MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(5), em2625
ISSN:1305-8223 (online)
OPEN ACCESS Editorial https://doi.org/10.29333/ejmste/16255

How to teach philosophy of science to science students

Mansooor Niaz [1*]

[1] Department of Chemistry, Universidad de Oriente, Cumana, VENEZUELA

Received 12 Mar 2025 ▪ Accepted 31 Mar 2025

Abstract

The importance of philosophy of science in understanding science has been recognized in the literature. Science textbooks, however, not only ignore the history of science but also the underlying philosophy of science. Examples are provided to show how philosophy of science can be included in teaching science.

Keywords: history of science, philosophy of science, science education

INTRODUCTION

In a recent Editorial, Holden Thorp (2024), "has emphasized the importance of understanding science by, revising undergraduate and graduate curricula to teach not just theories and techniques but the underlying philosophy of science as well" (p. 141). Furthermore, he considers science as work in progress and history of science facilitates self-corrections as interpretations are continually revised considering new data and this leads scientists to be passionate about their ideas and disagreements. Indeed, this is the crux of the issue as progress in science is replete with controversies (Machamer et. al., 2000, p. 3).

Oil Drop Experiment: Millikan vs Ehrenhaft

At this stage it would be interesting to consider how science textbooks present such controversies as this could provide an opportunity to enrich the curriculum. Robert Millikan (University of Chicago) and Felix Ehrenhaft (University of Vienna) worked on the determination of the elementary electrical charge (the electron). Although both had very similar experimental data Millikan postulated the existence of a universal charged particle (the electron), whereas Ehrenhaft postulated the existence of subelectrons (fractional charges). A bitter controversy ensued between the two that lasted for many years (1910-1923), when Millikan was awarded the Nobel Prize. Gerald Holton (1978), Harvard University, added a new dimension to the controversy when he examined Millikan's hand-written notebooks at CALTECH. In these notebooks Holton found data from 140 drops, but the published article (Millikan, 1913) reported results from only 58 drops. What happened to the other 82 drops? It seems that Millikan made a rough calculation for the value of electron charge as soon as the data for the times of descent/ascent of the oil drops started coming in and ignored any experiment that did not give the value that he expected. This leads to the question:

> What was the warrant under which Millikan discarded more than half of his data?

Students in a classroom would be excited to hear the response: Millikan's guiding assumption, based on the atomic nature of electricity and the value suggested by previous research. What are guiding assumptions-precisely this is how philosophy of science comes into the classroom. This shows that the oil drop experiment, contrary to popular belief, was far from being simple and straightforward (Niaz, 2015). Evaluation of freshman general chemistry textbooks has been reported by Niaz (2000), who found that of the 31 textbooks (all published in U.S.A.) evaluated, none mentioned Ehrenhaft nor the controversial nature of the oil drop experiment. It is important to note that both studies (Niaz, 2000, 2015), were revised by Dr. Gerald Holton before publication.

Alpha Particle Scattering Experiment: Rutherford vs Thomson

It is generally believed that Rutherford's (1911) nuclear model of the atom was based on his alpha particle experiments, that provided evidence for single atomic encounters-single scattering. Again, it is generally ignored that as soon as Rutherford's results were known Thomson started doing similar experiments in his own laboratory (reported by Crowther, 1910).

✉ niazma@gmail.com **(*Correspondence)**

According to Wilson (1983): "J. J. [Thomson] had people working in his own laboratory, and a paper by one of his men, Crowther [1910], became of crucial importance in the battle between the two concepts of the atom. It is, however, too often ignored that Rutherford's superior concept of atomic structure also involved the overthrow of his master's [Thomson] model …" (p. 295). Rutherford himself recognized the serious challenge posed by Thomson's hypothesis of compound scattering: "I have looked into Crowther's scattering paper carefully, and the more I examine it the more I marvel at the way he made it fit (or he thought he made it fit) J. J.'s theory … I am quite sure the numbers of the earlier part of the curve [Crowther's] were fudged (Rutherford's letter to Bragg, reproduced in Wilson, 1983, pp. 300-301). Based on probability theory Rutherford showed that the chance of an alpha particle being deflected through large angles (1 in 20.000) was "vanishingly small" and the probability of an alpha particle experiencing a second deflection was "negligibly small". It was for these reasons that the hypothesis of single scattering was so convincing. Some students may ask: How could J. J. Thomson ignore such arguments as at that time he was recognized as the world master in the design of atomic models. According to Niaz (1998) of the 23 general chemistry textbooks evaluated (all published in U. S. A.) none mentioned the conflicting nature of Rutherford and Thomson models.

