Investigation 1:
Observing, Predicting and Questioning using the Apparatus as a Focus

Scientists look at their world and what happens in it carefully. Their observations usually begin with unusual or peculiar events—things that arouse their curiosity. One scientist said, "The cure for boredom is curiosity. There is no cure for curiosity!" In this class you will be introduced to some apparatus that is quite new. Even many scientists have never seen such a device. Your task today is to observe, question and predict based upon what goes on in this class time.

As a scientist, you will make and write careful observations about what you see. These observations may be as simple as the color of the wires of the apparatus or as complicated as a guess at the chemical formula of the plastic used in the apparatus. There are no right or wrong observations. What you see is important.

As soon as your teacher has the apparatus ready for operation, look over the components carefully. You might consider:

- Do they have any signs on them that give some clue to what this apparatus does?
- Are any measuring devices in use?
- Are all of the materials familiar to you?
- Are any special precautions being taken during the setup?
- Is there any relationship between the colors of each component or connection?
- Can you see all of the apparatus or are some parts hidden?
- Can you name any parts of the apparatus or from their structure or position figure out what they are used for?

Remember that no one is evaluating these observations. They are simply the base from which we begin to predict and question what happens.

Imagine how Luigi Galvani (1737-1798) might have felt when during a thunderstorm he noticed how a frog's leg muscle, which he had suspended from a brass hook as part of an experiment he was working on, jumped for no apparent reason. For more information about Galvani and his famous observation, go to http://www.corrosion-doctors.org/Biographies/GalvaniBio.htm

When your teacher begins to work the apparatus you will be given a chance to make more observations.

- What do you notice happening that was not happening before?
- Are there any moving parts?
- Is anything moving or changing position?
- What do you think is happening?
- What do you observe has happened?

Now you can begin to form some predictions beginning with the words, "I think that…." But you need to experiment with the apparatus to be sure of what is happening. It is from such predictions we can design experiments that will prove or disprove our ideas. Some of your predictions may be easily tested, and others may be more complex, needing special equipment or equipment that has not been developed.

You are now experiencing something of the true nature of science where an idea must be tested, retested and shown to be repeatable. If you cannot see the same (or at least similar) results when you do your test again, then something else may be actually causing the phenomenon. Galvani originally suspected the electrical storm was causing the frog's leg to jump, but his subsequent testing showed that the combination of metals—copper in the brass hook and iron in the scalpel—was causing it.

Always remember that the nature of science is to look for events that may not quite fit into our understanding of the world and then test them to see if we can refine our understandings or create new ones. For every answer to an experiment or investigation there are countless new questions that may prove to be far more valuable than the small piece of information we obtained from the investigation.

This testing, the basis for scientific *truths*, can be a lengthy and exacting process. As Michael Jordan says, "Step by Step. I can't see any other way to accomplish anything." Scientists' steps are the many observations, predictions and questions that lead to more experimentation and testing that lead to more questions and so on. Your task today is to **observe** carefully, make some **predictions** about what you think may be happening and then design some **questions** that may allow you to confirm or negate your predictions.

Observe, Predict and Question. O – P – Q: part of the scientist's alphabet.

Teaching supplement for Investigation 1: *Observing, Predicting and Questioning using the Apparatus as a Focus*

The major goal of this investigation is to allow the students to begin to ask questions about the apparatus and what it is doing. The learning objectives may be written:

- Students will observe, predict and formulate questions while watching the apparatus being set up and operated.

Teacher Notes

OPQ stands for Observation, Prediction, and Question. These are the driving forces for the beginning of any scientific investigation. It is important for students to be allowed to practice these skills intentionally and with guidance from a teacher. This fits in well at the beginning of a unit as an Elicit activity (7E) and should be repeated intermittently throughout a school year to gauge student progress towards growth and mastery of these skills.

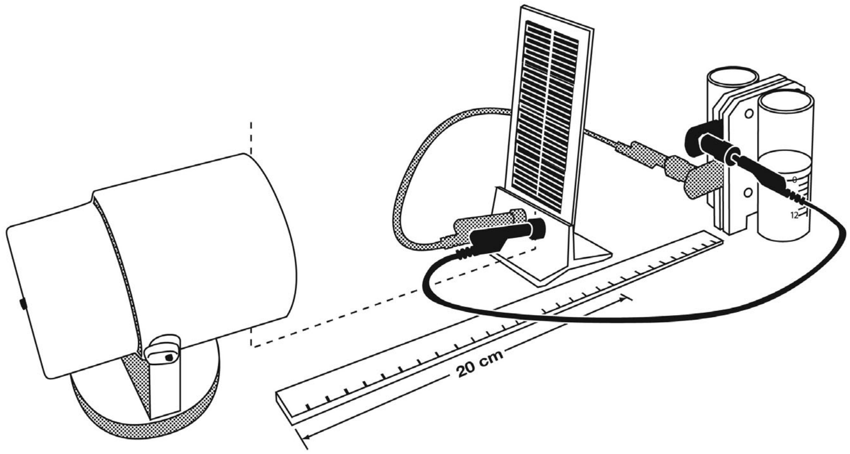
We use this Discovery Activity on the first day of the fuel cells unit. Discovery Activities are open-ended explorations for students to whet their appetites to explore and learn more. As you probably have only one Fuel Cell Model Car Kit, the Discovery Activity needs to be with the whole class.

