Does Exploration of Nature Lead to "Beauty and Truth"?

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I. Introduction

Beauty and truth have been central to human's pursuit ever since human's civilization. Up till now, they are still advocated and valued as part of our core value (Vatican Information Service). With the prevalence of modern science, I cannot help but wonder whether the scientific method widely adopted today still leads us to beauty and truth? After evaluating the way scientists explore the nature and the scientific knowledge they have created, it is my firm belief that scientists' endeavor leads to both "truth and beauty".

II. Beauty

i. Definition of Beauty

Beauty in the eyes of scientists is intellectual beauty. In the words of Poincaré, it is the "intimate beauty which comes from the harmonious order of [nature's] parts", which can be grasped by pure intelligence (165–166). To put it in another way, one must process one's sense experience rationally and logically before being able to perceive beauty. Only with the intellectual

sense of beauty would scientists be flattered by the similarities between various objects and phenomena hidden under their apparent discrepancies.

ii. Characteristics of Beauty

Similar to the definition of beauty proposed by Poincaré, physicist Franklin Yang pointed out three characteristics of natural phenomenon which scientists would perceive as beautiful, namely appropriate, ingenious and that the rules please scientists. He added that scientific knowledge has to explain natural phenomenon precisely to be deemed as appropriate and ingenious (潘國駒 44–45).

iii. Beauty as Motivation for Scientific Exploration

Instead of being motivated by utility, scientists explore the nature solely because they find pleasure in it. And scientists take pleasure by doing so as the nature possesses intellectual beauty (Poincaré 165). Scientists search for the harmonious order by selecting recurring facts to study because these facts are considered beautiful by scientists and therefore "best suited to contribute to this harmony" (166). With these beautiful facts, scientists are able to construct new scientific models and discover knowledge that are equally beautiful so as to please their aesthetic sense (Luria 159).

For instance, Newton was impelled by his admiration on the beauty of nature to formulate the laws of motion. He once complemented that the orderly motion of sun, planets and comets is the most beautiful system he had ever seen (Maclaurin 407) and on another occasion exclaimed "whence arises all that beauty and order we see in the world?" (Provinciale 64) It is also clear that such beauty drove his researches as he described himself as a boy searching for a shell prettier than the ordinary ones on the sea-shore, in which the shell refers to knowledge of the nature (Newton, *Newton's Principia* 58).

And indeed he has found a pretty shell by observing a recurring fact—free-fall of objects.

According to Newton's laws of motion, all objects, regardless of their mass, size as well as the time and space they are located in, abide by the laws of motion[1] (Newton 66–68). Not only do the laws explain the movement of almost all objects, it can also be used to make predictions of their motion. This illustrates a beautiful and ordered world, where seemingly different objects are regulated by the same set of laws. It is this beauty that he finds pleasure in studying the ordered movement of objects, ultimately motivating him to devise ordered and intellectually beautiful laws.

iv. Pursuit of Beauty Prioritized over Pursuit of Truth

Not only are scientists motivated by beauty, some of them are so obsessed with beauty that they value beauty over truth. Thus the knowledge formulated must therefore be beautiful. Theoretical physicist Paul Dirac, one of the scientists who was frantic of beauty, undergone his research with an ideology different from his fellow physicist Newton. Dirac once said, "If one is working from the point of view of getting beauty into one's equation . . . one is on a sure line of progress." He even asserted that it is more important to have beauty in his work than to fit it in an experiment (Dirac). His sense of beauty is remarkable and he contributed tremendously to the early development of quantum physics. The Dirac equation[2] he formulated was

1 Newton was partially incorrect as his laws of motion is an incomplete work. This is due to the fact that there are three exceptions to the laws, namely when describing the motion of objects in sub-atomic scale, moving close to the speed of light and influenced by powerful gravity (Silver).

2 The equation brought together quantum mechanics, which describes the behavior of sub-atomic particles; and Einstein's special theory of relativity, which describes the behavior of fast-moving objects. Therefore, Dirac equation can describe how sub-atomic particles behave when they travel close to the speed of light. It is considered the first step towards "quantum field theory", the standard model of particle physics and the Higgs boson (Silver).

voted as one of the most beautiful equations in a poll conducted by BBC (Hogenboom, "You Decide"). This is a further proof that we are approaching beauty in the exploration of nature.

v. Do Scientific Discoveries Correspond to the Characteristics of Intellectual Beauty?

