Science Investigations on the Web

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What's the best way to learn about friction, or the dew point, or human body systems? The National Science Education Standards say that students learn more science, and learn more about the nature of science, when they actively participate in finding out answers for themselves – using the process of inquiry.

Michigan established the importance of conducting investigations and finding answers to scientific questions with the publication of its state standards and benchmarks, which clearly outline the importance of constructing new scientific knowledge through inquiry. The MEAP test was designed to support the inquiry benchmarks by including a scientific investigation that all elementary and middle school students had to perform prior to the test. Students were asked questions about their investigations on the MEAP test, and allowed to use their investigation journals which contained observations and measurements.

Unfortunately, because of cutbacks in state funding, the MEAP tests no longer have actual investigations. So Michigan Science Teachers Association (MSTA) and the Michigan Mathematics and Science Centers teamed up to develop a set of investigations that can be used in classrooms to replace the MEAP investigations. These investigations are available through the MSTA website, at www.msta-mich.org.

Each investigation is based on several Constructing New Knowledge and Reflecting on Scientific Knowledge state benchmarks, as well as on at least one pertinent Earth, life or physical science benchmark. The MEAP office has agreed to use items on their tests that draw on the same "constructing" and "reflecting" skills as those developed through these investigations, making these investigations an invaluable addition to any science curriculum. The hope of the authors is that they can also serve as models or templates for refashioning existing science activities into engaging, hands-on inquiries.

To develop these investigations, a group of highly experienced teachers came together over a three day period, under the direction of Pete Vunovich from the Capital Area Science and Mathematics Center. They developed eight investigations, three for the elementary level, three for middle school, and two for high school. They also agreed upon an inquiry format for each investigation, which is described below.

The investigations are available on the web as text documents. Each includes background information, a step-by-step teacher's guide, and student pages. In the future, we hope to add web-based video that illustrates how to set up and conduct each investigation, and a feedback section that allows teachers who use the investigations to suggest alternatives or even new investigations.

The format of each investigation begins with students exploring some real-world phenomenon or event, and moves from there to a structured investigation where they collect and analyze data. In the description of the investigation format below, we use an example taken from an upper elementary experiment about friction.

Begin with student exploration and questions

The instructional approach we used begins by engaging students in an exploration of some real-world situation. The teacher presents the situation, either through some materials already in place on the students' tables, or through a short story (which we sometimes call a scenario) – or both. Students explore the phenomena presented through the materials or scenario, talking about it, suggesting answers to questions posed by the exploration, brainstorming possible explanations. The teacher keeps track of these brainstormed ideas and questions on the board, so students can watch as their ideas progress, and also so they can refine their ideas into testable hypotheses, which can guide their later investigation.

In the friction investigation, students are introduced to a problem through a scenario about Elena, who is trying to move a heavy box out of her room. The scenario includes the statement that Elena knows it will be easier to move the box once it is off the carpet in her room and onto the bare floor in the hallway – but they are not told to necessarily think about friction (or reducing friction) as a possible solution to Elena's problem. They generate questions about the situation and possible solutions.

The exploration continues with activities focused on friction, where students rub their hands together and notice the effort it takes to move them across each other. Then they try rubbing their hands on the table top, then on the table with marbles underneath, then on the table with dish soap underneath. For each exploration, they are asked to carefully observe and describe what they observe. These explorations are focused into a question about how much force it takes to move an object with different types of surfaces under it.

Determine a method for collecting data, then form a hypothesis

The most difficult part of doing investigations is determining a method or technique for collecting data that will be useful for answering the question. In the elementary grades, the teacher plays a major role in developing the techniques. In middle school and high school, responsibility for this is gradually shifted to the students.

In the friction investigation, we use a technique described in the force and motion unit from Battle Creek Mathematics and Science Center. The teacher rephrases the students' observations about how their hands move over different surfaces in terms of the motion of a block of wood. Different materials such as wax paper, sand paper, dish soap, and straws (acting like rollers) are placed under the block. The block is attached to a plastic cup "bucket" by a string, which is hung over the side of the table. Washers are added to the bucket to provide a measurable force on the block.

A difficult part of the technique in this experiment, one which students sometimes discover on their own, is that the block will move with a certain number of washers if it is given a little push to start its motion, where it takes even more washers to get it started without the push. This is because the friction is greater when the block is not yet moving. This aspect of the technique provides an opportunity for students to refine the method they use and shows the need for discussing the method carefully.

