

## Practice 7

### Engaging in Argument from Evidence

Whether they concern new theories, proposed explanations of phenomena, novel solutions to technological problems, or fresh interpretations of old data, scientists and engineers use reasoning and argumentation to make their case. In science, the production of knowledge is dependent on a process of reasoning that requires a scientist to make a justified claim about the world. In response, other scientists attempt to identify the claim’s weaknesses and limitations. Their arguments can be based on deductions from premises, on inductive generalizations of existing patterns, or on inferences about the best possible explanation. Argumentation is also needed to resolve questions involving, for example, the best experimental design, the most appropriate techniques of data analysis, or the best interpretation of a given data set.

In short, science is replete with arguments that take place both informally, in lab meetings and symposia, and formally, in peer review. Historical case studies of the origin and development of a scientific idea show how a new idea is often difficult to accept and has to be argued for—archetypal examples are the Copernican idea that Earth travels around the sun and Darwin’s ideas about the origin of species. Over time, ideas that survive critical examination even in the light of new data attain consensual acceptance in the community, and by this process of discourse and argument science maintains its objectivity and progress [28].

The knowledge and ability to detect “bad science” [29, 30] are requirements both for the scientist and the citizen. Scientists must make critical judgments about their own work and that of their peers, and the scientist and the citizen alike must make evaluative judgments about the validity of science-related media reports and their implications for people’s own lives and society [30]. Becoming a critical consumer of science is fostered by opportunities to use critique and evaluation to judge the merits of any scientifically based argument.



In engineering, reasoning and argument are essential to finding the best possible solution to a problem. At an early design stage, competing ideas must be compared (and possibly combined) to achieve an initial design, and the choices are made through argumentation about the merits of the various ideas pertinent to the design goals. At a later stage in the design process, engineers test their potential solution, collect data, and modify their design in an iterative manner. The results of such efforts are often presented as evidence to argue about the strengths and weaknesses of a particular design. Although the forms of argumentation are similar, the criteria employed in engineering are often quite different from those of science. For example, engineers might use cost-benefit analysis, an analysis of risk, an appeal to aesthetics, or predictions about market reception to justify why one design is better than another—or why an entirely different course of action should be followed.

## GOALS

By grade 12, students should be able to

- Construct a scientific argument showing how data support a claim.
- Identify possible weaknesses in scientific arguments, appropriate to the students' level of knowledge, and discuss them using reasoning and evidence.

- Identify flaws in their own arguments and modify and improve them in response to criticism.
- Recognize that the major features of scientific arguments are claims, data, and reasons and distinguish these elements in examples.
- Explain the nature of the controversy in the development of a given scientific idea, describe the debate that surrounded its inception, and indicate why one particular theory succeeded.
- Explain how claims to knowledge are judged by the scientific community today and articulate the merits and limitations of peer review and the need for independent replication of critical investigations.
- Read media reports of science or technology in a critical manner so as to identify their strengths and weaknesses.

## PROGRESSION

The study of science and engineering should produce a sense of the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments. In that spirit, students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose. Meanwhile, they should learn how to evaluate critically the scientific arguments of others and present counterarguments. Learning to argue scientifically offers students not only an opportunity to use their scientific knowledge in justifying an explanation and in identifying the weaknesses in others' arguments but also to build their own knowledge and understanding. Constructing and critiquing arguments are both a core process of science and one that supports science education, as research suggests that interaction with others is the most cognitively effective way of learning [31-33].

Young students can begin by constructing an argument for their own interpretation of the phenomena they observe and of any data they collect. They need instructional support to go beyond simply making claims—that is, to include reasons or references to evidence and to begin to distinguish evidence from opinion. As they grow in their ability to construct scientific arguments, students can draw on a wider range of reasons or evidence, so that their arguments become more sophisticated. In addition, they should be expected to discern what aspects of the evidence are potentially significant for supporting or refuting a particular argument.

Students should begin learning to critique by asking questions about their own findings and those of others. Later, they should be expected to identify possible weaknesses in either data or an argument and explain why their criticism is justified. As they become more adept at arguing and critiquing, they should be introduced to the language needed to talk about argument, such as claim, reason, data, etc. Exploration of historical episodes in science can provide opportunities for students to identify the ideas, evidence, and arguments of professional scientists. In so doing, they should be encouraged to recognize the criteria used to judge claims for new knowledge and the formal means by which scientific ideas are evaluated today. In particular, they should see how the practice of peer review and independent verification of claimed experimental results help to maintain objectivity and trust in science.