Apart from a bottom-up approach that evaluates whether scientists are approaching beauty by focusing on their motivation for exploring nature, we can take a top-down approach by judging whether scientific discoveries resemble the characteristics of intellectual beauty as defined by Franklin Yang—ingenious, appropriate and pleasing (44–45).

In the words of Yang, a scientific knowledge is ingenious when it describes models or structures in the nature which has a clever design, allowing it work efficiently; is appropriate when it precisely and correctly corresponds to the experimental results or observation that inspired the discovery. Operating with laws and patterns, the nature possesses order and harmony, which both comfort and please scientists intellectually.

Take the discovery of deoxyribonucleic acid (DNA) structure as a prime example. The immensely complicated DNA structure inherits all genetic material in every organism. To start off with, the DNA structure *ingeniously* codes the information necessary to guide the assembly instruction of everything in an organism's body and programs the activities in all the cells ("DNA Structure"). DNA structure is an *ingenious* design as it has incredibly high data intensity. One gram of DNA is able to store nearly one billion terabytes of data, exceeding the data intensity of any man-made storage system ("Microsoft Experiments with"). In addition, the DNA structure is *appropriate* as its double-chained alpha-helix structure corresponds to the

DNA density-measurement result and scattered diagram of X-ray diffraction respectively (Watson 122–131). The complementary base pairing in the DNA structure proposed by Watson also fits the data on base composition of DNA (128). Last but not the least, scientists are also *pleased* when they observed the DNA structure. When James Watson displayed the structure to a chemist, "the nature of the gene was so simple both surprised and *pleased* [the chemist]" just as it *pleased* Watson himself[3] (133; emphasis added). From the ingenious design of DNA structure and the way it pleased various scientists, clearly its discovery brings scientists a step closer to beauty.

vi. Exploration of Nature Leads to Beauty

As illustrated by Newton, Dirac and Watson, it is evident that the exploration of nature leads to beauty. First off, scientists find pleasure in exploring parts of nature which are beautiful. Some scientists even take it to the extreme by aiming at accommodating beauty into their work at any cost. Moreover, scientific discoveries share the same traits as beautiful natural phenomenon, indicating that scientific knowledge possesses intellectual beauty. Correspondingly, scientists' endeavor to uncover the secrets of the nature spawn beautiful theories and knowledge, leading us to beauty.

III. Truth

i. Definition of Truth

A widely held definition of truth is the Correspondence Theory of Truth, which implies that "a belief is true when there is a corresponding fact, and is false when there is no corresponding fact" (Russel). This view

3 "We felt sure that this was it. Anything that simple, that elegant just had to be right" (132).

is held traditionally with origin that goes to Greek philosophers like Plato and Aristotle[4]. The theory was also supported by 13th century philosopher Thomas Aquinas, who stated that "[a] judgment is said to be true when it conforms to the external reality" (qtd. in David).

ii. Characteristics of Truth

As the truth corresponds to reality, it exhibits characteristics which also correspond to the reality. Nathan Sivin gave us clues as to what these characteristics are when describing why modern science is truer than early sciences. He explained that it is because the modern scientific theory is able to explain natural phenomenon precisely and enables us to make accurate predictions (226). Interestingly, a theory is considered as both beautiful and true when it is able to explain natural phenomenon precisely. The implications of this similarity shall be examined in section "Would the Blind Pursuit of Beauty Diverge Scientists from the Pursuit of Truth?".

iii. The Aim of Modern Science Is to Search for Truth

Starting from the scientific revolution, the "demand for truth above all" has replaced other criteria for scientific exploration[5]. Since then, scientists believe that "knowledge . . . had no value except truth value" (237). As "the nominal definition of truth, that it is the agreement of [a cognition] with its object, is assumed as granted" (Kant 82), it can be deduced that modern

4 Aristotle once stated, "[t]o say that that which is is not or that which is not is, is a falsehood; and to say that that which is is and that which is not is not, is true." It means that we can deem a proposition to be true if the corresponding objects exist, while the proposition is a falsehood when it does not correspond to an object in reality (Ryckman).

