

Between China and the West: The Integration of Geometric Optics Knowledge in the Late Qing Encyclopedias

Yining Liu¹, Zhaojun Ding^{1*}

¹*University of Science and Technology of China, Hefei, China*

**Corresponding Author. Email: dzj.@ustc.edu.cn*

Abstract. A series of new compiled anthologies—encyclopedias—that emerged in the late Qing Dynasty reflected the syncretism of Chinese and Western optical knowledge among late Qing intellectuals. By systematically sorting out the distribution of geometric optics knowledge in late Qing encyclopedias, this paper discusses the compilers' absorption of Western optical knowledge and their expression of the connotation of traditional knowledge, thereby analyzing late Qing intellectuals' reception and cognition of Western learning.

Keywords: The Eastward Spread of Western Learning, Late Qing Dynasty, Geometric Optics, Encyclopedias

1. Introduction

Since the second wave of the eastward spread of Western learning, Chinese people's cognition of all things in nature has been greatly impacted. Under the social ideological trend of seeking self-strengthening, prosperity and national salvation in the late Qing Dynasty, the intellectual values of Chinese scholars gradually shifted from the traditional focus on humanities to the emphasis on modern science and technology. As a part of modern natural science, optics gradually entered the vision of late Qing intellectuals.

Wang Jinguang once stated in *A History of Optics in China*: "Compared with modern Western optical knowledge, traditional optical knowledge is fragmented and superficial, and can only be 'absorbed' by the former, with no possibility of forming another new optical system." [1] However, setting aside the traditional impact-response interpretation and Whiggish tendencies, against the backdrop of the eastward spread of Western learning, how was optics—a field in which China had achieved brilliant accomplishments since ancient times—"absorbed"? How did Chinese scholars interact with tradition in their cognition of Western science? Such questions are worthy of in-depth exploration.

The new compiled anthologies discussed in this paper emerged during this period. They were products of the drastic changes in the ideological concepts, academic horizons and knowledge structures of late Qing scholars, and can well reflect the cultural trends of the time. Zhong Shaohua, the earliest domestic scholar to notice these books, argued that from the perspective of knowledge dissemination, these books could be called China's earliest "encyclopedias" [2], a concept adopted in this paper. In terms of compilation purpose, encyclopedias differed from *Collected Essays on Statecraft* guided by the statecraft ideology, aiming to objectively introduce knowledge; in terms of

function, besides fulfilling the compilers' ambition of popularizing new knowledge and transforming society, encyclopedias were also used as textbooks for the imperial examination; in terms of stylistic rules, unlike ancient Chinese traditional leishu (reference books compiled by category), encyclopedias were compiled by late Qing intellectuals who rearranged the stylistic rules, order and content framework based on a large number of translations, newspapers and other materials; in terms of content, compilers comprehensively and systematically integrated existing knowledge according to different themes to introduce objective and extensive knowledge. For example, Chen Changshen, the compiler of *Classified Compendium of Current Affairs*, mentioned in his preface that he "collected extensively memorials of famous ministers of past dynasties and news facts of various countries to compile this book" [3]. It is evident that encyclopedias were a collective expression of ideologically enlightened people on relevant themes at that time, with universality and functionality.

Previous studies on encyclopedias have mainly focused on the history of books, conceptual history and biographical studies, emphasizing the origin and development of encyclopedias, their relationship with leishu, the compiler and reader groups, and their impact on social transformation. However, there has been little attention to the knowledge content itself in encyclopedias, especially scientific and technological knowledge, and research on optical knowledge, which had an important tradition in ancient China, is basically absent. This paper analyzes the optical content in late Qing encyclopedias, discusses the syncretism of Western optical knowledge and Chinese indigenous optics, and explores late Qing intellectuals' cognition, resistance and acceptance of Western learning.

2. New writing: Late Qing encyclopedias involving optical content

There was no precedent for encyclopedias in Chinese tradition. Late Qing encyclopedias emerged as the times required against the background of advocating Westernization and Western learning in the late Qing Dynasty, reflecting the shift of Chinese scholars from passive to active acceptance of Western knowledge. After the abolition of the imperial examination system, most encyclopedias were not reprinted in new editions, fading away like a flash in the pan, hence receiving little attention from academia. However, due to their temporal characteristics, encyclopedias can directly reflect the degree of intellectuals' cognition and acceptance of Western learning during this period.

