NEWTONIAN OPTICS IN THE EIGHTEENTH CENTURY: DISCUSSING THE NATURE OF SCIENCE

Breno Arsioli Moura & Cibelle Celestino Silva
Universidade de São Paulo – Brazil

Abstract

Despite the difficulty of precisely describing the nature of science, there is a widespread agreement concerning the necessity of incorporating into curricula some notions about how the scientific activity operates. Studying the history of conceptual development and the process of acceptance of scientific ideas by the scientific community may help teachers to incorporate valuable concepts on the nature of science in science teaching. Shortly afterwards the publication of the book Opticks, by Isaac Newton, in 1704, there appears a number of popular lectures and published works presenting the content of this book, attempting to make it suitable for the general public. These published works and popular lectures, however, did not discuss some conceptual problems in Newton's book. The present paper analyses the development and acceptance process of Newtonian optics during the eighteenth century in Europe, and emphasizes some aspects of nature of science that can be learnt by the study of this historical episode.

Introduction

The importance of the history and philosophy of science (HPS) as one of the necessary elements for a good scientific education is almost a consensus among most of the researchers in the area. Those who defend the inclusion of HPS in science teaching and in science teacher training programs advocate in favor of a contextual approach, in which scientific contents are taught in their different contexts: ethical, social, historical, philosophical, religious person, cultural and technological. According to Matthews (1994), the inclusion of HPS is an essential element to provide students with subsidies, which allow them to develop a more sophisticated understanding concerning the nature of scientific activity (Abd-El-Khalick & Lederman, 2000). Nowadays, academic researchers, journals and organizations like International History and Philosophy of Science Teaching Group consider teaching on the nature of science an important goal to be pursued by the scientific education. Therefore, science teaching should be accompanied by teaching about the nature of science, and its relations to culture and society is as important as to learn about scientific contents and procedures. (Gil, 1992; Matthews 1994; Bevilacqua & Giannetto, 1996). The study of the history of science values the mutable character of science exposing to view its dependence of historical and cultural contexts, defeating myths, humanizing geniuses and showing that the current scientific knowledge is susceptible of transformations (Martins & Silva, 2001).

Nature of Science

A historically grounded science teaching practice, among other strategies, might supply students with resources for a better understanding of the nature of the scientific activity (Abd-El-Khalick & Lederman, 2000). Nature of science convey a large group of knowledge about science that portray its methods, objectives, limitations, means of communication, as well the influence of external factors. The inclusion of notions about NOS in science classes is one of the current goals for good scientific education.

Philosophical subjects and even the contents related to nature of science will always be disputable, as well as the lack of a complete agreement on what science is and how it works. Some important points on the nature of science are still themes of great discussion by some researchers. Among them, we can mention the relations between scientific knowledge and social and historical factors, the veracity of scientific theories and their existence apart the scientists (Eflin *et al*, 1999). However, we can also mention some consensual opinions about the nature of the scientific enterprise: science has as one of its main purposes to acquire knowledge on the physical world, science is dynamic, changeable and temporary; there is not an exclusive method to be followed that ensures scientists to arriving to the same knowledge accepted nowadays. These aspects can be discussed from the study of particular historical episodes of history of science.

The Newtonian optics in the eighteenth century

The book *Opticks*, published in 1704, by Isaac Newton was very influential on the optical studies throughout the 18th century. The Book I and the *Queries* of the Book III were the parts of *Opticks* that called more attention of Newton's followers. While the Book I presents a detailed description of several experiments designed to demonstrate the heterogeneity of the white light, the *Queries* present conceptual arguments about the corpuscular nature of light, the existence of forces acting at distance between light rays and bodies, the existence of a universal ether, among other issues. These arguments were important for the 18th century Newtonians establish relations between Newton's dynamics and his theories of light and colors, since for most of the followers of corpuscular conception of light, optics should be able to mechanically explain the interactions between light rays and bodies. Thus, these authors intended to merge optics with the principles of Newtonian mechanics, such as those presented in the *Philosophiae Naturalis Principia Mathematica* by 1687.

Although *Opticks* was a great success and had won a great number of supporters, the followers of Newtonian optics did not assimilate many of its ideas. The parts that could not be incorporated into Newtonian dynamics, or were too obscure to be easily understood, were ignored or slightly developed. Among them, we can mention the theory of fits of easy transmission and easy reflection, exposed in the Book II of *Opticks*, and developed to explain the formation of colored rings in thin films, the famous "Newton's rings". The fits were part of a larger project of Newton. His intention was to develop a unified explanatory model to explain all known optical phenomena, including refraction, reflection and Newton's rings. For Newton the fits were original properties of light rays, like refrangibility; thus to inquire their origins or causes were not among *Opticks* purposes (Sabra, 1981). Although the fits of light are a central concept in the Newtonian optics, they were almost ignored or unknown or treated superficially by the 18th century opticians.