5 Before the European Scientific Revolution, the philosophers and scientists preferred discoveries that are beautiful, conventional, morally improving and lead to perception of the Good. Among the above criteria, whether the discoveries are true is only one of the equally important criteria when searching for new knowledge (237).

scientists aim at discoveries that correspond to the reality more than ever.

The significance of such change in ideology can be illustrated by the search for the Solar System model. Although advocates of the heliocentric model like Galileo Galilei proved that the model is true with his observation with telescope[6], the church forced them to abandon their thought and adopt the traditional geocentric model[7]. The reasoning being is that the heliocentric model was thought to be in conflict with the Bible[8], thus considered heretical and morally incorrect. This serves as an example of how aims deviated from searching for "truth above all" might lead to falsehood as their theory has to conform to other "important criteria" instead of corresponding to the reality.

iv. Scientists Construct Truer Models that Correspond to the Increasing Amount of Facts on Hand

With the advancement of technology, humans have developed more sophisticated equipment like telescopes, microscopes and X-ray imaging for scientists to observe the nature in finer detail than ever before. Thus, scientists can gather more facts about the nature that we previously have not been able to examine.

More importantly, with more facts on hand, scientists can construct new scientific models that correspond closely to the increased amount of facts. The more facts the model resembles, the more the model corresponds to reality. Resultantly, the model can make more precise explanation and more accurate predictions of natural phenomenon.

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6 Venus goes through sequences of phases like the moon due to its relative position to the Sun and the Earth ("Galileo and the Telescope").

7 Insisting on what he thought was the truth, Galileo was found guilty of heresy. He was forced not to write about the heliocentric model anymore and had to spend the rest of his life under house arrest ("Galileo Is Convicted of Heresy").

8 Ps. 93.1: "Thou hast fixed the Earth immovable and firm."

In the field of astronomy, the invention of telescope brought us more facts and helped astronomers establish truer models of the universe. By observing the sky with naked eye, astronomers like Claudius Ptolemy saw the retrograde motion of Mars and recorded the movement of other planets across the sky to construct the Ptolemaic model[9], which was perplexing and differed a lot from reality ("The Ptolemaic Model"). While Galileo, being one of the first astronomers to observe the sky with the use of telescope, discovered different phases of Venus in support for his heliocentric model ("Galileo and the Telescope"). Apparently, the model of Solar System has improved with the facts generated from the development of observation tools.

v. Exploration of Nature Leads to Truth

Desiring only the truth, scientists can formulate theories as long as they correspond to the reality instead of worrying about consequences for not conforming to moral values and being political correct. Furthermore, scientists construct ever-refining models that resemble the reality to a greater extent by evaluating the increasing amount of facts on hand . It is therefore obvious that scientific exploration leads to the truth.

VI. Objections and Counter Arguments

i. Would the Blind Pursuit of Beauty Diverge Scientists from the Pursuit of Truth?

Some may argue that since scientists are motivated by intellectual beauty and sometimes prioritize beauty over truth when pursuing knowledge,

9 In the Ptolemaic model, the motion of plants moves on a small sphere called epicycle, which moves on a larger sphere called deferent. The stars, on the other hand, move on the celestial sphere outside of the deferents. It complicated as Ptolemy took as many as 28 epicycles to explain the detailed motion of the planets ("The Ptolemaic Model", Schombert).

the theories they adopt may be beautiful but may not necessarily conform to the truth.

This is not true as knowledge that is both true and beautiful shares the same characteristic: able to explain natural phenomenon precisely. In other words, on the path to pursue beautiful facts and yield beautiful theories, the scientists are unconsciously searching for the truth. As an illustration, as Dirac searched for his beautiful equations, he unintentionally embarked on the journey of discovery in the field of quantum physics (Hogenboom, "The Most Beautiful").

ii. Would Sense Deception Conceal Scientists from the Truth?

