Joseph Priestley and *The History of Optics*: Historiography for Science Education

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Abstract

In 1772, Joseph Priestley published a historical account about the nature of light, from Ancient times to his days. The book, entitled *The History and Present State of Discoveries Relating to Vision, Light and Colours* (a.k.a. *The History of Optics*), presented a unique portrait of 18th century Optics and Natural Philosophy. Priestley's book was a representative of how the Newtonian view of the universe shaped later interpretations about past and present research about light, dividing the studies on Optics between before and after Newton. This proposal describes a detailed analysis of the book and highlights how it could be an example of the use of Historiography in Science Education.

Keywords: *History of Optics, Nature of Science, Newton, Priestley*.

Introduction

In 1772, Joseph Priestley (1733-1804) published the book *The History and Present State of Discoveries Relating to Vision, Light and Colours*, known as *The History of Optics.* The book was one of the first historical accounts about the nature of light and remained the only one of that kind for over fifty years in Europe (Schofield, 2008, p. 142). The book covers the discoveries and theories on optics since the Ancient Greece to Priestley's own time. Priestley presents a comprehensive account of the discoveries and ideas in optics, what makes his book a unique source for historians of science in this field.

The History of Optics was not the first historiographical book written by Priestley. In the preceding decade, he published *A Chart of Biography* (1665) and *A New Chart of History* (1669), which contained visual descriptions of names and events that Priestley considered relevant to the development of human race. He published his first historical account of a scientific topic, the electricity, in 1667. His *The History and Present State of Electricity, with Original Experiments* was a success in sales, being not only a source for historical curiosity, but also for electricians who searched for updates to their own research (Brock, 2008, p. 55). Years after *The History of Optics*, Priestley published other historiographical books, mainly in Religion, like *An History of the Corruptions of*

Christianity (1782) and the *Lectures on History and General Policy* (1788), all of them with Priestley's particular historical method and bias.

The present paper discuss how some aspects of Priestley's *The History of Optics* can be used in classroom situations to discuss nature of science. Educators have been long advocating for the introduction of History of Science in everyday science lessons, in order to enhance students and teachers' views of how science changes. The claim here is in a complementary direction: the study of *The History of Optics* shows how *the view of science* also changes over the decades and centuries. Therefore, an analysis based on meta-historiography might be also relevant when discussing nature of science and it should be explored more often in classrooms situations, especially in science teacher training courses.

In *The History of Optics*, Priestley followed a series of commitments related to his preferences and ideas about light and colors. His historical approach demonstrates that he was truly an 18^{th} century English natural philosopher. He assumed that light was a particle, defended Newton against his objectors and explicitly neglected other theories of nature of light. If compared to modern historical approaches about the history of optics until the 18^{th} century, like Sabra (1981) or Cantor (1983), *The History of Optics* has significant differences. Exploring them could be an interesting activity to show that not only Science is an ephemeral enterprise and influenced by personal commitments, but also the way we understand it. The introduction of historiography of science may add important contributions in the constant effort to make future teachers more prepared to understand and discuss nature of science in high school teaching.

The History of Optics

Priestley divided *The History of Optics* into six parts. The first one, with no more than thirty pages, covers the developments of more than a millennium and a half in optics, from the Ancient Greece to the beginning of 17^{th} century. The second and third periods describe the achievements in the 17^{th} century, especially the ones of René Descartes (1596-1650) and Johannes Kepler (1571-1630). The fourth period includes the discoveries until Isaac Newton (1642-1727), whose theories are analyzed in detail in the fifth part. The sixth and last period covers the 18^{th} century optics.

The History of Optics is often considered less successful than Priestley's preceding book of the same kind, *The History of Electricity*. While this last one was a best-seller, *The History of Optics* faced a general lack of enthusiasm. Priestley had to publish the book by subscription, what means that he did not have any guarantee of financial feedback (Brock, 2009, p. 56). Additionally, while *The History of Electricity* had original contributions to the field, *The History of Optics* was mainly a description of past theories, with little new subjects. Schofield (2008, p. 142) says that the only original parts of the book are those that describe the ideas of John Michell (1724-1793), who had personally helped Priestley composing the book. The author indicates that the "masses of material requiring condensation" gave a tedious character to Priestley's descriptions throughout the book.

There is no doubt, however, that Priestley invested a huge amount of time to write his historical account. At the end of *The History of Optics*, he listed nearly two hundred books, many of them published in his own days.