Once the technique is determined, students need to think through what might happen in their experiments and make a prediction, or hypothesis. We use a formalized approached to making a hypothesis, structured by an Investigation Design student page, which includes these steps:

1. What is our question? Students write something like: *What amount of force is required to move a block of wood when it is on different kinds of surfaces?*
2. What do we know? – How does the block act when it is pulled? Students write something like: *It moves if the pull is hard enough.*
3. What will we do? – How will we change things to affect how it acts? Students write something like: *We will make different surfaces for the block to move on.*
4. What data will we collect? – How will we measure the response of the block to what we change? Students write something like: *We will measure how many washers it takes to get the wood to move.*
5. What is our hypothesis? If we change the surface that the block slides on by (#3): ____ (students write what they have in #3: *putting different surfaces under it*), then (#4) ____ (students write what they have in #4: *the number of washers needed to move it*) will change by (students write their prediction: *decreasing when the material under the wood is more slippery.*)

The last step of the Investigation Design student page asks students to consider and list the aspects of the investigation that are purposefully not changed. In this case, the size and weight of the block is not changed during the various trials, the length of the string is not changed, the cup and washers are kept the same, and so forth.

Develop and record the details of the investigation

Once the technique is determined and the hypothesis is developed, students need to write an explicit and detailed procedure. They do this for two reasons: First, they need to think carefully about the procedure before they do the experiment, and writing it out makes them do that. Second, they learn that others who are interested in their results might want to repeat the experiment, and need to do it exactly in the same way that they did it. Others might also want to critique their methods.

The detailed procedure is written by the investigation groups in a journal or on separate paper, and titled Research Methods. Students might find it necessary to change their procedure as they conduct the investigation – for example, as mentioned earlier, they may find that tapping the block is an important aspect of the technique.

As part of the planning they do before the investigation, students develop data charts for recording their data. These charts will be useful later when they analyze their data.

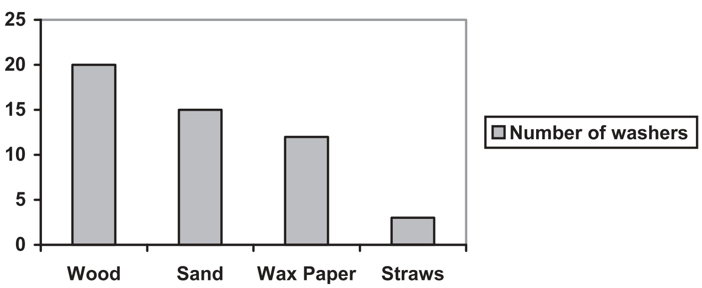
Conduct the investigation and collect data

Now the fun begins. Students do the investigation trials, and record their data in the tables that they have constructed. Careful teacher monitoring is essential during this step, to remind students that their results will only be meaningful if they collect the data carefully. Students can repeat their measurements if time allows.

Analyze the data, answer the question, and communicate the results

Data can be analyzed by graphing or plotting in various ways to look for patterns. Students should be able to answer their research question and determine if their hypothesis was correct from the analysis of the data.

Graphing the data provides an opportunity for students to think about what kind of graph would be appropriate for their data. In the case of the friction investigation, students might create a bar graph such as this:



Students need to complete their work by presenting their question, hypothesis, technique, design, data and conclusions to an appropriate audience. They may present their work to others in the class, or to audiences outside of the classroom such as at parent open houses or school board meetings. They may also prepare posters of their work to present in common areas in the school.

Explain the results

As stated in the *National Science Education Standards* (1997, National Academy Press) "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). In other words, the goal of scientific inquiry is to form explanations based on evidence. Therefore, the goal of the summary discussion at the end of each of these investigations is to assure that students understand the phenomenon by being able to explain it, using the evidence they gathered and making appropriate generalizations.

Each of the investigations contains background information for teachers that explains the phenomena by elaborating on the concepts. In the case of the friction investigation, the ideas that students need to understand from their work are that 1) friction acts on an object when it rubs against another object or material; 2) friction is involved anytime we try to move an object across a surface; 3) the force needed to move an object in one direction (the push or pull) is opposed by the force of friction in the opposite direction. This means that a force is always needed to keep an object moving if friction is acting on the object. 4) The force of friction depends on several factors: the weight of the object; the type of contact surface; 5) the force needed to overcome friction is far less for a rolling object than it is for a sliding object; 6) it is also greater when starting motion than it is when maintaining motion.

These are important concepts for students to understand, but their understanding must be grounded in actual examples and uncovered through their investigations, in order to be learned, not just memorized.

The last sections of the investigations help students review and reflect on their work, and draw conclusions that lead to this core knowledge. Students also build on their work to propose new questions and new investigations, and so the cycle continues. The investigations also include ideas about how students' learning can be assessed.

The great benefit of inquiry learning is that students come to deeply understand important science concepts while also learning how scientists make sense of the world. They participate in doing real science while developing long-lasting understandings of how the world works. And at the same time, they develop a sense of power in their abilities to shape and control their own learning. That's why we consider these investigations such powerful ways of doing science.