The popularization of Newtonian optics

Part of the success reached by *Opticks* may be attributed to the role played by published books and lectures addressed to broad publics, whose main purpose was to show an easy and uncomplicated natural philosophy. One of the principal lecturers of that time was J. T. Desaguliers, who became very well known in the scientific society of his time due to his defense of Newtonian physics. Besides the translation into English of the book *Mathematical Elements's* by 'sGravesande, Desaguliers was well known in the scientific society for his defense of the Newtonian theory of light and colors. He published his ideas in the books *Physico-Mechanical Lectures* (1717) and *Course of Experimental Philosophy* (1744); both books are sets of lectures on natural philosophy.

Desaguliers' lectures presented natural philosophy as a collection of truths about nature, and illustrated practical applications of science, for instance, the use of lenses to correct vision defects. The lectures on optics were generally based on exhibitions of experiments. His discussions on the light phenomena were very simple, with very few mathematical arguments. In these lectures, more complicated phenomena such as double refraction, "Newton's rings" and the inflection of light were seldom mentioned.

In the *Physico-Mechanical Lectures*, the first topic of the lecture on optics states the corpuscular character of light:

Lecture XVI

1. *That light is a body, appears from its reflection, refraction, composition, division, and moving in time; but especially from its being propagated in right lines, and being stopped by an obstacle, (how thin soever, if not transparent) which shows, that it cannot be an action*

upon the medium, which would be communicated beyond an obstacle, as in the case of sound. (Desaguliers, 1717, p. 42)

Desaguliers also accepted the existence of forces between light rays and bodies, using them in order to explain optical phenomena:

Lecture XVII

The Physical Cause of the Refraction, is the Greater or Less Attraction of the new Medium, as for Example, when the Refraction is made towards the Perpendicular, in the Case of a Ray of light going obliquely our of Air into Glass, just as the Ray enters the Glass, it is acted upon by two Forces […].(Desaguliers, 1717, p. 46)

The large number of popular books published in the period was another important channel of communication of Newtonian optics. A quite influential and successful book was Francesco Algarotti's *Newtonianism for ladies, or dialogues on light and colours*, published in 1737. The book presented some of Newton's ideas about light and colours in the form of a dialogue between a chevalier and a marchioness. It was among the most widely read books in Europe in the eighteenth century (Mazzotti, 2004).

In order to defend the corpuscular nature light, the lectures usually based on Newton's arguments and on the analogy between the behavior of light and particles of material bodies. Besides, they showed that other theories of light, such as the vibrational ones, were not able to satisfactorily explain all phenomena explained by corpuscular theory (Cantor, 1983). Those conferences, however, did not address several conceptual problems of corpuscular theory; many of them were already present in the *Opticks*.

Some problems in Newtonian optics

During the first four decades of the eighteenth century, the corpuscular theory of light was based on the *Queries* and on the experiments of Book I, which were arranged in a didactic and systematic manner, emphasizing the empiric and inductive character of Newtonian science. Even though fits were one of the fundamental concepts of Newtonian optics, they were either ignored or superficially considered by the 18th century opticians.

The situation only began to change in the 1750s, when new experiments were performed in Europe and some traditional ones were reinterpreted, putting in evidence some problems with the corpuscular theory. In this period, books and papers defending vibration interpretations for light were published; among them, it is worth of mention the *Nova theoria lucis et colorum* by Leonhard

Euler, *New experiments in electricity* by Abraham Bennet, *A dissertation upon the philosophy of light, heat and fire* by James Hutton and *An attempt to demonstrate, that all the phaenomena in nature may be explained by two simple active principles, attraction and repulsion* by Gowin Knight.

The main criticisms were related to the mass and volume of light particles, with the influence of gravity in the movement of light rays, with the explanations on the inflection and with the existence of forces acting between light and bodies, concept broadly used at that time. Besides, there were some phenomena that could not be explained by the Newtonian dynamic model such as the rings in thin films, explained in the *Opticks* by the concept of fits of easy reflection and fits of easy transmission.

In the late 18^{th} century wave theories of light gained room due to the fact that it could quantitatively and qualitatively explain important optical phenomena, for instance, "Newton's rings", polarization and diffraction of light. The increasing number of works based on the wave conception, mainly those by Young, Wollaston, Brewster and Fresnel, gave a great impulse to the subsequent development of wave theories of light.

What can we learn from this episode?

The historical analysis of the reception process and subsequent criticism of Newtonian optics throughout the eighteenth century points out many important characteristics of the scientific dynamics, which should be discussed and explored in teaching situations, such as:

♦ Scientific ideas are affected by their social and historical milieu: The rise of popular lectures and scientific books in the Enlightenment was crucial for the propagation and acceptance of Newtonian optics;

♦ Ideas of famous scientists can be greatly changed by their successors: Newton's followers selected and modified his ideas, creating a new corpuscular theory, much simpler than the Newtonian one;

♦ Previous prestige of scientists influences the process of acceptance of their later ideas: 18th century opticians built an optical theory that fulfilled the *Philosophiae Naturalis Principia Mathematica* paradigm;

♦ Many scientific ideas are ignored, even if they hold significant roles in their original context: Obscure ideas like fits of easy transmission and easy reflection were dismissed and their evident problems were not criticized.

The study of acceptance and development of Newtonian optics during the XVIII century evidences the temporality of science, providing fine examples that there is no true and definite scientific knowledge.

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