In the Preface, Priestley described the "historical method" he used to study the works of the natural philosophers and to write the book.

> I have adopted the *historical method*, because it appears to me to have many obvious advantages over any other for my purpose; being peculiarly calculate to enlarge the attention, and to communicate knowledge with the greatest ease, certainty, and pleasure. (Priestley, 1772a, p. vii)

The reader must be aware that Priestley's "historical method" have no resemblance nor it is a primitive form of modern historiographical approaches adopted nowadays. As Kragh (1987, p. 3) points out, although pioneer, Priestley's historical accounts are biased by a view that the history of science was a "natural part" of his science. Historical account should portray how science progressed and not make a critical analysis of it. Priestley believed that a systematic approach favored a quick learning of historical facts, especially by "young students" (Priestley, 1772a, p. vii).

The practical approach of his "historical method" is also present in the Biographical Chart, in the frontispiece of *The History of Optics*. The chart is perhaps the first remarkable element of the book, where Priestley shows the most relevant researchers on optics according to him. He described them as the ones "who have must distinguished themselves by their discoveries relating to vision, light and colours". Priestley included famous names until the present days, like Newton or Christiaan Huygens (1629-1695), but also some that are not usually mentioned in historical approaches on optics, like Roger Bacon (1214-1294) or Charles Du Fay (1698-1739).

