Experiencing the Nature of Science: An Interactive, Beginning-of-Semester Activity

By Ann Cavallo

Students are often anxious about taking their first college science course. Perhaps this can be attributed to difficulty with science in high school, or having an aversion to science in general. Studies show that part of this aversion may be a misunderstanding of the nature of science (Abd-El-Khalick 2006; Flick and Lederman 2006). Many students view science as an unchanging body of facts that must be memorized. With this view, students consider that the experts—the scientists—have already discovered these facts, thus science is already known. This view may affect students' attitudes toward science as a discipline, and discourage learning. Students may view the learning of science as a mechanical chore in which they memorize notes and the textbook information and parrot it back, as much as they can, on the examination. This view of science was substantiated in two separate studies over two years in a nonmajors college physics course that showed a significant correlation between a student's view of science as fixed and unchanging and rote-learning approaches (Cavallo, Potter, and Rozman 2004; Cavallo et al. 2003). In the second of these two studies, the students in the physics course lacked confidence in their ability to successfully learn science, which was significantly related to rote learning and the belief that science is unchanging and authoritatively known (Cavallo, Potter, and Rozman 2004).

Why students believe science is authoritative is not fully explained in the literature. Perhaps this fixed, unchanging belief stems from the way science is so often taught—as a set of definitions and facts to be memorized. This belief may also originate from an unfounded yet public perception that scientists have the "answers." What students do not see is the work and diligence that went into finding, not necessarily answers, but possible explanation*s* for world phenomena. In other words, students do not have an understanding of the nature of science (NOS).

NOS is more accurately defined as a tentative and dynamic process upon which explanations about phenomena are supported, or in some cases, refuted. According to results of the same two studies in a nonmajors college physics course, students who hold this view of NOS are more likely to approach science using more integrated, meaningful learning; higher-level thinking abilities; and higher self-efficacy or belief in their ability to successfully learn and achieve in science (Cavallo, Potter, and Rozman 2004; Cavallo et al. 2003).

Introducing students to the nature of science

Students' learning about NOS consists of two related aspects that include their understandings of and ability to apply science processes, and their beliefs about NOS. To help students begin to develop such understandings of NOS, I implement this activity in the first class of the semester. The activity is designed with three goals in mind: (1) to help students better understand the nature of science (NOS), (2) to help establish the format and level of critical thinking that will be used in our science course throughout the semester, and (3) to help students begin to experience the exchange of ideas and argumentation skills that are necessary in science.

The activity is especially effective in courses enrolling primarily nonscience majors. I have used the activity in nonmajors biology and physical science courses, science teacher education courses, and also in professional development seminars with college professors. This activity is also consistent and promotes the NSTA Position Statement on The Nature of Science, which may be found at *www.nsta.org/about/positions/natureofscience.aspx*.

New Society activity

In the first meeting of the semester, I engage students in the New Society activity, which I learned many years ago (I can't recall the exact origin). To begin, I ask four students to volunteer to be "scientists" and to temporarily wait in the hall for further instructions. I make sure to choose either two males and two females, or two individuals with blonde hair and two with dark hair, or two who wear glasses and two who do not, or individuals with other opposing characteristics (jeans or no jeans), depending on the similar characteristics that may be found among the remaining students in the class who make up the "new society." For example, if two males and two females are chosen to be the scientists, there must be roughly equal numbers of males and females remaining in class as the new society; if two students wearing glasses and two not wearing glasses are chosen as scientists, I ensure there are sufficient numbers of students who remain in the class as members of the new society who wear glasses and who do not wear glasses. I also gauge students' personalities and emphasize that being a scientist is voluntary. Whoever is selected needs to be a good sport and have a sense of humor. I also explain that the volunteers will be asked to complete a somewhat difficult task.

Next, I select the four volunteer scientists, not telling them why I chose them other than they volunteered. While the scientists are out of the room, I inform the remaining students that they are a new society that has not yet been discovered by other humans (perhaps they are on a yet undiscovered island and it is the past, or they are inhabitants of a planet and it is the future). I tell them that the four students who are waiting in the hallway will be scientists (anthropologists, perhaps) whose task is to find out as much as possible about the members of the new society. Next, I reveal to the class that the four scientists will not be told, and thus do not know, that the new society lives by three strict rules (see Figure 1).

