The Millikan Case - Discrimination Versus Manipulation of Data

Ethics in the Science Classroom Case Study #2

Author(s)

Michael Pritchard
Theodore Goldfarb

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Description

This historical case study looks at the work of Robert A. Millikan who is famous due to his important and innovative measurement of the charge on the electron and some important ethical issues raised by his collection, treatment, and presentation of his scientific data.

Abstract

This is one of six cases from Michael Pritchard and Theodore Golding's instructor guide, "Ethics in the Science Classroom."

Categories of Ethics/Values Issues Illustrated by This Case: Issues related to the collection, treatment and presentation of scientific data.

Body

1. Introduction

Of all the various types of "ethical dilemmas in science," the temptation to "fudge", or even invent data outright, is probably the one which high school science students will find most familiar. It happens all the time: their instruments give one result -- but they *know* that everybody else is getting some other result, or that something's wrong with the way they have done it, or that the result that people got last year is different, or that the result in the book is different.

What makes this an ethical issue, rather than just an issue of laboratory practice, is that the action that most promotes one's self-interest can be different from the "right" thing to do.

The Millikan case highlights a number of the important issues involved. But by itself, it is probably too complicated to use in helping students to navigate this issue. One can, however, set up simpler situations to illustrate the same points. As those historians who have analyzed the record of Millikan's treatment of his experimental data, and other similar cases, have pointed out, it is not always easy to distinguish between the "right" thing to do, inappropriate but inadvertent manipulation, and intentional fudging. Scientists agree that there are circumstances when some of the data collected in an experiment can be rejected or disregarded. In some cases statistical rules can be used as guidance, but in many situations it is left to the judgement of the experimental scientist to decide if a problem with the equipment or some other consideration justifies discarding a datum or a set of data. An acceptable practice, but one that is rarely followed, is to decide in advance what specific observed circumstances in a particular experimental situation would justify data rejection.

2. Background

In the 1930s and 1940s, Robert A. Millikan was the most famous U.S. scientist of his time. He had won the Nobel Prize in 1924, largely due to his important and innovative measurement, carried out around 1910, of the charge on the electron -- one of the most central physical constants that scientists of that era had been seeking to determine.

In 1897, British experimenter J. J. Thomson had discovered the electron and measured the ratio of its charge to mass (the e/m ratio) -- an event which helped to usher in the electronic age. The e/m ratio of the electron was related to a number of other important quantities of interest to scientists. But without knowing either the charge e or the mass m of the electron, all one had was a set of relative values; it would be like knowing a set of values in units of a foreign currency -- that a house costs x times what a car costs, which in turn costs y times what a newspaper costs -- without knowing the value in your own currency of any one. Measuring the mass of an electron seemed out of the question; you couldn't put one on a scale and read a dial. But neither, it seemed, could you isolate an electron and measure its charge on an electrometer. Around the turn of the century, Thomson and several of his students at the Cavendish Laboratory tried various means of indirect measurement, with unconvincing results. Moreover, until one had a relatively direct way of measuring the charge on the electron, one couldn't really be sure that the electron was indeed an "atom of electricity." It was still at least possible that electrons came in a spectrum of charges.

Millikan's method involved watching the behavior of oil droplets in an electrically charged field. Tiny oil droplets are ionized by passage through an atomizer; they have an extra electron or electrons riding on them. A droplet is allowed to fall between two plates, and then an electric field is created which pulls the droplet upwards. The speed of the droplet depends on the charge riding on it. Thus the basic measurement is the rise time; how long it takes a particular drop to rise a certain distance. If electrons had a spectrum of charges, one would expect a corresponding continuous spectrum of rise times. If, on the other hand, all electrons had the same charge, the charge on each ion would be multiples of a single number, a fact which would be reflected by rise times that would also be simple multiples of each other.

Millikan published tables of his measured drops and their rise times. What these tables indicated was that the charges on the droplets were, indeed, multiples of the same number -- thus, the charge of the electron. He then wrote a series of papers on his experiments. He would win the Nobel Prize in Physics for this work; he was only the second American to be so honored.

Millikan considered the experiment to be such a direct and irrefutable demonstration of the atomicity of electric charge that he wrote in his autobiography that "he who has seen that experiment, and hundreds of observers have observed it, [has] in effect SEEN the electron."