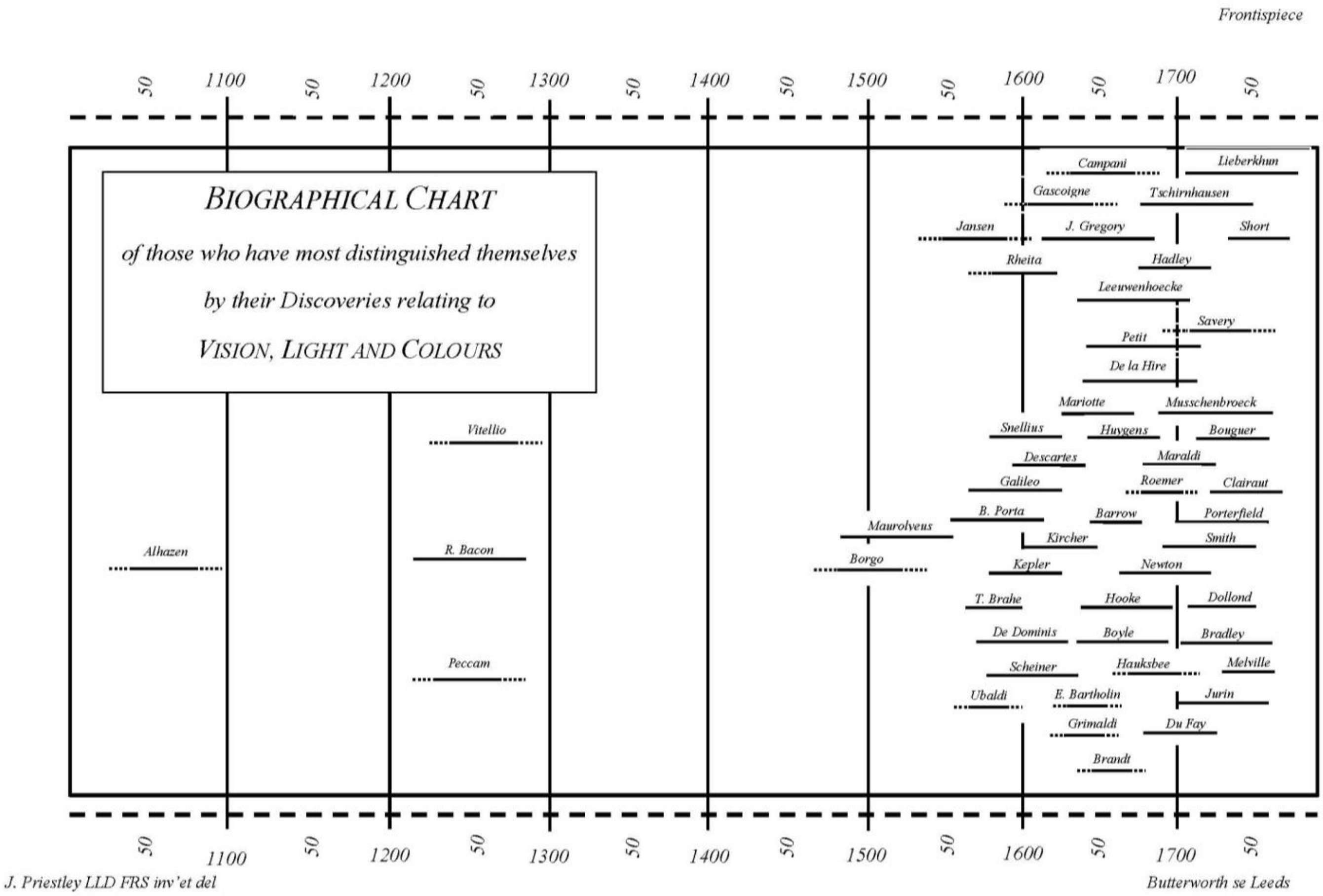

Figure 1 – Reproduction of the Biographical chart of Priestley's *History*. The original chart was analyzed in the *Bancroft Library* at the University of California (Berkeley).

The charts were designed as a rapid source to know the main philosophers and events. Years before *The History of Optics*, Priestley published two materials in which the charts played a central role, *Chart of Biography* (1765) and *New Chart of History* (1769). The first one contained a list of two thousand people divided into six categories, such as "Mathematicians and Physicians" and "Poets and Artists". The second one shows important historical events in more than a hundred places, divided by decades. Both of them were elaborated along the years Priestley was teaching history in Warrington Academy, in Yorkshire. Sheps (1999, p. 142) asserts that the "purpose of the charts, he explained, was as an adjunct of his lectures" and that they intended "to be hung on the wall of private study to augment and help reinforce what was learned or reading by using the imagination and by association".

The History of Optics shows itself as book of its time. Priestley believed that light was a particle and contributed to idealize Newton's works and theories, especially the *Opticks* (1704). Like many other Newtonian followers of the 18th century, Priestley portrays a perfect Newton and, very often, a mistaken Descartes. Acting as a historian, Priestley had in his hands the opportunity to describe a tendentious course of history.

Meta-historiographical analysis of *The History of Optics*

In the analysis of Priestley's *The History of Optics*, it was possible to identify at least three topics that can promote debates about how historiography and the views of science change throughout the centuries. The first topic is *Priestley's views of the history of optics*. If we compare the Biographical Chart displayed at the beginning of *The History of Optics* with a modern timeline (Figure 2), it is possible to point out some significant differences.

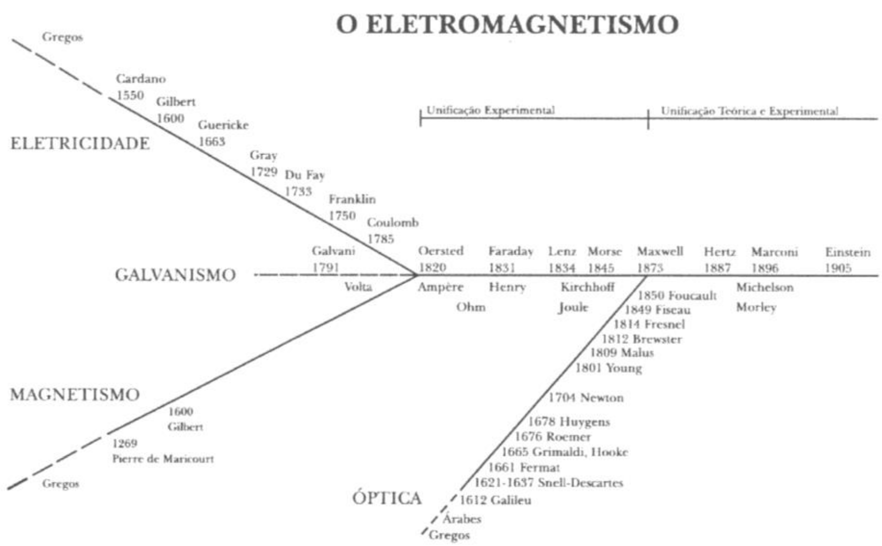

Figure 2 – Modern timeline presented in a Brazilian book of history of physics. The history of optics is introduced within the electromagnetism section. Source: Rocha (2002, p. 189)

The quantity of names listed in the two timelines is remarkably different. Priestley's list includes names that are not associated with the history of optics currently, like Bacon, Du Fay, Tycho Brahe (1546-1601) or Antoine van Leeuwenhoek (1632-1723). The modern timeline ignores the 18th century optics, since it is clear the gap between Newton and Thomas Young (1773-1829). Priestley, otherwise, mentioned about fourteen names of natural philosophers that made optical research in this period. He also gave a good emphasis on those natural philosophers that studied the eye, what is usually unrecognized in present historical accounts. Priestley discussed the works on vision made by Kepler and François Pourfour du Petit (1664-1741), for example. In 18th century, it was common that optical books included several pages to the discussion of vision and the eye (Cantor, 1983, p. 20). It seems that this tendency extended to historical approaches like *The History of Optics*.

