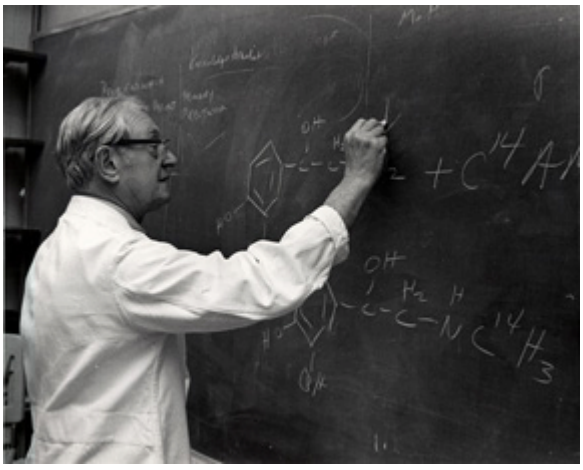
Misconceptions and missing conceptions about the process of science

Visionlearning

This list was compiled by Anne E. Egger, Stanford University, as part of a collaboration between Visionlearning and the SERC Pedagogic Service, and includes the products of a July 2009 workshop on Teaching the Process of Science.



Students hold a wide variety of misconceptions about the process of science that range from the nature of scientific knowledge to what scientists themselves are actually like. In addition, there are many aspects of the process of science that they know nothing about - they are *missing* conceptions about things like the role of the scientific community. The following list of student misconceptions and missing conceptions was compiled from comments submitted by college faculty and high school teachers who participated in the 2009 Process of Science workshop.

The overarching misconception that students hold is that **science isn't a process at all - it's just a bunch of facts**. But misconceptions fall into several categories, and this is by no means an exhaustive list:

The scientific method

The linear 4- or 5-step scientific process is drilled into many students starting at a young age. This generates many misconceptions, including:

- There is only one way to do science, and it is a linear, straightforward process. All true science is conducted using the step-by-step method.
- All scientists conduct experiments in a lab.
- Doing science does not require creativity - it is tedious and boring, not fun.
- It is obvious how to frame a research question and proceed toward an answer.
- Science is simply a process of collecting data and putting it in a book.
- The purpose of scientific inquiry is to prove that a scientific hypothesis is correct.
- A scientific problem is something you solve: there is a right or wrong answer; only one test is necessary; the test is to prove that their hypothesis is correct.
- The purpose of experiments in science are to validate the concept being taught.
- You have to be given the problem in order to use the scientific method.

The nature of uncertainty and change in scientific knowledge

This is a complex concept: that something can be both tentative but still be established knowledge, and that knowledge can change. Students hold many misconceptions about uncertainty, including:

- Science is a large collection of absolute facts that is fairly static in nature.
- Science is EXACT! (How can you make approximations and be right?) Science is without uncertainty (or at least should be).
- The meaning and the importance of error bars and uncertainties.
- There is always a right answer.
- Students struggle with the idea of the tentativeness of scientific knowledge;
- Scientific ideas are either 'proven' or 'not proven' - there is no sense of the quantitative nature of uncertainty.
- The theory-laden nature of scientific observations
- Scientists are always changing their minds.
- Or, conversely, scientific knowledge is fixed and unchanging.
- On the other end of the spectrum with regard to uncertainty, the process of science is fundamentally uncertain (there is a potentially infinite number of alternative hypotheses to account for any particular observation; confirmation is possible but proof isn't; even experimental disproof is uncertain; Karl Popper notwithstanding).
- If you have 'data' then it has one correct meaning; and is not open to interpretation.

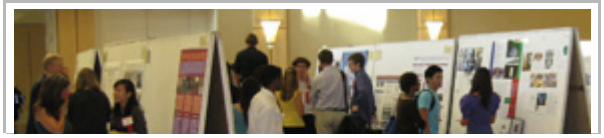
They are often missing conceptions about:

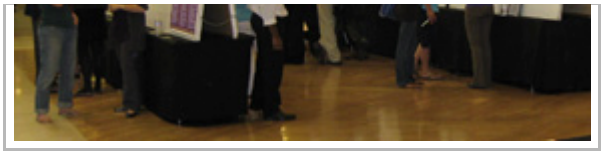
- How statistics are used in science
- How scientists build on the new knowledge they generate.

The community of science and the role it plays

Regarding the role of the scientific community in the process of science, students are mostly missing conceptions about things like:

- The role of community generally in the scientific process





- The meaning, nature, and importance of peer review
- The role of culture and societal influences on science

They also hold misconceptions about:

- The role that funding plays in science, and where that funding comes from
- How we communicate in science, and that it differs from other types of communication
- Why scientists seem to disagree on the 'scientific facts': they feel it is important to pay attention to the minority opinion, implying that the community of scientists is usually accepting of the ideas that most people like rather than the ideas that are best supported by evidence.

The nature of scientific theories

Misconceptions about the nature of scientific theories are rampant and well-known. These misconceptions include:

- The idea that "it's *only* a theory": the difference in meaning between the colloquial and scientific use of the word "theory"
- That what they are told in lecture as evidence supporting a hypothesis or theory is fact.
- That there is a hierarchy among "laws", "principles", and "theories"
- That calling something a scientific theory means it is tentative and uncertain.
- Misunderstanding the definitions of and differences between a scientific law, a hypothesis, and a theory.
- That a hypothesis that is well supported by data and other evidence is promoted to a 'theory' and a well-supported theory becomes a 'law'
- Confusing scientific hypotheses as proven facts.

Who can do science

These misconceptions about their ability to do science can can prevent students from learning more about science or taking more science classes. These misconceptions include the ideas that:

- Only smart or really well-educated people can participate in science; it is reserved for a special few - the "science people".
- You have to be really good at math to do science.
- Science is a difficult and obscure subject.
- All scientists are atheists and science is the sworn enemy of faith.
- The only people that can use the scientific method are scientists with PhDs.
- Scientists know everything and are never wrong.
- Science is only for "men" in white lab coats.
- Scientists must be emotionally detached from their work.
- They do not feel that science is something they can do. In labs, activities, or tests, students avoid using the scientific process (or thinking scientifically) for making a conclusion.

- Students accept what they are told as the truth without critically assessing the legitimacy of the statement or fact.