have a gravitational attraction for one another, attraction is influenced by the masses of the objects, and attraction is influenced by the distance separating the two objects). Remind them that objects such as people, the desks in the classroom, and the school building itself are held to the earth by gravity.

Now, show your students an ordinary-looking coffee can (the come-back can), and then place it on the floor. Ask students what they think will happen when you give it a push to roll. They should answer that it will keep rolling, and they may point out that eventually friction (or a wall) will stop it. Then give the can a push to roll across the floor. After it rolls for a moment, use your most authoritarian voice, and command the can to STOP and RETURN. (Practice the timing a few times before doing this in front of the class!) The can will slow, stop, and roll back.

Ask the students what they think happened. Did gravity behave oddly? Did it respond to some other force at your control? Remind students that things are not always as they seem. Allow the students to hold the can and finally look inside the can. Upon more careful inspection, the can will reveal the reason for its odd behavior. Tell students that similarly careful investigation can change magic into science.

(Teacher: The kinetic energy of the initial push to roll the can is transferred to potential energy as the rubber band is twisted by the inertia of the hanging weight. Then the can returns as the tightly wrapped rubber band unwinds, transferring that potential energy back into kinetic energy.)

Option #2: Engagement using the UV beads
Give each student a bracelet of UV beads on a loop of string. Have them slide the beads around the loop until the knot on the string is just to the left of the first bead. Ask students to list as many characteristics of the beads as they can – color, dimension, mass, anything they can thing of – and write down the list on the board. Now, take the students outside and have them make as many new observations about the beads as they can. After five minutes outdoors, have them make any last observations in their notebooks and return to the classroom.

Ask your students what they think caused the beads to change when they were outside. Ask them what happened when they returned to the classroom. Was there some odd force at work? How did the beads know when they had gone outside? What could be outside that caused the color to change? Explain to the students about UV radiation – the kind of radiation that causes skin to tan and burn – and that these beads respond to UV radiation. Show what happens to the beads in sunlight filtered by a window (which usually has UV-filtering), so it is not just bright sunlight. Tell students that similarly careful investigation can change magic into science.

II. Exploration

Option #1: Exploration using the UV beads
Give each student a bracelet of UV beads on a loop of string. Have them slide the beads around the loop until the knot on the string is just to the left of the first bead. Ask the students to record as many observations about the beads as they can in their notebooks. Encourage them to record quantitative observations, including how many beads there are, their dimensions, mass, anything you can measure and record with numbers. Also encourage them to record qualitative observations including descriptions of color, texture, and general appearance using adjectives or adverbs. Now, take the students outside and have them make as many new observations about the beads as they can. After five minutes outdoors have them make any last observations in their notebooks and return to the classroom.

Ask your students what they think caused the beads to change when they were outside. Ask them what happened when they returned to the classroom. Have them write a hypothesis in their notebooks to explain what factor (variable) caused the changes in the beads. Now ask them to design an experiment to test their hypothesis. Remind them that a good experiment has only one variable at a time while keeping all other variables constant. For instance, if they place the beads under a bright desk lamp, are they testing the effectiveness of light or heat?

(Teacher: Try to do this experiment on a day when the outdoor temperature is considerably different than the indoor temperature, either colder or warmer. Most students will attribute the color change to temperature because that is most obvious. When you are outdoors, try to be in an area that is in bright sunlight but still the same general temperature as the ambient air. Some students will connect the color change with light, but will think it is the brightness of the light that matters most.)

(Teacher: Provide thermometers, beakers, ice, desk lamps, dark cupboards, hot water (not over 50˚ C), and as many other materials as possible so that students can design their experiments. Usually it is best to allow the students to work in teams of two, but remind them to carefully record their data because they will be sharing with the class later. Eventually results should show that neither temperature nor intensity of light is the factor that affects color change.)

Option #2: Exploration using the come-back can
Ask your students to list all of the "facts" they have learned about gravity (possible answers might be all objects in the universe have a gravitational attraction for one another, attraction is influenced by the masses of the objects, and attraction is influenced by the distance separating the two objects). Remind them that objects such as people, the desks in the classroom, and the school building itself are held to the earth by gravity.

Now, show your students an ordinary-looking coffee can (the come-back can), and then place it on the floor. Ask students what they think will happen when you give it a push to roll. They should answer that it will keep rolling, and they may point out that eventually friction (or a wall) will stop it. Then give the can a push to roll across the floor. After it rolls for a moment, use your most authoritarian voice, command the can to STOP and RETURN. (Practice the timing a few times before doing this in front of the class!) The can will slow, stop, and roll back.

Ask the students to write down their first thoughts about the motion of the can. What features made it possible to move across the floor in the first place? (It is a cylinder, which makes it able to roll across the floor and back in a fairly longitudinal direction as opposed to a ball, which can roll in any direction. The can might not be able to flip end over end as easily.) What might have made the can come back? Have students write down a hypothesis of what made the can come back.

It would be helpful to have several cans for the class so they can work in groups of 2 or 3 students. Allow the students to explore the can, but tell them not to take off the lids just yet.