The way Priestley wrote about the history of optics also calls our attention. The majority of his book, as Schofield (2008) observed, is filled with prolonged descriptions of other natural philosophers' ideas. The result is a tedious book in most of its parts, being a hard work to follow Priestley's discourse. If in his own time, *The History of Optics* was an unsuccessful book, today it maybe would not have been published. Works that condense vast periods of the history of a discipline are not usual currently. In general, modern historians have been working with specific topics related to an epoch or a scientist. In optics, the descriptions of Priestley are nowadays included in several books and papers. For instance, if we focus on 18th century optics, there are today at least three recent books on this issue, Steffens (1977), Cantor (1983) e Hakfoort (1995), all of them with different interpretations and conclusions. Of course that we cannot compare the nature or the purpose of these studies with Priestley's. Ranking them in good or terrible approaches is not the goal, since that would be an anachronistic reading. However, it is precisely this difference that illustrates how distinct was the view of history of optics of an 18th century historian and a modern one and at what extent this view has changed. If today each natural philosopher or historical episode can originate a new historical approach, in Priestley's own time, the systematization favored the reception of this kind of book.

The second topic is *Priestley's views of 18th century optics*. This topic is particularly relevant because Priestley was an 18th century natural philosopher writing about the period. Therefore, studying his interpretation of the achievements in optics in 18th century is important to comprehend how he saw the development of the field in contrast to what modern accounts portray. There is a popular belief that this period was somehow "infertile" and that no natural philosopher made a relevant optical study. This belief was propagated, in part, by William Whewell (1794-1866) in the 19th century (Cantor, 1978). Nevertheless, the current historiography has demonstrated the flaws of it (Steffens, 1977; Cantor, 1983; Silva & Moura, 2012). These modern studies show that the 18th century was filled with controversies, disputes and intense investigations on the nature of light, a scenario very different from that one described by Whewell. Priestley's account for 18th century optics confirms the modern approach.

Priestley wrote more than four hundred pages about the optics in 18th century. He described some developments of that time, like the making of achromatic lenses by John Dollond (1706-1761), the ideas of Thomas Melvill (1726-1753) about the minuteness of light and observations on the phosphorescence of some materials made by several natural philosophers. His portrayal shows a vivid field of research, with new ideas and improvements.

The third topic is his *decisions and commitments as a historian of optics*. Priestley believed that light was a particle and had Newton as the creator of the projectile theory of light. Accordingly, he immersed his account in an idealized view of Newtonian optics, what made *The History of Optics* more than just a simple reappraisal of optical theories and developments, but a deep defense of the projectile theory. In accordance to this tendency, Priestley frequently criticized the work of those before Newton or the ones who proposed other theories of light.

The Greeks were the first ones to be censured. As mentioned before, Priestley wrote no more than thirty pages about the period covering the Ancient Greece and the Renaissance. For him, the "first conjectures we meet upon this subject, it must be owned, were not very promising" (Priestley, 1772a, p. 1). He mentioned the works of Euclid (c. 300 B.C.) and Ptolemy (c. 90-168), but with little enthusiasm. He did not even mention these names in the Biographical Chart. Most of the first part of *The History of Optics* contains descriptions about the works of Alhazen (965-1040), Bacon and Witelo (c. 1230).[1]

Descartes was also criticized by Priestley. Although he discussed the Cartesian theory of light and colors in a quite detailed manner, he did not lose the opportunity to lessen it. Priestley claimed that Descartes had imagined too much, "which led him into many mistakes" (Priestley, 1772a, p. 97). He mentioned other natural philosophers contemporary to Descartes, apparently to diminish his importance. Names like Willebrørd Snell (1580-1626) – he reprehended Descartes for not quoting him properly – and Pierre Gassendi (1592-1655) were among the ones. Priestley said that Descartes, in his discussion of the law of refraction, gave "no account of any experiments that he made, in order to discover this law" (Priestley, 1772a, p. 103). However, he admitted that the Cartesian theory remained as a reference for the studies on light and colors, but stressed that the analogy between light and sound was a crucial problem. He concluded: "The followers of Descartes amended his hypothesis in several aspects, but without relieving it from this great objection" (Priestley, 1772a, p. 126).