Encyclopedias were the outcome of the localization of new learning, with a complex composition of compilers, generally including diplomats and upper-class gentry, reformists, new-style literati and ordinary enthusiasts of Western learning, among whom were cultural celebrities such as Ma Jianzhong [4]. Restricted by the compilers' level, the compilation quality of encyclopedias varied greatly, and mutual copying was common. Among the important late Qing encyclopedias published between 1897 and 1903 that involved optical content, *Textual Research on Current Affairs* and *Sequel to Textual Research on Current Affairs* were the earliest two; subsequent books such as *Classified Compendium of Current Affairs*, *Complete Book of Global Political and Technological Studies*, *Textual Research on Modern Technological Studies of the Five Continents*, and *Comprehensive Compilation of Technological Studies* were all compiled by deleting and piecing together these two books. Wu Dazheng once talked about the merits of *Textual Research on Current Affairs*: "Once perused, everything is clear; those who discuss statecraft almost keep a copy at home and regard it as a reliable edition." [5] This reflects the popularity of encyclopedias among late Qing intellectuals from a side.

The content of late Qing encyclopedias can be described as all-encompassing. Most of the physical knowledge involved was under categories such as "gezhi (the investigation of things and extension of knowledge)", "craftsmanship", and "measurement", mainly including mechanics,

electricity, vapor studies (hydrology), optics, acoustics, etc. From the perspective of disciplinary classification, like other modern physical disciplines, optics was not regarded as an independent discipline in the late Qing Dynasty, but still seen as a branch of gezhi. The sources of optical knowledge in encyclopedias were extensive. At the beginning of the "Optics Research" in Complete Book of Global Political and Technological Studies, a list of twelve Chinese and Western optical works for selection and reference was enumerated, namely Essentials of Optics, Illustrated Notes on Optics, Key Points of Optics, Introduction to Optics, Calculations in Optics, Optics, Treatise on Microscopes and Telescopes, Illustrated Notes on Photometers, Perspective, Jing Jing Ling Chi (On the Fantasy of Lenses), Supplements to Ge Shu (Geometric Techniques), and Notes on Optics [6]. The chapter "On the Levels of Light" summarized the basic content of optics: "1. Luminous emission and transmission, 2. Reflection, 3. Refraction, 4. Light sources, 5. Visual instruments." [6] This basically covers all optical content in late Qing encyclopedias. The following discussion examines geometric optics knowledge to explore the selection and reconstruction of Western optical knowledge by late Qing intellectuals from a traditional perspective.

3. Intersection of Chinese and Western geometric optics knowledge

Ancient Chinese understanding of optics was mainly in the field of geometric optics, achieving important accomplishments in pinhole imaging, light reflection, spherical mirror imaging, lens ignition, etc., such as the famous eight optical entries in Mo Jing (Mohist Canon), Shen Kuo's research on camera obscura technology, Zhao Youqin's pinhole imaging experiment and the concept of illuminance. The deficiency of traditional optics lay in that it mainly stayed at the level of qualitative observation and recording, lacking quantitative theoretical summarization to establish a knowledge system. By the late Qing Dynasty, geometric optics remained the core part of optical knowledge. The geometric optics content in late Qing encyclopedias distinctly reflected the encounter between traditional optics and Western optics, mainly including the following three aspects.

3.1. Disenchantment of optical phenomena

One of the uses of traditional Chinese optical knowledge was to measure nature, with an obvious pragmatist tendency, and the understanding of optical phenomena stayed at the level of description and empirical cognition [7]. The scientific explanations of natural phenomena in late Qing encyclopedias were significantly different from traditional Chinese explanations, and the difference was reflected directly. If the introduction of Western optics was a disenchantment process of replacing "non-scientific explanations" with "scientific explanations" [8], late Qing encyclopedias well reflected the result of the replacement of mysticism.

For example, in the explanation of the eye and vision, Ge Zhi Zhong Fa (Chinese Methods of Investigating Things) compiled by traditional scholars almost in the same period still inherited the ancient medical concepts of qi, pulse and spirit, and understood the phenomenon of the eye being able to see light through psychology and the interaction of yin and yang [9]. In contrast, "On Vision" in Textual Research on Current Affairs introduced the eye structure through five entries: "small substance in the eye, visual axis, three transparent substances, pseudofat shape, and binocular vision" [10].

Ancient people believed that the eye could emit light, while most later late Qing encyclopedias abandoned this mystical explanation of the eye and vision. Under the category of "Principles of Vision" in Sequel to Textual Research on Current Affairs, there were 28 entries that detailed the

structure of the eye and its imaging principle, myopia and hyperopia, glasses, and judging the size of objects. Unlike the previous confusion of names, under the entry "Eye" in *New Learning Compendium*, modern names such as "retina" and "eye axis" were adopted, and the retina was regarded as "the dark box of a camera." [11] This progress was also due to the gradual clear understanding of the solar spectrum and luminous sources by late Qing intellectuals. With the improvement of optical theoretical level, Chinese people in the late Qing Dynasty increasingly accepted Western explanations of the eye and vision, and their cognition continued to approach the scientific level.