OPQ is a format that allows students as a class to observe and consider an event in a non-threatening manner, with all students having the chance to participate. It is good to let students explore in any direction they choose, even if the ideas presented are incorrect. Students may end up arguing with each other about misguided concepts, but it is best you don't intervene, other than to encourage extended thinking about the concepts and to encourage students who have differing views to try to support them in a logical manner. This is quite important, as one vocal student with an incorrect idea may mislead less-sure students. This activity is designed for open exploration. You should emphasize that today's "I think" ideas are nothing more than possible predictions until we have established them conclusively through a scientific investigation.

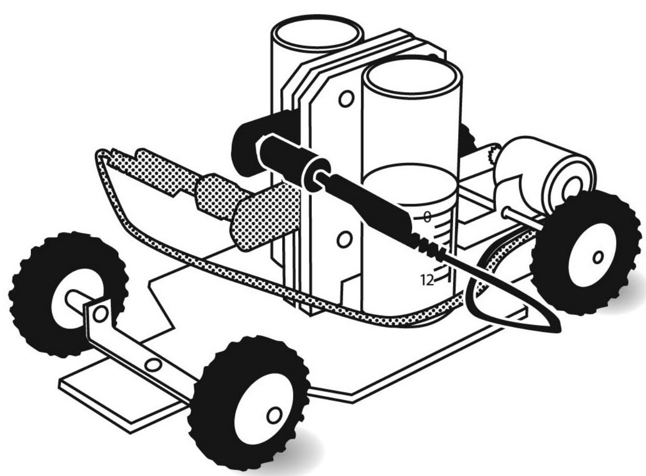
To begin the class, show the students the set up procedure. Let them see you pour the water, plug in the cords, and turn on the light as the event unfolds. Follow the directions at the front of this booklet regarding the use of distilled water, placement of the light, etc.

Demonstrating the Model Car Kit

1. Put on goggles. Remember that they will protect only if worn properly.
2. The bottom of the fuel cell storage cylinders should be filled with distilled water, with no air space or other gas in the cylinders. If you need to add distilled water to the fuel cell, refer to *Filling the Electrolyzer* at the front of this book.
3. With the patch cords, connect the solar module to the reversible fuel cell, which we are using here as an electrolyzer. Red to red and black to black. Position the solar panel so it faces the light source at a distance of at least 20 cm.



4. When the hydrogen storage cylinder has filled to at least 5 ml, remove the solar panel from the system by disconnecting the patch cords from the reversible fuel cell.
5. On the top side of the car base directly in front of the gears, there is a felt-covered upright piece of plastic. Turn the fuel cell so that the red and black contacts are towards the front of the car. Carefully slide the fuel cell over the black felt and push down gently until the fuel cell is fully seated on the car base. You may need to hold the connecting cables out of the way as you do this.
6. Connect the black and red wires from the motor to the fuel cell. The car should start to move.



If you have time, you might try the following. Set up the solar panel and the electrolyzer again as in step 3. This time let the hydrogen fill the entire storage cylinder until hydrogen gas bubbles rise through the small tube, the upper reservoir and escape. Hold a lighted match above the escaping bubbles to see and hear the effects of burning hydrogen.

When you have completed the set up, explain the OPQ activity to the students. Ask them to write ten observations of the entire apparatus. Everything—no matter how mundane it may seem—is important. You should affirm each student's observations as valid. Many students may try to scoff at others' responses, but some of the most basic observations may offer critical insights into the apparatus. We can use this opportunity to train students to not overlook things that they may feel are unimportant. For example, the wires are red and black. Background knowledge may suggest some kind of direct current circuit is involved.

As the electrolyzer begins to bubble, encourage students to offer any observations. Don't evaluate any response; just allow students to engage. At this point many students will begin to think about what is going on and may offer explanations. You can use one of their first explanations as a jumping-off point to say that while their explanation may be true, we don't have enough evidence at this time. Indeed, by saying, "I think that…" they are really making a *prediction*.

Some of these predictions are easily tested, some will take more time later on, but you should encourage students to write or state several "I think that…" predictions. Here is also an opportunity to talk about the nature of science as a process whereby events must be tested, retested, and found to be repeatable. It is not merely something that we dictate as things already learned. You want your students to realize that the nature of science is to look for events that may or may not quite fit into our understanding of the world and then test those events to perhaps refine our understandings or create new ones.

By the end of the period, students will have started to ask questions. Take the lead from the students to use some quiet time to write in their journals and come up with some questions. The purpose of this time is to allow the students to engage in the unit and start the exploration of the fuel cell. Some of the questions that students ask can be tested immediately. Some other questions are challenging the fuel cell industry at this time. Either way, just as scientists need a question to guide their scientific investigations, students need the opportunity to develop the skill of forming those questions.

There are no right or wrong questions. Do not evaluate the questions as good questions or not-so-good questions. Instead, model for students a way to frame their thoughts into a scientific investigation. You might suggest a similar question that can be answered through investigation.

This may not turn out to be the most scientifically intense day with the most content learning. However, the Discovery Activity is vital to the success of this unit. Students may later remember the time that a teacher took to get them hooked. It's like fishing. You have to allow time for the fish to swallow the bait so you can eventually reel it in. Today is a day for your patience and guidance, and allowing the students to direct the pace and path of the class.

If this is the first time your class has experienced the OPQ format, you may need to take time to discuss the timing of the activity. If students get going with ideas and arguments, it may be difficult to finish OPQ in a single period. Trust in the process, avoid judgments or pronouncements and within a few OPQ sessions you will find that the students are able to commit to some ideas and possible investigations that will maintain intense interest for the remainder of the unit. As discussion leader you are needed as a focusing agent, but do allow the students to choose the aiming point.

The work of Luigi Galvani is fascinating and may be further explored with Internet searches. Several sites have original drawings and translations from Galvani's original documents.