In his examination of 18th century optics, Priestley overlooked the ideas of Leonhard Euler (1707-1783). Many modern accounts of history of optics will certainly include a discussion about his vibration theory of light in the *Nova Theoria Lucis et Colorum* (1746). Hakfoort (1995), for instance, made a comprehensive analysis of Euler's assumptions. Priestley, on the contrary, wrote about him in four pages only. Evidently, Priestley did not want to give much attention to a vibration theorist.

According to Priestley, Euler opposed Newton "strenuously" in the *Nova Theoria*, "in which he revived and maintained the hypothesis of M. Huygens" (Priestley, 1772a, p. 357). Priestley claimed that he would not "trouble" his "reader with mere hypothesis, any farther than they are absolutely necessary to explain the appearances of nature" (Priestley, 1772a, p. 358). He gave a brief summary of Euler's theory, but in respect to the theory of colors, he said that it was "intirely [sic] inconsistent with the principal part of Sir Isaac Newton's doctrine" (Idem).

In the opposite direction, Priestley made frequent eulogies to Newton. The "great" Newton and his "famous" ideas helped to bring the true knowledge about the nature.

[1] Priestley refers to him as Vitellio.

Newton "could bear no rival in any thing [sic] that he himself pretended to" (Priestley, 1772a, p. 349). His opponents "were not persons who had advanced any hypothesis of their own, to which they could be supposed to be attached" (Priestley, 1772a, p. 348).

The biased approach favoring Newton is evident in Priestley's report of the discovery of achromatic lenses by Dollond. One of the crucial aspects involved in Dollond's account was that it showed that Newton's theory of dispersion was wrong. Priestley came to defend Newton by quoting the words of some "Mr. Murdoch".[2] The defense was based on the argument that Newton might had not "be mistaken in his account of the experiment above-mentioned" and that he did not discover what Dollond did because he made use of different prisms (Priestley, 1772b, p. 474).

In his defense of Newton, Priestley frequently classified his theories as "excellent", "more precise" or "more probable". Besides, he adopted terms that Newton had used in his *Opticks*, such as "inflection" of light instead of "diffraction", the original term used at least since the works of Francesco Grimaldi (1618-1663). Priestley also attributed to Newton ideas that were not discussed entirely in his works. For instance, in the case of "inflection", Priestley did not hesitate in repeating letter by letter the experiments of the Book III of *Opticks*, although Newton himself had made clear that he had not determined the cause of it.

> I do not think I can discharge my duty as an historian, without reciting a very considerable part of the third book of his Opticks. Besides, as these experiments were the last that he made, and are acknowledge by himself to be incomplete, it is the more necessary to be particular in relating the circumstances of them; that others may be enable to repeat them, and carry them still farther. (Priestley, 1772a, p. 317)

Priestley also claimed that Newton argued about the attraction and repulsion of particles of light, as being the cause of phenomena such as refraction and reflection. According to him, it "never occurred to any person before Sir Isaac Newton, that reflexion [sic] and refraction may the caused by *powers of repulsion and attraction*" (Priestley, 1772a, p. 330). The idea that Newton gave a full account of these two powers was recurrent in the works of 18th century Newtonians. Modern historians have shown, instead, the Newton's accounts were highly hypothetical, since he only discussed these powers explicitly, but also superficially, in the "Queries" of the *Opticks* (Hall, 1993, p. 87, 90; Shapiro, 2002, p. 251).