Similarly, ancient Chinese scholars had many discussions on the phenomenon of "rainbow", but basically confined to common sense understanding and failed to draw scientific conclusions about its causes. Most late Qing encyclopedias introduced light dispersion through the "rainbow". In *Complete Book of Global Political and Technological Studies*, there was a question in "Optics Studies": "Why is a rainbow always opposite to the sun?" [6] It can be seen that the cause of the rainbow had become common sense in the late Qing Dynasty, even appearing in exercises. In the explanation of natural optical phenomena, Chinese people in the late Qing Dynasty almost fully absorbed the optical knowledge introduced from the West, and their cognitive level achieved a qualitative improvement, filling the gaps in traditional Chinese optics.

3.2. Integration of optical theories

The optical entries in *Textual Research on Current Affairs* included discussions on shadows, reflection, refraction, etc., involving traditional Chinese optical knowledge of reflection, refraction and imaging, giving relatively accurate geometric optics definitions such as "angle of incidence", "angle of reflection", "perpendicular line", and "angle of refraction", and exploring concepts related to geometric optics such as the speed of light and illumination, as well as the principles of various lenses and optical instrument groups.

At the same time, there were still descriptive laws with traditional characteristics in the entries, such as "the principle that the angle of incidence equals the angle of reflection" and "small shape without inversion". The juxtaposition of laws and concepts may have facilitated people's understanding and reading at that time, but also led to confusion in the entries. Some entries were piled up, obscuring their internal logic, such as placing "speed of light propagation" under "On Shadows" and introducing "perpendicular line, water surface perpendicular line, and direction of perpendicular line" separately.

Textual Research on Current Affairs and *Sequel to Textual Research on Current Affairs* were compiled by the same author successively. The latter supplemented the content of "light color" in the geometric optics part [12]. The author had a deeper understanding of subtle points, no longer confusing definition explanations with property descriptions, but integrating related themes, distinguishing knowledge levels, and reconstructing a knowledge framework with internal logic.

In general, late Qing encyclopedias no longer limited themselves to using optics to solve practical problems, nor did they surpass the qualitative conjectures of ancient traditions. Instead, while introducing accurate knowledge and principles, they still retained some inertia of traditional descriptive knowledge. Restricted by the compilers' cognitive level of the modern Western optical knowledge system, the entry logic and knowledge structure showed obvious transitional characteristics of Chinese-Western syncretism.

3.3. Application of optical instruments and optical knowledge

In the late Qing Dynasty, although the optical theoretical level of Chinese intellectuals was not high, emerging optical toys and instruments had been widely circulated among the people. Even the kaleidoscope, the latest Western optical toy at that time, could be imitated locally [13]. Comprehensive Compilation of Technological Studies dedicated a volume to introducing optical instruments, including the visual principle of the eye, various telescopes, glasses, lenses, lamps, microscopes, etc. [14]. Meanwhile, there was a knowledge disconnect in the introduction of optical theories and applications. For example, the introduction of double refraction theory often ignored the interpretation of Huygens' principle, but introduced the Wollaston prism invented based on the double refraction principle in terms of application. This practice of deleting theoretical details and only retaining conclusions and applications reflected the preference of traditional Chinese scholars for practical value, as well as their learning method of "seeking only a superficial understanding" of Western learning.

From Textual Research on Current Affairs to Sequel to Textual Research on Current Affairs and then to Comprehensive Compilation of Technological Studies, there was a process of "knowledge expansion" in late Qing intellectuals' cognition of geometric optics. The geometric optics in early encyclopedias filled the theoretical gaps in traditional Chinese optical knowledge and corrected its errors, but still retained the fragmented characteristics of traditional optical knowledge, and the qualitative description tendency of knowledge naturally led to inherent logical defects between entries; while the later encyclopedias, although still failing to form a rigorous theoretical system of geometric optics and with uneven understanding of subtle points, generally enriched the knowledge foundation and framework of geometric optics. This "knowledge expansion" process reflected the syncretism of Western optical knowledge and traditional Chinese optics.

In summary, from the perspective of optical knowledge, late Qing encyclopedias presented intellectuals' selection and reconstruction of the knowledge introduced from the West. As the core, geometric optics knowledge was introduced relatively completely, and related natural phenomena had lost their mysterious color in the eyes of Chinese intellectuals, with Western scientific explanations becoming a consensus. Based on the optical entries in encyclopedias, we can roughly see the mastery of geometric optics knowledge by late Qing intellectuals (as shown in Table 1).

