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Scientific Inquiry in Renaissance Art: The Artistic Characteristics of Leonardo's Works

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Abstract. In the Renaissance, due to the rise of humanism, people started to break through the confines of previous medieval thought, paying more attention to real life and drawing inspiration from it. Artists began to abandon the traditional way of painting, gradually changing their previous way of creating, and decided to get inspiration from nature. During this period, artists focused on the study of the phenomena and laws of nature so that they could create artworks that were more in line with the laws of nature. During this period, the artists' research involved botany, anatomy, mathematics, physics, and other fields. Their research results not only helped their creations but also made great contributions to the development of natural science in later generations. As one of the most important artists in the Renaissance, Leonardo da Vinci was involved in many fields such as anatomy, physics, and mathematics, and applied his research results in his artworks. In his artworks, science and art are skillfully combined. According to Leonardo's works such as "*Annunciation*", "*The Last Supper*" and "*St. Jerome*", it can be analyzed that there was a close connection between Leonardo's works and disciplines such as anatomy, mathematics, and physics. This could be helpful for understanding the application of knowledge of natural sciences in Leonardo's paintings and providing a reference for the subsequent research on Leonardo and science.

Keywords: Leonardo da Vinci; Renaissance; Anatomy; Perspective; Golden ratio.

1. Introduction

In the Renaissance, with the rise of humanism, the secular spirit was gradually at the core of culture. On the contrary, the central position of Roman Catholic Theology in the cultural structure was broken. Secular knowledge received wide attention in the era in which it took place, and it had a profound impact on many fields of human activities, which led to the formation of a habit of treating life and cultural and spiritual activities with a secular attitude, and inspired people to study human and real things, brought about the development of many fields such as art, natural science, philosophy. And this brought about a fundamental transformation in the structure of Western culture [1]. Leonardo da Vinci, one of the three masters of the Renaissance, was also a genius with multiple identities. The breadth of his achievements covers nearly every aspect of the natural and social sciences, including painting, anatomy, engineering, aerodynamics, mechanics, water construction, botany, geometry, astronomy, optics, architecture, urban planning, mechanical design, and more.

This study focuses on a few of Leonardo's paintings, explores the theories of natural science connected to them, and analyzes the connection between Leonardo's paintings and natural science, which is of great significance to the study of the development of natural science in the Renaissance, and the influence of science on artistic creation. This study focuses on the connection between physics, anatomy, mathematics, and paintings such as *Annunciation*, *The Last Supper*, *St. Jerome*, etc., and uses the method of literature analysis to read and find relevant information and literature. The advantage of this research method is that it can combine the results of previous research and well analyze the correlation between the knowledge of natural science and Leonardo's paintings, which is beneficial for the research. The purpose of this study focus on Leonardo's artworks and explore the science in Renaissance artworks. Based on this purpose, documentary analysis and visual analysis were conducted.

2. Scientificity

2.1. Physics

Leonardo believed that the first principle for painting was perspective. With an exact attitude towards science and physics, Leonardo was very cautious in his exploration of perspective. It was this attitude that made him make significant contributions to the visual arts. Leonardo repeatedly explored the perspective theories that were left behind by Alberti. The results of Alberti's theories on the reproducibility of space had a deep influence on Leonardo, which also greatly contributed to Leonardo's exploration of perspective. Leonardo's artistic achievements were full of scientific rationality and theoretical methods. He believed that painting was not only a branch of art but also a scientific discipline [2]. After summarizing the theories of his predecessors on linear perspective, Leonardo put forward the new theory of "air perspective". By the time Leonardo was living, linear perspective was no longer a new discipline. Leonardo himself had a deep understanding of linear perspective. From ancient Greek paintings and Euclid's geometric perspective to Brunelleschi's early experiments with linear perspective to Masaccio's use of linear perspective, Leonardo was deeply impressed by the shortcomings of linear perspective theory in creating a realistic reproduction of space. Thus "air perspective" appeared in this context. After studying Alberti's theory of cone vision, Leonardo discovered that there were other non-parallel planes beyond each cross-section. It was the existence of these facets that led to the shortcomings of Alberti's theory of reproducible space.

In the process of studying perspective, Leonardo found that the air, which exists in nature all the time, also has different colors. Just like the nearness in perspective, the color of the air in the distance will be darker, which means the color of the object will change according to the distance. The different distance between the object and the line of sight will change the color of the object. The air will make the object lose its inherent color in the line of sight. The concept of air had never appeared in the previous research on perspective, which was a breakthrough in the essence of the concept. The use of air perspective made paintings more colorful, real, and three-dimensional [3]. Leonardo had his interpretation of linear perspective, and the previous linear perspective theory was not comprehensive enough in the process of derivation, so he made further changes on this basis. He discovered that perspective was not only about linear perspective. According to his research on optics in other fields, he not only invented the "air perspective", but also invented the famous "invisible perspective", also called invisibility. It is roughly believed that the farther the object is from the point of view, the more blurred the outer edges of the line, and at the same time the colors and shades also change. This was fully reflected in the *Mona Lisa*, where both the distant mountains and the sky became without distinct boundary lines with distance, handled by the method of gradual concealment [4]. The discovery of this concept of perspective is a manifestation of the spirit of combining science and art that Leonardo has been implementing. After this treatment, the picture becomes more delicate and richer in content, and the painting space is qualitatively changed. This is a manifestation of the progress of science and social civilization, and it also furthered people's understanding of nature.

