GUEST EDITORIAL

THE MISSING COMPONENTS IN TEACHING SCIENCE

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Many students, especially non-science majors, graduate from high school or college with a view of science that embraces only the narrower list of components of the scientific method: making observations, formulating hypotheses, and conducting experiments. This view largely results from the way we teach science in the classroom, how textbooks present what scientists do, and how the media depict science and the work of scientists. Some recent textbooks have started to present a more comprehensive view by going beyond the narrower components of the scientific method to include *communication*: the ways in which scientists share their tested results, identify implications and applications of their findings, and generate new sets of research questions and better explanations. Thus, presentations of the scientific method as a series of steps that starts with observations and ends with experimentation must be amended to recognize that scientific findings are also shared with scientific communities, often through publications and presentations to stimulate wider discussion and inquiry and lead to refinements and additional research efforts. These are all components of the scientific approach of discovering the truths of nature and the world around us, and they make the scientific approach "the most powerful and reliable guide to truth about the world that human beings have devised" (Easton, 2002, p. xiv).

Because the scientific method includes the expectation that findings or conclusions can be confirmed, science teachers must also place an emphasis on the fact that results and conclusions must be clearly stated and explained, and then shared with the scientific community through formal presentations and/or publication.

But communication with other scientists and researchers is only part of the obligation of those who practice science and teach science to students. Particularly in the educational setting, we need better communication of science issues to students, so that they become proponents of the scientific method as they advance in school and grow in their lives and careers. We must strive to teach science in ways that stimulate student interest and model the scientist's own methods and approaches. Here are some general suggestions for enhancing science teaching:

- Emphasize the importance of making accurate observations by designing activities that place a premium on precision and accuracy. For example, a high school chemistry teacher asks the class to record their observations of the behavior of tea bags in cups filled with hot and then cold water. He then asks the students to rewrite their observations as many times as necessary – to the point where taking a single key word from the descriptions would render them meaningless. Only then are students allowed to start conducting lab experiments. We can vouch for the efficacy of this approach through personal experience.
- Strive for clear explanations and simple, non-technical language in presenting the complexities of science. This is simply because as Deutsch (2011) has argued, explanation is one of the driving goals of science. Having breadth of knowledge, depth of understanding, and imaginative creativity grounded in observational facts is necessary for explanations that are clear, simple, and elegant. Science teachers can help students learn how to provide good explanations for observable phenomena and experimental results.
- Ask students to analyze intriguing cases and issues that require personal involvement and exploration.
- Let students work through scientific problems and issues by doing their own guided research, including trying to disprove (falsify) existing results and trying to replace existing explanations with better ones.
- Structure the research process for students to include hypothesis testing through logic as well as empirical observation. Through this process, scientists are able to use evidence to construct testable explanations, to predict natural phenomena, and to generate new knowledge about the world in which we live.
- Ask students to work in groups and to discuss results with other students and groups in formal and informal settings. The group process can be an important stimulus to clarification of ideas, to collaborative effort, and to development of communication skills.
- Require students to present their findings and evidence-based conclusions orally and in writing. Emphasize the fact that having a breadth of knowledge and depth of understanding is not enough to come up with a better explanation and effectively communicate it to others. They also need to learn communication skills, relationship management skills, respect for the field and profession, and empathy.

These elements are, of course, not unique to the teaching of science, but they have been, arguably, too often absent in our educational settings, with the result that for many students science is a remote, technical subject of no personal relevance. Such attitudes, not surprisingly, tend to follow the student from the schoolroom into life and career. The implications of this consequence point to a third obligation of scientists and teachers of science.

Both scientists and teachers of science must pay more attention to communicating with the general public in their role as citizens and voters. Regardless of their own knowledge of and interest in science, the public elects representatives charged with making decisions about the society's health and welfare, education, the economy, public policy, the environment, and international relations. In the absence of an awareness of scientific findings and facts, the public too often has tended to adopt the beliefs and opinions of those who speak persuasively or engagingly for scientifically untenable

positions. As a result, some politicians acting in the interests of economic, commercial, or ideological considerations could make decisions with consequences harmful to the long-term welfare of the public.

As an example, while some 97% of scientists agree that climate change is real and is being affected by human activity, politicians and political parties continue to argue that "more study is needed" and to push for decisions that would further contribute to climatic and environmental degradation. As another example, comments by politicians during the recent elections about women's reproductive systems in response to rape point to the need for a well-informed, scientifically literate public. Even though several of these politicians were defeated largely by arousing the revulsion of many voters, they had won their primaries and were strong candidates. At the same time, a politician who expressed his belief in a "young Earth" (measured in thousands of years, as literally calculated from the Bible), with the caveat that those who disagreed might go straight for Hell, was comfortably re-elected and retains his seat on the House Committee on Science and Technology.

Improved communication about science must begin in the schools, where research conducted by students can show them new ways of looking at things as well as adjust some of their "scientifically untenable" beliefs. Such communication may also help to better educate the general public and help them make more informed decisions about the representatives they empower to make the decisions that affect us all.

References

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