Some may say that scientists may be misled by their observation and devise theories that may deviate from the truth. This concern arises from the argument that scientists rely on their perceptual experience as the foundation to yield new knowledge, as in the discovery of the first antibiotics—Penicillin[10]. Indeed, our perceptual experience may not always correspond precisely to the reality[11], just as the horizon may look horizontal yet the Earth is spherical (Martin). Moreover, the reality sometimes deceives our senses because our subjective feelings such as hotness vary under different

10 Biologist Alexander Fleming once said, "in many cases it was a chance observation which took [scientists] into a track which eventually led to a real advance in knowledge or practice. This is especially true of the biological sciences for there we are dealing with living mechanisms about which there are enormous gaps in our knowledge." This is illustrated by in an accident where a mould contaminated a petri dish. He observed that bacterial colonies had become translucent and evidently lysis occurred, proving that Penicillin has antibiotic effect ("Sir Alexander Fleming").

11 As our brain has an overwhelming amount of work to do when processing in the details of our environment, it may miss details outside of our focus or even make up information because of an expected outcome. Therefore, our sight is subjective and our vision relies on how the brain processes the light we see. Examples of visual deception includes Benham's rotating discs, which is a color illusion; and Pulfritz's Pendulum, which is visual deception created by interference of overlapping patterns (O'Connor, "Visual Deceptions").

conditions[12]. Nevertheless, this does not stop scientists from their quest for truth.

First of all, technological advancement helps scientists avoid many of the sense deceptions. With the technology on hand, scientists can make use of equipment to observe the nature accurately. A case on point is when scientists examine the curvature of the horizon by observing the Earth in the outer space with space shuttles, they can avoid the deception of a "horizontal horizon" and conclude that the Earth is spherical. Furthermore, man-made equipment also yields objective measurements in scales to make up for the subjectiveness in human's senses. For instance, various kinds of thermometer can measure temperature objectively and accurately in Kelvin, Celsius or Fahrenheit scales. By avoiding deception and subjectiveness in scientists' observation, they can observe the nature more accurately and create theories that correspond closely to the reality.

Secondly, even if there are deceived theories, they are replaced by theories that better resemble the reality. When better observations are made with the use of advanced machineries brought by the technological improvement, better theories that correspond more to the reality are derived. For instance, inspired by observation like the gravitational lensing of a quasar and the change in orbit of Mercury, Einstein suggested in his theory of general relativity that time and space are relative and may be distorted by massive objects (Redd). This theory replaced the absolute time concept in Newtonian physics. This new theory is considered more true as it makes more accurate predictions that correspond to the reality. It is able to accurately

12 Feeling of hot or cold is subjective, so our feeling does not correspond to the reality accurately. For example, you feel varied degree of hotness when you place your hands into water of different temperature and subsequently placing your hands into water of the same temperature ("Temperature and Thermometer").

predict astronomical phenomenon such as gravitational waves, gravitational redshift and distortion of space-time around rotating objects. This clearly shows that in the long run, scientists are not concealed from the truth but rather steering constantly to truth.

V. Conclusion

To sum up, the exploration of nature indeed leads us to beauty and truth. Various knowledge discovered is beautiful because scientists are motivated to explore the nature due to its intellectual beauty, and the scientific discoveries throughout the course of history fulfilled the characteristics of beauty. Moreover, exploration of nature also brings us closer to the truth as scientists value truth above all, they constantly construct truer scientific models with more facts on hand and theories that correspond better to the reality kept on replacing ones that correspond less.

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Teacher's comment:

Lok Sze has produced a solid piece of writing. He argued that the exploration of nature by scientists throughout the ages leads us to truth and

beauty. He started his essay by carefully defining “truth” and “beauty”, followed by providing ample examples from the fields of physics and biology to justify his stance. The essay is, however, not a single-sided argument to the problem; Lok Sze has also considered the otherwise and given adequate responses. His discussion regarding the advancement of technology and the limitation of sense perception is insightful. Besides, he has identified the linkage between the pursuit of truth and beauty, which adds colors to his central argument. (Ng Ka Leung Andy)