Lastly, I ask the new society to (if possible and without being noticed) jot down their observations of the scientist team. The society members should note what the team does (e.g., how they work) and record some highlights of what the scientist team members say while conducting their investigation of this new society.

After answering questions and ensuring that all students of the new society understand their society's rules, I relay instructions to the scientist team waiting in the hall. I explain to the team of scientists they have just found/discovered this new society (the class) and they are to find out as much as they can about this society. I do not tell them there are rules, only that they are to find out as much as possible (e.g., by interviewing the society members and asking them questions). During the activity, I remain quiet, except to ask a few questions of the scientist team as needed to help them think and continue to go about their research on the class. It is best to provide at least 45 minutes for this activity to be successful.

FIGURE 1

New Society rules.

Rule 1: The society members' only vocabulary is either "yes" or "no."

Rule 2: If the scientist is *smiling* when he/she asks them a question, then the answer is always "yes," and if the scientist is *not smiling* when asking the question, the answer is always "no," regardless of the question and the accuracy of the response.

Rule 3: Depending on which outstanding characteristic we used among our scientist group (e.g., either gender, hair color, or glasses) the society members can only speak, that is, say *yes* or *no,* to the scientists who have the same characteristic that you have chosen, or in the case of gender, the *opposite* characteristic. So for example, if gender is chosen as the outstanding characteristic, then *females* can only speak to *males* (answering yes or no), whatever the question, but they *do not respond at all* to questions asked by other female scientists. Likewise, male students of the new society would not answer male scientists' questions, but would respond yes or no to questions posed by female students. If instead, wearing or not wearing glasses was selected by the instructor as the outstanding characteristic, then society members wearing glasses may only respond yes or no to scientist team members who are also wearing glasses. Thus, they do not respond at all to the two scientists not wearing glasses when these scientists ask them a question. Likewise, if hair color was selected as the outstanding characteristic, then blonde society members only speak to blonde scientists and society members with dark hair only respond yes or no to scientists who also have dark hair color. No response is given by society members to scientists with the opposite hair color.

The scientists enter the room and begin their work. The scientists sometimes cluster at the front of the room and call out questions to the entire class. In this case, if a female calls out the question, then only the males together respond, and visa versa (likewise if the selected characteristic was hair color or other). The scientist team often begins with questions to the society such as "Who is your leader?" and "What is your name?" to which the responses are either only "yes" or "no." After awhile of this type of questioning with not much information being revealed to them (if the scientists do not bring it up themselves), I ask the team how they may be able to gather more detailed information about the society. The scientists decide it may be a good idea to divide their team and conduct some one-to-one interviews around the classroom with society members. The activity becomes very lively and even humorous, as students in class become very engaged in observing the processes the scientist team is using during the investigation.

Relatively early in the activity, the scientist team does realize that the society's only language is "yes" and "no." The next observation they make, which takes somewhat longer to discover, is that members of the society only speak to the opposite gender, for example, or to those with the same hair color, or those wearing glasses (depending on the instructor-selected variable). However, why a society member responds either "yes" or "no" to their questions is a long, difficult process, and forces the scientists to make hypotheses and conduct experiments on those hypotheses.

Here is where I often need to prompt the scientists to summarize what they have found/concluded so far. The group usually concludes and writes on the board that (1) the society has a yes/no language and (2) the society members only speak to those of the opposite gender (or other selected factor). Once the scientist team has determined these two patterns or rules, I reveal that there are, in fact, three rules that the society lives by, and they have just discovered two of these rules. There is still one more rule they need to discover. The scientist team continues their work to discover the third rule. In time, one or more team members usually suggest it may be something about them (the question-asker) that prompts the society members to respond either yes or no, such as whether or not their arms are crossed when asking the question. I may suggest that they test that hypothesis. If necessary, I suggest that one or more scientist team members observe the question-asker to see if anything new can be discovered by observation. Eventually, the scientists do successfully discover this final rule of the society. We always hear a sigh of relief from the team (and some society members) at which time we applaud the scientist team and thank them for their hard work.