Photoelectric Effect: Einstein vs Millikan

The photoelectric effect constitutes an important part of both the chemistry and physics curricula, and general physics textbooks consider it useful for the introduction of quantum theory. Einstein (1905) proposed that ordinary light behaves as though it consists of a stream of independent localized units of energy that he called *lightquqnta*. Thus, if light consists of localized quanta of energy, an electron in an atom will receive energy from only one lightquantum at a time. Monochromatic light of frequency υ can, therefore, grant electrons only energy $h\upsilon$, where h is Planck's constant. Einstein's equation:

$$½mv^2 = Pe = h\upsilon - p \quad (1)$$

Where ½ mv^2 is the maximum kinetic energy of the ejected electrons; p the energy used to eject the electron from the metal; P the decelerating potential. Based on Einstein's equation Millikan (1916) calculated the experimental value of Planck's constant h, which was accepted by the scientific community. It is interesting to note that in the same publication (Millikan, 1916), he recognized the validity of the Einstein's photoelectric equation and also questioned the underlying hypothesis of lightquanta: "This hypothesis may well be called reckless first because an electromagnetic disturbance which remains localized in space seems a violation of the very conception of an electromagnetic disturbance, and second because it flies in the face of the thoroughly established facts of interference" (Millikan, 1916, p. 355). This led Holton (1999) to conclude, despite belief to the contrary, that Millikan (1916) is not an experimental proof of the quantum theory of light. Holton goes on to explain that Millikan's presupposition based on the classical wave theory of light made it difficult for him to accept the quantum hypothesis. In other words, this refers to underdetermination of scientific theories by experimental evidence, viz., no amount of experimental evidence can provide conclusive proof for a theory. Niaz et al. (2010) have reported that of the 103 general physics textbooks (all published in U. S. A.) evaluated, none of them point out that scientific theories are underdetermined by experimental evidence and that scientists have prior theoretical beliefs that resist change.

CONCLUSION

After having read Holden Thorp's Editorial (2024), it appears to me that teaching philosophy of science to science students may require more than simply recounting the historical events. The actual history of science is so different from that presented in science textbooks that it is precisely the underlying philosophy of science that can arouse students' interest in science. Furthermore, this task is even more important as some world-renowned authors of science textbooks have suggested that history of science is not necessary for teaching science (i.e., all is well if the book is selling well).

REFERENCES

Crowther, J. G. (1910). *Proceedings of the Royal Society* (Vol. 84). Royal Society.

Einstein, A. (1905). Über einen Erzeugung und Verwandlung des Lichtesbetreffendenheuristisch-Gesichtspteacunkt [On a heuristic point of view concerning the production and transformation of light]. *Annalen der Physik, 44*, 17, 132-148. https://doi.org/10.1002/andp.19053220607

Holden Thorp, H. (2024). Editorial: Teach philosophy of science. *Science, 384*(6692), 141. https://doi.org/10.1126/science.adp7153

Holton, G. (1978). Subelectrons, presuppositions, and the Millikan-Ehrenhaft dispute. *Historical Studies in the Physical Sciences, 9*, 161-224. https://doi.org/10.2307/27757378

Holton, G. (1999). R. A. Millikan's struggle with the meaning of Planck's constant. *Physics in Perspective, 1*, 231-237. https://doi.org/10.1007/s000160050020

Machamer, P., Pera, M., & Baltas, A. (2000). Scientific controversies: An introduction. In P. Machamer, M. Pera., & A. Baltas (Eds.), *Scientific controversies: Philosophical and historical perspectives* (pp. 3-17). Oxford University Press. https://doi.org/10.1093/oso/9780195119879.003.0001

Millikan, R. A. (1913). On the elementary electrical charge and the Avogadro constant. *Physical Review, 2*, 109-143. https://doi.org/10.1103/PhysRev.2.109

Millikan, R. A. (1916). A direct photoelectric determination of Planck's "*h*". *Physical Review, 6*, 355-388. https://doi.org/10.1103/PhysRev.7.355

Niaz, M. (1998). From cathode rays to alpha particles to quantum of action: A rational reconstruction of structure of the atom and its implications for chemistry textbooks. *Science Education, 82*, 527-552. https://doi.org/10.1002/(SICI)1098-237X(199809)82:5%3C527::AID-SCE1%3E3.0.CO;2-B

Niaz, M. (2000). The oil drop experiment: A rational reconstruction of the Millikan-Ehrenhaft controversy and its implications for chemistry textbooks. *Journal of Research in Science Teaching, 37*, 480-508. https://doi.org/10.1002/(SICI)1098-2736(200005)37:5%3C480::AID-TEA6%3E3.0.CO;2-X

Niaz, M. (2015). That the Millikan oil-drop experiment was simple and straightforward. In R. L. Numbers, & K. Kampourakis (Eds.), *Newton's apple and other myths about science* (pp. 157-163). Cambridge, MA: Harvard University Press. https://doi.org/10.4159/9780674089167-021

Niaz, M., Klassen, S., McMillan, B., & Metz, D. (2010). Reconstruction of the history of the photoelectric effect and its implications for general physics textbooks. *Science Education*, *94*, 903-931. https://doi.org/10.1002/sce.20389

Rutherford, E. (1911). The scattering of alpha and beta particles by matter and the structure of the atom. *Philosophical Magazine, 21*, 669-688. https://doi.org/10.1080/14786440508637080

Wilson, D. (1983). *Rutherford: Simple genius*. MIT Press.

https://www.ejmste.com