On the other hand, Priestley was prudent when discussing some Newtonian ideas controversial at that time, in particular, the theory of fits of easy transmission and easy reflection described in Book II of *Opticks* and used by Newton to explain the appearance of colored rings in thin films. Newton believed that the fits were original properties of light, as its colors, and were responsible for the alternate reflections and transmissions of rays when they interacted with thin films of air, water or soap. This theory was widely ignored by 18th

[2] Probably Patrick Murdoch (?-1774), a mathematician Fellow of the *Royal Society*.

century Newtonians, especially because it did not fit in the mechanical models elaborated in that period (Silva & Moura, 2012). Priestley followed this guideline and mentioned in detail only the experiments performed by Newton. He distorted the descriptions in the *Opticks*, affirming that the theory of fits was a "hypothesis":

> […] but, like a wise man and a curious philosopher, he professes not to lay much stress upon it, though he seems not to entertain any suspicion of its truth. (Priestley, 1772a, p. 305)

Priestley's commitments with the Newtonian conception of light is also evident in his defense for the projectile theory. He was not careful at all in stating that light was composed by particles infinitely small and that this was the only way to explain the multiple optical phenomena. To prove the legitimacy of the projectile theory, Priestley relied on the experiments performed by Michell to show that light rays had a momentum. The experiments – never published elsewhere – supposedly showed a little disturbance of a thin plate of copper when illuminated by sunrays focused with the help of a concave mirror. Although Priestley – and apparently, Michell himself – admitted some flaws in these experiments, he said that "there seems to be no doubt, however, but that the motion abovementioned is to be ascribed to the impulse of the rays of light" (Priestley, 1772a, p. 389). Nevertheless, other natural philosophers made similar experiments and did not find any evidence of a momentum in the rays of light (Cantor, 1983, p. 57).

At the end of *The History of Optics*, Priestley wrote a summary containing the core of the doctrine of light. According to him, the observations made since Newton's time "will authorize us to take it for granted, that light consists of very minute particles of matter, emitted from luminous bodies" (Priestley, 1772b, p. 769). This defense, along with the other methodological choices, makes clear that Priestley was not simply a historian, but what we may call a "Newtonian historian of science".

Historiography for Science Education – final comments

The meta-historiographical analysis above shows that Priestley had a particular bias in his historical account, what illustrates that views of science also change throughout time. In this section, we point out two possible debates that this analysis might enhance in science teacher training courses.

Historians of science are also influenced by social and cultural milieus

When introducing history of science in science education, researchers often stress the importance of cultural, social, political etc. contexts in the development of a scientific idea and that scientists are creative and not just simply follow a "universal step-by-step method" (McComas et. al. 1998, p. 513). Therefore, the development of scientific knowledge involves many factors and cannot be described linearly. However, does that happen with historians of science?

As mentioned above, Priestley was an 18th century British historian of science. He was immersed in a context where Newtonian theories played a major role and Newton was considered a "national hero" (Fara, 2002). He believed in the projectile theory of light and considered Newton a brilliant man. His disapproval of vibration theories like Descartes' and Euler's and his explicit defense of the projectile theory of light indicate that Priestley wanted to establish the Newtonian ideas about light and colors as the only true way to comprehend optical phenomena.

From the analysis of Priestley's work, one can wonder if the modern historiographical account are also immersed in a particular context and if they are influenced by it. Besides, at what extent does our biased approaches affect the interpretations of historical episodes? These questions indicate that the works of historians of science are dependent of social and cultural milieus as much as the works of scientists. It is not adequate to think that historians are external agents looking to the course of events. Additionally, this is not exclusive of past historians, since current researchers may also impregnate their work with private standpoints. Science teachers might understand that a historiographical account can also be imbued with personal ideas and beliefs. From this, it is possible to stimulate a critical thinking, in which the teacher is not just a passive receiver of historical information, but an active and transformative individual.

Historiographical interpretations are mutable and provisional

The Biographical Chart elaborated by Priestley shows, from one side, his view of optics until the 18th century, as well his own preferences about who should be included in it and who should not. The omission of Euler is an important sign to comprehend that Priestley was compromised in not discussing ideas that opposed the projectile theory. From another perspective, his comments about several optical researchers of the 18th century imply that they were considered important figures of that time, even in a biased approach. The modern timeline includes other names and excludes many others. Both of them are portraits of its own time about the history of optics.

These differences denote that the interpretations that historians have of history of science is mutable and provisional, like science. In the future, historiographical approaches that nowadays are considered relevant may become aged representations of an obsolete historiography. Therefore, educators should not indoctrinate their students with a "definitive" historical view. If Newton was an alchemist, as the majority of modern historiographical studies say, this interpretation possibly will change in future decades or centuries, reinforcing the current historiography or completely disagreeing with it. Similarly, how can we know if Einstein, for instance, will be in a timeline in 200 or 500 years from now? Will he occupy a prominent place like today? This kind of debate can advance the growth of critical thinking not only about the scientific knowledge, but also about knowledge as a whole and our part to improve and expand it.

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