Debriefing the New Society activity

When students have discovered all three rules, we have a discussion about the scientific processes the team members recalled using, and that students in class had observed and noted. Students may offer that during the interview/research process the scientist team made observations, recorded data, made inferences, analyzed data they collected, collaborated and communicated with other team members, formed and tested hypotheses, were confused and frustrated, looked for and found patterns among society members' responses, and made conclusions—in essence they used virtually all of the processes of science. They note that sometimes the team members worked effectively together and communicated with each other, and other times that was not the case. They also recall mild disagreements/argumentation among team members, and sometimes division among them. Students recall that sometimes team members carefully recorded data, and other times not, at which time we stress the importance of making detailed notes and using clear communication skills in science. They also notice that sometimes hypotheses were tested, such as arms crossed when asking the question, though not often using controls and not repeating it enough times or with enough society members to be able to draw sound conclusions from their observations.

Throughout the activity I made a list of the scientists' activities and "alternative concepts" generated during their research. When I read this list to the class, it becomes clear that our own perceptions are tied to our observations and inferences. For example, at the beginning of the activity scientists often joke aloud that the society is "being rude" or "not listening," or that they "lied" when responding in a way that was, based on the scientist's perspective, an untruth. We discuss that, frequently, scientists may follow alternative explanations for scientific phenomena in their entire life's work, only to find, or have another scientist bring forth, a unique perspective that changes prevailing theory, such as the Earth-centered (Ptolemy) versus the Sun-centered (Copernicus) models of the solar system. We also discuss that the feelings of frustration they describe are common among scientists who may work for years or a lifetime to solve a scientific problem or make a significant discovery. We then discuss how science is communicated, and what factors lead to the ultimate acceptance of theory. Our observations of the research teams' dynamic interaction may reveal, for example, that primarily one or two team members' ideas went forward and were tested, whereas other ideas may have been overlooked. For example, we may notice during the activity that one or two scientists made a good suggestion early in their investigation/interview process, but the idea was not followed through. We discuss how similar phenomena have occurred throughout the history of science and persist today in the scientific community, (e.g., see *Linus Pauling and The Race for DNA* in Resources). There is also opportunity here to introduce issues regarding gender and underrepresented groups in science from both historical and modern perspectives (e.g., see *The History of Heart Medicine* and Blue Baby Operation Exhibit in Resouces). Through the activity, students begin to understand how science may be tied to social acceptance of theories.

There are many aspects of their experience that students relate to the nature and processes of science and to our global culture. But, importantly, the activity helps students begin talking to each other about science, using the language of science such as observing and hypothesizing, accepting and considering others' viewpoints and ideas, and acclimating to the inquiry-based scientific processes to be used throughout the course and beyond.

Summary

Educators have the distinct obligation to help students understand science so our future citizenry may be well situated with respect to society's changing scientific discoveries on a global scale. Students must be able to interpret and critically analyze articles printed in online and paper media, and make sound judgments as to the credibility of the information being conveyed. Students have to judge, for example, very public scientific issues such as global warming and its science-based explanations (rather than emotion), along with countless national and international topics such as bird flu, SARS, AIDS, energy shortages, and teaching evolution in schools.

References

Abd-El-Khalick, F. 2006. Over and over again: College students' views of nature of science. In *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education,* eds. L. Flick and N.G. Lederman, 389–426. Dordrecht, The Netherlands: Springer.

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Resources

Linus Pauling and the Race for DNA. Oregon State University—*http://osulibrary.orst.edu/specialcollections/coll/pauling/dna*

Nature of Science—*http://evolution.berkeley.edu/evosite/nature/index.shtml*

Science for All Americans Online—*www.project2061.org/publications/sfaa/online/chap1.htm*

The Blue Baby Operation—*www.medicalarchives.jhmi.edu/page1.htm*

The History of Johns Hopkins Heart Medicine—*www.hopkinsmedicine.org/stlm/history.html*

What Is Science?—w*ww.fotuva.org/online/frameload.htm?/online/science.htm*

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