2.2. Anatomy

Leonardo attached great importance to the role of anatomy in painting. There is a strong connection between anatomy and Leonardo's artworks. In the Renaissance, he learned about the structure of the human body through anatomical research. Then he accurately depicted various parts of the human body and made his paintings more vivid and accurate.

When it comes to painting, Leonardo believed that artists should have a scientific and correct understanding of anything, including the human body. He believed that an artist should understand the skeletal structure, nervous system, and muscular system within the human body. This reflected Leonardo's emphasis on anatomy. In his book *A Treatise On Painting*, he wrote: "The painter who has obtained perfect knowledge of the nature of the tendons and muscles, and of those parts which contain the most of them, will know to a certainty, in giving a particular motion to any part of the body, which, and how many of the muscles give rise and contribute to it; which of them, by swelling,

occasion their shortening, and which of cartilages they surround. He will not imitate those who, in all the different attitudes they adopt, or invent, make use of the same muscles, in the arms, back, chest, or any other parts." [5]. He believed that only by correctly understanding the whole structure of the human body could artists paint images that were in line with nature.

Although there were many anatomical records passed down in ancient times, there were very few useful parts, and most of the records were about the anatomy of animals, without dissecting one complete human body. Therefore, in the Renaissance, knowledge of anatomy was very shallow. The chemistry in the Renaissance did not develop to today's level. There was no Formalin to ensure long-term preservation of the human body that could allow dissection to be completed with just one body. Leonardo conducted dissection under conditions where the body was highly perishable and lacked relevant knowledge. Compared with others, Leonardo had an innate advantage in conducting anatomical research. He could use both text and precise painting to present his anatomical results [6].

Leonardo had the advantage of conducting anatomical research. His teacher, Andrea del Verrocchio, was passionate about painting techniques and human anatomy research. Therefore, Leonardo's involvement in human anatomy research would be relatively easy, which was also an opportunity for him to get involved in human anatomy. This condition laid a solid foundation for his future research in human anatomy. This experience had an immeasurable promoting effect on his painting expression skills and methods.

In his painting *St Jerome*, the way he depicted Jerome reflected the fact that he applied anatomical research results to his artworks. When drawing *St Jerome*, Leonardo fully showcased the details of Jerome's body, clearly demonstrating the state of his muscles and bones. Leonardo changed the way artists used to depict Jerome. He strengthened Jerome's dynamism by improving the accuracy of Jerome's body structure. Unlike the stiff posture of Jerome in previous paintings, Leonardo depicted a more dynamic Jerome. Jerome's muscles were tight, and he had a lively facial expression. His posture was extremely tense. This was because Leonardo restored the real muscles and bones of humans. The muscles on Jerome's arm were in different sizes and shapes, which were very similar to the muscle state of a real person. By dissecting the human body, he gained a comprehensive understanding of the muscles, bones, joints, and other parts of the human body, which allowed him to apply correct anatomical knowledge to his artworks. In this painting, when Leonardo depicted Jerome, he fully showcased the state of the muscles of Jerome's body, including his calves, shoulders, arms, back, and other parts. He also clearly displayed the bones of Jerome's neck and shoulders. When depicting muscles, Leonardo first depicted the bones of the person, followed by the tendons that connected the bones. This made Jerome look like a real person with strong emotions. These clear and vivid displays of bones, muscles, and tendons reflected Leonardo's profound understanding of the human body and his outstanding achievements in anatomy. What Jerome looked like in St Jerome demonstrated that Leonardo applied his anatomical research to this artwork [7].

2.3. Mathematics

Leonardo invented a new way of drawing polyhedrals in his illustrations to make these complex structures more superficially understandable. For example, he used a skeleton with a perspective effect, which would make the polyhedron look as if it had been constructed with wooden beams. This style was porous which meant that through each face one could see how the whole shape fit together.

In 1498, Leonardo painted 60 illustrations for Pacioli, and nearly 90% of them were based on variations of five kinds of Regular Polyhedron, which were the tetrahedron, hexahedron, octahedron, dodecahedron, and icosahedron, also known as the Platonic three-dimensionality. These illustrations were the only paintings that were published in Leonardo's lifetime. These paintings provided Leonardo with revelations. Guided by this interest, he also continued to explore the similarities between various proportions. The golden ratio is closely linked to geometry and art, including the proportions of the human body, musical scales, and other proportional relationships behind the beauty of nature. The Golden Triangle, the Golden Rectangle, the Pentagram, and the Golden Spiral are

related to the golden ratio [8]. This kind of proportion was often found in his paintings, such as the paintings *Annunciation* and *The Last Supper*.

