Scientific Teaching

Handelsman, Miller, and Pfund

The Wisconsin Program for Scientific Teaching

Part of the Teaching Mentoring Program

Sponsored by the CVM Teaching Academy

Presented by: John Nilson & Kay Brothers

"I wasn’t trained as a teacher, how can Scientific Teaching help me?"

- Learn about scientific teaching
- Explore misconceptions of scientific teaching
- Explore an ongoing process to make teaching more scientific and evidence based

The Call for Good Science Teaching

- Report offering recommendations for a new biology curricula that better reflects the dynamic and interdisciplinary nature of science with a rapidly changing frontier (NRC 2003, *Bio2010*)

- Charged higher education with “…teaching scientific habits of mind.” (AAAS, 1990; NRC, 2003)

- Recognized that employers are demanding more efficient and effective problem-solving and analytic skills along with the ability to work in teams (AAAS, 1990)

Case of the Frustrated Professor

Before the semester started, I worked really hard to set goals for the course. During the semester, I have been covering the content in clear, efficient, lectures that I think are really well-organized, but the students don't seem to be learning the material. In fact, 40% of students failed the first exam.

Students these days don't know how to take notes and study. They just don't get it.

How many of you have faced or witnessed a similar course challenge?

[The Good, the bad, the ugly]

Small Group Discussion

- Where did the economics teacher go wrong?
- How was the physics teacher different?

What is Scientific Teaching?

“Teaching science in a way that

1. Represents the nature of science as a dynamic, investigative process based on evidence,
2. Engages a diversity of people in a collaborative process and
3. Has clear learning goals in mind, uses methods and instructional materials designed to improve student learning, and evaluates the methods iteratively.”

What is the nature of science?

EMBO reports

Revisiting "Is the scientific paper a fraud?"

The way textbooks and scientific research articles are being used to teach undergraduate students could convey a misleading image of scientific research

Susan M Howitt[1] & Anna N Wilson[2]

In 1963, Peter Medawar gave a talk, *Is the scientific paper a fraud?*, in which he argued that scientific journal articles give a false impression of the real process of scientific discovery [1]. In answering his question, he argued that, "The scientific paper in its orthodox form does embody a totally mistaken conception, even a travesty, of the nature of scientific thought." His main concern was that the highly formalized structure gives only a sanitized version of how scientists come to a conclusion and that it leaves no room for authors to discuss the thought processes that led to the experiments.

Medawar explained that papers were presented to appear as if the scientists had no pre-conceived expectations about the outcome and that they followed an inductive process in a logical fashion. In fact, scientists do have expectations and their observations and analysis are made in light of those expectations. Although today's scientific papers are increasingly presented as being hypothesis-driven, the underlying thought processes remain hidden; scientists appear to follow a logical and deductive process to test their idea and the results of these tests lead them to support or reject the hypothesis. However, even the trend toward more explicit framing of a hypothesis is often misleading, as hypotheses may be framed to explain a set of observations *post hoc*, suggesting a linear process that does not describe the actual discovery.

There is, of course, a good reason why the scientific paper is highly formalized and structured. Its purpose is to communicate a finding and it is important to do this as clearly as possible. Even if the actual process of discovery had been messy, a good paper presents a logical argument, provides supporting evidence, and comes to a conclusion. The reader usually does not need or want to know about false starts, failed experiments, and changes of direction.

This approach to scientific communication has implications for teaching undergraduates the nature and practice of science as it creates a completely wrong impression of how science actually works and perpetuates a stereotype of scientists as logical and rational beings, doggedly adhering to the scientific method. Students may confuse the presentation of a logical argument with an accurate representation of what was actually done. This leads to a view of science that is unrealistic and may even be damaging as it implies that failure, serendipity, and unexpected results are not a normal part of research.

> *"Students may confuse the presentation of a logical argument with an accurate representation of what was actually done"*

Textbooks further reinforce this view. They typically present a discovery as having been made by a single scientist, or small group of scientists, with little explanation of the fact that these scientists were building on the work of others. In addition, the discovery is often presented as apparently logically emerging from a crucial experiment or observation. This completely conceals both the process of discovery and the thought that preceded it.

A case in point is the discovery of the double helical structure of DNA by James Watson and Francis Crick. Their *Nature* paper reporting the discovery is famous for its elegance and brevity [2]. A typical textbook account mentions that Watson and Crick used models to generate the double helix structure accommodating complementary base pairs. It usually also mentions the X-ray data of Rosalind Franklin and Maurice Wilkins but says little beyond this. As with a scientific paper, this is a question of purpose; students read textbooks to "learn facts," rather than to learn about scientific discovery.

As Watson's book, *The Double Helix* [3], makes clear, the actual process of discovery was anything but straightforward. In fact, Watson says in the preface that his reason for writing the book was because he was concerned about the general public's impression of scientific progress: "There remains general ignorance about how science is 'done'. That is not to say that all science is done in the manner described here. This is far from the case, for styles of scientific research vary almost as much as human personalities. On the other hand, I do not believe that the way DNA came out constitutes an odd exception to a scientific world complicated by the contradictory pulls of ambition and the sense of fair play."

By way of example, two crucial mistakes were made during the discovery. The first resulted from Watson misunderstanding the X-ray data, which he described as a humiliating experience when he presented an incorrect model, with the bases on the

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- How does the paper contribute to the true nature of science?
- Why is the SP a fraud?
- What is the true nature of the "hypothesis"
- What's the difference between deduction and induction
- Does published science build on the work of others? What is the implication for ST?
- Does ST focus on facts or discovery?
- What is the principle of limited sloppiness?
- Why is the social side of science important?
- Is good in exams enough preparation for good science?
- Is science just about collecting facts?

What is the nature of science?

Science & Society

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- Final Take Home

  “… students need to learn that mistakes or false starts are not time wasted, but are an essential part of making progress. They also need to understand that the scientific method is not a series of well-defined steps that always produce an answer, but a dynamic process that requires intellectual engagement and judgement.”

Three Pillars of Scientific Teaching

- Active Learning
- Assessment, both formative and summative
- Diversity, through cooperative/collaborative groups

Large Group Discussion

- What are the barriers to scientific teaching?
- How can barriers be removed?

Prelude to Session II: Tools to EnGauge Students

- Brainstorming
- Case Studies
- “Clicker” questions
- Decision making
- Group exams
- One-minute papers
- Pre/post questions
- Strip sequences
- Think-pair-share

Exit Assessment

Address the following questions in one minute or less:

- What is scientific teaching?
- Give an example