Table 1. The framework of geometric optics knowledge among Late Qing intellectuals

Natural Phenomena	Theoretical Explanations	Devices or Experiments
Principle of eyeball and vision, rainbow, mirage, solar eclipse	Shadow, light intensity, reflection, refraction, double refraction, luminosity	Spherical mirror imaging, lens imaging, glass, camera, magnifying glass, microscope, telescope, glasses, kaleidoscope, pinhole imaging

4. Ways of knowledge expression in Late Qing encyclopedias

The entry-based expression of late Qing encyclopedias can directly reflect the compilers' knowledge structure and selection tendencies. The stylistic rules of late Qing encyclopedias were inclined to the compilation methods of traditional Chinese leishu, with content classification as the outline, a general catalog at the beginning of the volume, each entry standing alone, ranging from dozens of characters to hundreds of characters, with punctuation in some books; compared with traditional leishu, it was easier for readers to check the order. The following discusses the expression methods and characteristics of Western optics in late Qing encyclopedias.

First, neglect of quantitative experiments and light path diagrams.

Wang Jinguang mentioned in *A History of Optics in China*: "Some people think that ancient Chinese physics did not attach much importance to experiments. This may be true for physics as a whole, but it is inconsistent with historical facts for optics alone." [1] Admittedly, ancient China had many exquisite experiments ahead of their time. For example, Zhao Youqin's pinhole imaging experiment in the Song and Yuan dynasties, which used a two-story building and thousands of candles, was the largest optical experiment in the world at that time. However, due to the lack of quantitative measurement, he could only draw qualitative conclusions. Western optical works introduced into China, such as *Introduction to Gezhi* and *Calculations in Gezhi* written by W.A.P. Martin, devoted a lot of space to optical calculations, but most of these calculation contents were ignored by compilers in the compilation of late Qing encyclopedias.

Similarly, some not complicated light path diagrams in Western monographs were not generally reflected in late Qing encyclopedias. Encyclopedias such as *Textual Research on Current Affairs*, *Sequel to Textual Research on Current Affairs*, *Classified Compendium of Current Affairs*, *Textual Research on Modern Technological Studies of the Five Continents*, *Complete Book of Global Political and Technological Studies*, and *Comprehensive Compilation of Technological Studies* had no attached figures throughout the text. Quantitative calculation and drawing of light path diagrams were not the traditional research habits of Chinese optics, and it would take time for late Qing intellectuals to fundamentally accept Western scientific methods.

Second, presenting Western numerical symbols and formulas in traditional ways.

The introduction of Western learning into China adopted a certain degree of localized compromise in expression. Late Qing encyclopedias basically followed traditional Chinese expression methods: writing numbers in uppercase, and using Heavenly Stems, Earthly Branches, constellation names, etc., to replace foreign letters. Although Arabic numerals were introduced into China as early as the 13th-14th centuries, they were not effectively popularized in the late Qing Dynasty. Among the 8 encyclopedias mainly examined in this paper, Arabic numerals only appeared sporadically in a few places.

The traditional expression methods of late Qing encyclopedias reflected the process of "opposition-compromise-integration" in the dialogue between China and the West.

5. Conclusion

This paper examines the geometric optics content and expression methods of late Qing encyclopedias, reflecting the significant expansion of the cognitive scope of Chinese intellectuals under the transformation of their attitudes towards Western science. The Chinese-Western syncretism reflected therein is both the acceptance and construction of knowledge content, and the selection and resistance of expression methods. Traditional geometric optics knowledge was developed and supplemented, which is clearly reflected in encyclopedias. Late Qing scholars' understanding of natural phenomena lost their mysterious color due to the acceptance of Western scientific explanations. In the application of optical instruments, encyclopedias showed a tendency of "knowing the what but not the why", and reflected obvious pragmatism. In terms of expression methods, late Qing encyclopedias followed the Western entry-based compilation structure, but adopted the traditional Chinese expression method of using Heavenly Stems, Earthly Branches and Chinese characters.

Research shows that most late Qing Chinese intellectuals were in a state of selectively absorbing Western knowledge, and their knowledge level was still far from establishing a modern optical system. Optics was still in the initial stage of disciplinary development. Through the interpretation

of geometric optics knowledge in late Qing encyclopedias, we can obtain important clues for understanding the Chinese-Western syncretism under the background of the eastward spread of Western learning.

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