Annunciation depicts the angel descending to tell the story of Mary's virginal conception. This painting contains traces of the golden section and the golden rectangle. When looking at this painting, people usually When eyes level with the painting, due to the influence of inertia of human vision, very often it is first along the horizontal movement and then vertical movement, so the horizontal direction of the object is often the first to be seen. The horizontal direction of the human visual habits is the direction of the left-to-right movement. Leonardo utilized this characteristic to paint the angel on the left and the Virgin Mary on the right, with their lines of sight on the same horizontal line. People would first look along the horizontal line from the angel's gaze to feel the Virgin Mary's shock with a slight shyness. Mary's elegant hands posed as expressive as her face, her left hand raised in shock, her right hand elegantly placed index and middle fingers on a book. The desk was located on the golden section line, attracting people's attention. Mary's bedroom was in the light and shadow of the subtle processing. The angel in his ornate robes leaned forward slightly, tilting at the exact diagonal of the golden rectangle. The winged god pointed his finger toward Mary and drew people's attention to the focal point of the picture, which was also located in the golden section. The main idea of this painting was presented through a style of abstraction coupled with the golden section [9].

The Last Supper adopts the perspective to place Jesus in the visual center, with the twelve disciples in groups of three, and the four groups are symmetrically distributed on the left and right. The combination of the figures used both the golden section composition and the triangle composition, arranging Judas in the vicinity of the golden section point of the picture. So it was not easy to tell who was the Judas that betrayed Jesus just from the light of the visual aspect. It is worth mentioning that some painters at that time mostly adopted the method of Jesus and the twelve disciples sitting around a round table to describe *The Last Supper*. Sometimes in order to emphasize Judas, they also placed him alone in the picture, which seemed to be less suspenseful and imaginative compared with Leonardo's *The Last Supper*. And this kind of treatment made the picture more dramatic effect [10]. In the treatment of drawing Jesus, Leonardo used the focal point perspective to focus all the eyes on Jesus and designed a window behind him. So the halo on Jesus' head seemed to be caused by the light hitting it, making the whole person look bigger compared with others. Also, from the window, people can see the boundless scenery outside, which has the effect of expanding the space.

3. Discussion

During the Renaissance, in Italy, when scriptural philosophy was in decline and humanism was rising, Leonardo used art as a means of exploring the mysteries of the natural world, combining art and science to enhance his creativity while leaving behind a valuable legacy for the development of natural science for generations to come. His designs, ideas, and artistic legacy show no sign of diminishing with time and continue to emanate energy today, stimulating and enlightening new academic knowledge. Leonardo’s research in the fields of anatomy, physics, and mathematics brought great breakthroughs in his art creations and also contributed to the development of science in the following generations. He approached painting with a rigorous attitude, treating it as a science based on the knowledge of perspective, anatomy, and optics. He utilized anatomical knowledge and the golden ratio to represent the human body, and the study of optics to improve the skills of light, shadow, and perspective in his works, which are perfectly embodied in his works. In modern painting, Leonardo's techniques of perspective and other painting techniques continue to play an important role in artists' creations. He has inspired many artists to master and apply knowledge of multiple disciplines to their artistic creations. Art and science became his tools for exploring the world, and they complemented and promoted each other.

In the Renaissance, when the various disciplines were not yet clearly delineated, science gradually became a character that played an important role in painting and sculpture. In Leonardo's view, there was no boundary between science and art. These two were closely intertwined and inseparable. The

progress of science promoted the development of art, and the improvement of art level fed the progress of natural science. Leonardo used his talent as an artist to investigate deeply in the field of natural science, and his research results in natural science also promoted his artistic creation. His achievements in art and science were inseparable. Perspective and human anatomy were applied to his paintings to make the works conform to the requirements of the laws of nature. At the same time, in terms of freedom of mind, he dared to stick to his ideas, free from external interference, and create according to his own aesthetics, while integrating his perception of nature into his works, which enabled him to reach an unprecedented state of art.

4. Conclusion

In Leonardo's artworks, both rationality and sensibility are emphasized. He was keen on the study of perspective and anatomy and used scientific theories and methods in creation. He gave full play to his creativity and imagination while making scientific creations of his paintings to reveal the character traits of his characters profoundly. Leonardo's creative thinking still has an immeasurable guiding role in modern art. The findings of this study are that Leonardo's paintings are closely related to the knowledge of natural sciences, and his discoveries in the field of natural sciences have been fully applied to his artistic creations, thus further concluding that science has played an important role in artistic creations during the Renaissance. There is frequent interaction between art and science. This study provides a lot of valuable references for future research on Leonardo and mainly has an important impact on the study of the relationship between Leonardo's artworks and science. Future research should focus more on the connection between Leonardo and other scientific fields for in-depth investigation.

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