Some things you might suggest that they do with the can include:

- Tell them to let the can come to rest on the floor in front of them. Have them gently rock it slightly left or right and release. What happens? (There seems to be some inertia that "pulls" it back to its starting position.)
- Have them sit the can up on one end. Ask them if it seems inclined to move as easily as it did when lying on its cylindrical side. (No, but they should notice that it does feel like something is rocking around inside.)
- Ask students to write any observations with their other senses as they observe the can's motion again. (They may hear a clinking sound as the weight bumps the side of the can.)

Now, review what the students already know about kinetic and potential energy. When they roll the can across the flat floor, what provides the kinetic energy to cause the motion? (Movement of your muscles in hand and arm.) How might the can convert that kinetic into potential energy? How could "rolling" facilitate that conversion? (Rolling is like winding something up and many toys store potential energy because of a wind-up mechanism).

Finally, have the students look inside the can by gently prying up the lid, but not removing it. Have them roll the can slowly along a table while they observe the inside of the can. Ask them to describe what they see. (The weight remains hanging down due to inertia, which causes the rubber band attached to it to begin to twist as the can turns round and round. The rubber band is elastic and will untwist when released.)

Ask students to write an explanation of the "come-back can" using the terms potential energy, kinetic energy, inertia, elastic, winding, and unwinding. Compare the results and conclusion of their investigation with their first explanation written after first seeing the can in action.

III. Explanation

Explanation for the UV beads
When the students have completed their experiments and presented their results to the class, ask the class if they can come to a consensus about which factors do not cause changes in the beads. Sometimes things are not always what they seem to be. What other factors existing outdoors but not indoors could have an effect on the beads? If necessary, have the class go back outdoors. Have the students hold the beads in the palm of their hands and cover a few of the beads as completely as possible with one lens of a pair of sunglasses. Or have them hold a bracelet of beads against the inside of the front windshield of a car making sure that the only light reaching the beads is coming through the glass. Have them do the same thing against the inside of a back seat passenger window. Does the glass of the car windows or sunglasses have any effect? How could they design another experiment to test any new factors they now think could cause the color change?

(Teacher: UV blocking sunglasses and the front windshield of the car should reduce or prevent the color change. The side windows of most cars are not as effective at blocking

UV and the beads should show some color change. Some sunglasses are less effective at blocking UV so you will see some variation and the students should begin to start talking about UV. If they still need some hints, ask them why we wear sunscreen when we are outdoors. Walk into some shady areas so that the students realize that UV radiation is present in any sunlight and not just a result of the direct brightness of the sun. Back inside of your school building, try standing near different windows. Older windows are not UV resistant, but most recent construction, especially skylights and large panels of glass are. If you have an ultraviolet lamp to test the fluorescence of minerals, you can demonstrate the UV effect on the beads back in the classroom. A small UV light source is sold in pet stores to detect urine. A party "blacklight" might cause some effect.)

Explanation for the come-back can
When the students have completed their experiments and presented their results to the class, ask the class if they can come to a consensus about which factors might cause the can to come back. Sometimes things are not always what they seem to be. How does the weight inside the can affect it's motion? Why is the rubberband necessary? Would the same thing happen if the weight was held inside by a string?

IV. Extension

When astronomers view distant galaxies they can calculate the masses of the stars they observe, and they can also calculate the speed at which the stars are moving. Ask students what would happen if they placed an object on a record player turntable or a lazy Susan and spun it fairly fast. What would happen to the object? It would fly off the table. Stars in galaxies are moving much faster than a lazy Susan, yet they do not fling themselves off into space, and the galaxies don't disintegrate.

Tell students that the gravity of the great masses of the stars should hold them together. However, when the astronomers calculate the gravity needed to hold the galaxies together at the speed they are moving, all of the stars they can see just are not enough mass. Things must not be what they seem. Scientists are asking big questions for which we do not have many clues for answers. The terms "dark matter" and "dark energy" are used today to refer to these explanations we don't have. Perhaps there is a type of matter and/or energy for which astronomers have not developed the tools to perceive or measure. Maybe there are factors about the principles of gravity and mass we don't understand as well as we think we do.

Have students finish this lesson by brainstorming with their classmates to make a list of questions for which we still do not have answers. (A few possible answers: precise predictions of tornadoes, causes of several major diseases, exact cause of global warming.)

Next, have the students pick one of those questions and try to map the steps scientists would need in order to search for the answers. Do they need a new technology to find and record information, a new material that can withstand extreme environmental conditions? Do they need to break the bigger questions into smaller ones? (For example: Scientists have studied nuclear fusion of hydrogen in stars. If they could harness that process on earth, we would have a source of energy that would use water as a source of hydrogen fuel and be pollution free. But how could we duplicate the enormous mass and temperature of a forming star? One problem was to find a way to make a container for hot hydrogen, so hot that it would melt or burn any substance currently known. We know that matter in stars is in the form of plasma, which is matter in a charged condition. Scientists created a donut-shaped toroidal magnetic field, charged so that the hot hydrogen is "held" inside of that field without actual contact with a physical container! It was a totally different approach to making a "container," but it was very effective. However, there are still many questions to be resolved before hydrogen fusion is possible on a practical scale.)

The deep secrets of the universe are no more magical than the "come-back can" or the UV beads. We just need to keep asking questions and designing careful experiments. There are real answers; we just need to keep doing real science to find them.