Advice about Scientific Investigations

This document was prepared to provide assistance to teachers in preparing to conduct scientific investigations with your students. The guidance comes from the "Understanding Science: How Science *Really* Works"[1] website, Michaels et al. (2008) Ready, Set, Science! Putting Research to Work in K-8 Science Classrooms[2], and Harwood (2004) A New Model for Inquiry: Is the Scientific Method Dead?[3].

Teaching Scientific Investigations:

1. Scientific investigations involve more than just experiments (manipulating some factor in a system in order to see how that affects the outcome). For many ideas in science, experiments are impossible, inappropriate, or only part of the picture. In those cases, investigations are often a matter of making the right observations.
2. Remember there are no set steps or order of activities that define "good science."
3. Strive to create an environment where students':
    a. Engage in a process of logical reasoning about evidence
    b. Work cooperatively to explore ideas
    c. Examine, review, and evaluate their own knowledge
    d. Apply their existing knowledge to new problems or in new or different contexts
    e. Make connections between different representations of a concept
    f. Ask themselves why they believe something and how certain they are
    g. Become aware that their ideas change over time as they confront new evidence or use new tools or models to examine the data
    h. Learn how to ask fruitful and researchable questions
4. The process of data interpretation can be complex, and often, multiple interpretations of a single result are possible. To help your students with this component of science: ask them to brainstorm as many possible explanations as they can for why they got the results that they did – including aspects of the test design that might not have functioned as expected. Then ask students to brainstorm how they could figure out if any of these explanations are more likely to be correct.
5. Strive to direct conversations in classes that encourage scientific communication skills, using practices such as: revoicing, asking students to restate someone else's reasoning, asking students to apply their own reasoning to someone else's reasoning, prompting students for further participation, asking students to explain their reasoning, and using wait time to allow more students to think.
6. Strive to engage students in a number of talk formats to help them think like scientists: partner talk, whole-group discussion, student presentations, and small-group work.

** There are many Teaching Resources on the "Understanding Science: How Science *Really* Works" website (http://undsci.berkeley.edu/teaching/index.php) by grade levels **

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[1] http://undsci.berkeley.edu

[2] Sarah Michaels, Andrew W. Shouse, and Heidi A. Schweingruber. Ready, Set, Science! Putting Research to Work in K-8 Science Classrooms. 2008. National Research Council of The National Academies. The National Academies Press. Washington, D.C.

[3] Harwood, William S. 2004. A New Model for Inquiry: Is the Scientific Method Dead? Journal of College Science Teaching. 33:7

Scientific Investigations:

1. Effective investigations should be organized, structured activities that guide students in using scientific methods to work on meaningful problems.
2. Investigations typically unfold over weeks to months.
3. The process of science is iterative, at any point in the process leads to many possible next steps (known or unknown), and lacks tidy endpoints.
4. Investigations generate raw data but those data must be analyzed and interpreted to develop a scientific argument about the investigation/question.
5. Three parts of a scientific argument (aka explanation of the meaning of your results):
    a. Claim/Idea – what happened, and why did it happen? (make sense of the phenomena under study)
    b. Expectations/Evidence – what information or data support the claim? (articulate that understanding)
    c. Observations & Reasoning – what justification shows why the data count as evidence to support the claim? (defend that understanding to their peers)

Help Your Students Be Scientists By Having Them:

1. **Question what they observe**. First they should ask general questions, and then limit the arena they explore by defining the problem to develop a question that can drive their investigation.
2. **Investigate further**. They should research what is currently known about the topic/question.
3. **Articulate their expectations of the results**. They should be skeptical and try to refute their own ideas of what will happen.
4. **Seek out more evidence and make observations**. They should choose a means to investigate their question, gather or create the materials, and collect the data.
5. **Be open-minded**. They should examine the raw data and process/analyze the data and change their mind if the evidence warrants it.
6. **Think creatively**. They should try to come up with alternate explanations for what they observe and reflect on their findings by thinking about what the results mean.
7. **Communicate with others**. They should talk with others about their idea, questions, expectations, methods, raw data, analyzed data, and results (at many points during the investigation).