3. The Case

An examination of Millikan's own papers and notebooks reveals that he picked and chose among his drops. That is, he exercised discrimination with respect to which drops he would include in published accounts of the value of e, leaving many out. Sometimes he mentioned this fact, and sometimes he did not. Of particular concern is the fact that in his 1913 paper, presenting the most complete account of his measurements of the charge on the electron, Millikan states "*It is to be remarked that this is not a selected group of drops but represents all of the drops experimented upon during 60 consecutive days.*" However, Millikan's notebook shows that of 189 observations during the period in question, only 140 are presented in the paper.

Millikan's results were contested by Felix Ehrenhaft, of the University of Vienna, who claimed to have found "subelectrons." Moreover, Ehrenhaft claimed that his finding was in fact confirmed by some of Millikan's own data -- droplets that Millikan had mentioned but discounted in his published writings. The result was a decades-long controversy, the "Battle over the Electron," over whether or not there existed subelectrons, or electrons with charges of different values. This controversy makes an excellent case study because we are fortunate, thanks to Millikan's notebooks, to be able to see very specifically which drops he included and which he did not.

In retrospect, we know that Millikan was "right" and Ehrenhaft "wrong." Electrons, to the best of our present experimental and theoretical knowledge, have a specific, discrete charge.

Those scientists and other scholars who have carefully reviewed this case have failed to agree on whether Millikan was guilty of unethical behavior or "bad science" in the treatment and presentation of his data. One of the expressed opinions condemns Millikan on the simple basis of the fact that his published statement is at odds with what can be concluded from an uncritical examination of his laboratory notebooks. Others exonerate Millikan on the basis of a careful analysis and interpretation of comments on the data that appear in the notebooks. In the opinion of these Millikan defenders, the assertion that all drops were presented in the paper refers to all of the data taken under those conditions when the apparatus was working properly. Some of the scientists who have commented on this case appear to permit Millikan much discretion in the use of his "scientific intuition" to decide which data to include or exclude. This latter view seems to be guided by the principle that any scientist who consistently gets what turns out to be the correct answer is doing "good" science.

4. Readings

For biographical information about Robert A Millikan and the history of the oil-drop experiment that will provide the context for this case we suggest that you read:

- "Robert A. Millikan," by Daniel J. Kevles, *Scientific American*, 240, pp 142-151 (January 1979).
- "My Work With Millikan On the Oil-drop Experiment," by Harvey Fletcher, *Physics Today*, pp 43-47 (June 1982).

For a detailed analysis of the Millikan's work on the oil-drop experiment, including what he wrote in his laboratory notebooks see:

- "Subelectrons, Presuppositions and the Millikan-Ehrenhaft Dispute" in *The Scientific Imagination*, by Gerald Holton (Cambridge, Mass: Cambridge Univ. Press, 1978).

For several perspectives on the Millikan case and on other controversies concerning the analysis and presentation of scientific data see:

- *Betrayers of Truth*, by William Broad and Nicholas Wade (New York: Simon and Schuster, 1983).

- "Forging, Cooking, Trimming, and Riding the Bandwagon," by Allan Franklin, *American Journal of Physics*, 52, pp 786-793 (1984).
- "Moral Theory and Scientific Research," by Bernard Gert in *Ethics, Values and the Premise of Science Sigma Xi Forum*, *San Francisco 1993* (Research Park, NC: Sigma Xi Publishing Office, 1993).
- "Scientific Fraud," by David Goodstein, *The American Scholar*, 60, (Autumn 1991).
- *False Prophets: Fraud and Error in Science and Medicine*, by Alexander Kohn (New York: Basil Blackwell, 1986).

5. The Issues

Ethical questions specifically related to the Millikan case:

- Does the contradiction between Millikan's unqualified statement that he has published all the oil-drop data and the evidence of unpublished oil-drop measurements in his notebooks prove that he is guilty of unethical scientific behavior?
- If Millikan had not claimed to have published all the data, would he still be guilty of questionable behavior?
- Should the fact that Millikan was a highly successful scientist, and that he got the right answer in the controversy about the charge on the electron be a consideration in judging his scientific ethics?

More general questions about the manipulation and presentation of data raised by this case:

- What criteria should be used in deciding whether data can be legitimately discarded?

- When a scientist uses his or her "intuition" as the basis for deciding whether to ignore certain data, is the question of the ethics of this action dependent on whether the conclusion reached by the scientist is later proven to be correct?
- Is the intentional manipulation and selection of data in order to falsely prove a scientific premise less of a violation of acceptable ethical standards than the outright fabrication of data?
- Does the need for an accurate record to determine whether data have been treated and presented appropriately imply certain universal standards for the recording of observations by scientists? If so, what are these standards?

Resource Type

Case Study / Scenario

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