Teaching The Nature of Science

Presenting ENSI Lessons for Maximum Effect
Dispelling Popular Myths About Science

See More About What IS the Nature of Science

If you are unsure about the need for taking 2-3 weeks to teach the nature of science **explicitly**, take a look at the number of Misconceptions by Teachers for Teaching the Nature and Processes of Science (and their corrections), by the ***Understanding Science*** team.

The main goal for all of our Nature of Science (NoS) lessons is to give students real experiences that characterize the search for answers the way that scientists do. We encourage this by moving away from the usual recipe of steps called "The Scientific Method," and instead focus on the key experiences and other elements of science that are involved.

We recommend that you introduce the nature of science in the first 2-3 weeks with in-depth experiences using ENSI-NOS lessons. Research shows us that repeated, explicit and interactive experiences are critical for students learning this material. Also, do not dwell or repeat the misconceptions, rather focus on the correct conceptions. Then, throughout the course, relate current topics to eleents of the nature of science, wherever possible.

We do this mainly for two reasons.:
1) There is no one scientific method; different fields of science generally use different approaches to solving problems, so there is no universal set or sequence of steps. "The Scientific Method" is a false construct, at best an oversimplification that usually misses the point of what scientists actually do.

2) Deeper understanding of the true nature of science comes from personal experiences with simple problem-solving processes that can be discussed and analyzed. Out of this, many of the common misconceptions about the nature of science can be repaired, so students will be less vulnerable to those who would intentionally distort or misrepresent science for ulterior motives that could be medical, political, economic, or theological.

OUR APPROACH: During these experiences, we begin with an engaging or discrepant event that heightens interest and raises questions. We then gather some experiences, followed by some probing questions to help students begin to analyze the experience, and to see key elements of the problem-solving process, the patterns of scientific inquiry. Later, we assign terms to those components that are usually used, so we can talk about what they have been doing, then check their understanding by applying the experience to a new situation (which could be a new lesson). This approach, based on the BSCS 5E Instructional Model, has been shown to be very effective in building true understanding of concepts. Memorizing words or sequence of steps is played down in favor of using and understanding the general approaches used in scientific problem-solving.

There's nothing wrong with coming up with a list of steps for solving a problem scientifically, as long as students realize that this is only a summary of *one way* some scientists may solve problems. Sometimes they're just looking for clues, sometimes they're just gathering information, sometimes they're trying to relate different data sets to each other, or to look for patterns. Sometimes they're trying to disprove a possible explanation; sometimes they're looking for clues that fit a possible explanation, or something predicted by a possible explanation. Ultimately, science is the search for explanations and understandings, combined with critical strategies to refine and test those ideas.

SOLUTIONS: In all of our NoS lessons, the main goal is not "getting the right answer" - but rather understanding how scientists try to solve problems and answer questions about the natural world. You will need to point out that, in science, there is never absolute certainty - there is no one "right answer" - which is one of the common misconceptions about science. Unfortunately, this idea has been reinforced by generations of teachers and textbook authors with good intentions, but who bring their own misconceptions. Instead of seeking certainty, scientists do all they can to find answers that come as close to reality as possible. In doing this, they find that some answers *are* better than others, meaning that some explain more facts than others. The question is, how can we tell which is the best answer?

HIGH PROBABILITY: Students sometimes say (or think) "If scientific ideas can change, why do we have to learn these things?" Students need to learn that in spite of the general tentativeness or "uncertainty" in science, there are many understandings (theories and facts) in science that have survived repeated testing, and for which we therefore have the highest level of confidence - that are as close to reality as we may ever get. It's that high level of confidence, with its strong reliability and usefulness that has made science so valuable in bringing us important developments in medicine, agriculture, personal comfort and economic advantages. In other words, science deals with probabilities, shooting for very high probabilities, not "proof" or "absolute certainties." But "high probability" turns out to be good enough, for all practical purposes, if it works.

THE TEST: In science, we're always looking for the "most likely" solution to some problem. Ideally, we would want confirmation of that explanation from as many lines of evidence as possible, and no evidence that weakens that explanation. But, in reality, scientists often engage in efforts to *test* or *disprove* their ideas, where new evidence could quite possibly weaken a favorite idea. If one scientist doesn't do that test, another one will. If there's a flaw in the idea, sooner or later it will be discovered, and the idea must be revised or replaced. If repeated efforts to disprove an idea fail, then the idea is strengthened. That's the core power of science. The long-term goal of science is explanations that work, consistently and reliably. With the processes scientists use, our knowledge and understanding of the natural world comes closer and closer to reality.

PRESENTING THE LESSON:
Therefore, before doing this lesson with students, the wise science teacher will DO the lesson privately, *then*, do the lesson with the students. We realize how tempting it will be to respond to student pressure to "explain why that happened!" But you MUST resist. If you don't know, say "I don't know! But in science, we try to figure out why something strange happens." [If you DO know, still say "I don't know," or if you want to be totally honest, "That's for you to figure out, the way scientists do."] Don't even confirm or accept the currently held explanation if it is offered as a hypothesis from one of your students (and you happen to know it). Neither should you give the impression that one hypothesis is as good as the other. Every **hypothesis** (tentative explanation) must provide a reasonable **explanation** (not a prediction) that satisfies all the observations, and it **must be testable**.

Encourage students to create and describe **tests** for their hypotheses, along with predicted results of the test that would be one way if the hypothesis is valid, and *different* if the hypothesis is *not valid*. If possible, have them carry out the test. Hypotheses that survive (or meet predictions of) good tests are the better (best?) hypotheses. Let it rest there.

DISPEL A FEW MORE IMPORTANT MISCONCEPTIONS ABOUT SCIENCE
"**Let's vote for the best answer**." Don't ever have the class vote for the "best hypothesis." **Science is not democratic**. The best explanation is the one that works best, *not* the most popular, logical, or prettiest one.

"Science can solve any problem." The purpose of science is to understand how the *natural* world works, using natural explanations. Questions involving opinions, judgment, beliefs or values are not appropriate questions for science. The realm of science is restricted to natural phenomena.

"Science can use any explanation." As described above, some explanations are better than others, simply because some work better than others - they satisfy more observations than others. But one class of explanation can never be used: explanations that involve supernatural or mystical forces are completely unacceptable, simply because such forces can never be disproved, therefore they cannot be properly tested. That doesn't mean that such forces don't exist, only that science, by its fundamental nature, cannot tell us that, one way or the other.

All of these are part of the core of "the nature of science," much of which runs counter to popular notions about science. Your job, as a science teacher, is to help your students have vivid experiences with real science thinking that conflict with those popular myths, and replace them with a more accurate understanding of how science operates and what science has discovered.