More Than Scientific Hard Facts: Exploration of the Rules Behind

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1. Introduction

Science has played an unprecedentedly large role in our everyday life. We may be so accustomed to it that we assume general knowledge of the nature of science. Nevertheless, mass media and classroom learning tends to overemphasize what to know rather than how to know. Misinterpretation of science as unchangeable may also lead to rejection of the usefulness of science. It is therefore important to understand the nature of science in order not to be spoon-fed but to appreciate the power and limitation of science and thereby to draw our own conclusion critically.

2. Nature of Science

2.1 Tentativeness

Science is a non-dogmatic, self-correcting discipline that allows tentative conclusions. It never claims to be able to seek absolute truth. Science only aims to determine what is most likely to be correct currently with the evidence at our disposal. Instead of endorsing the traditional view of scientific progress which assumes that science advances as a continuous accumulation of accepted facts and knowledge, modern scientists endorse scientific revolutions of paradigm shift. For instance, the paradigm shift from metaphysical foundation of Aristotle's *Physics* to mathematical and experimental physics took two millennia to complete. Aristotle's *Physics* dealt with science as a natural philosophy which focused on establishing general principles governing all natural changes. His held a teleological explanation of Physics purporting to seek goals, purposes and functions of phenomenon. For example, he theorized that "the geometric center of the universe was the natural place of all heavy bodies." (Grant 15) The revolutionary changes started with the challenges from different schools of thoughts such as Jesuits, Physician, Cartesian and Newtonian. The French Academy of Sciences and the Royal Society in London both were skeptical about Aristotelian theories and committed to the breakthrough of science through experiments and mechanistic theories (Porter 39). The new Cartesian Physics, which was adopted and popularized by Jacques Rohault, centred on experiments in corpuscular mechanistic theory (Porter 38). At last, Newton's three laws of motion significantly marked the shift to experimental and mathematical science which focused on the mathematical relationship between variables. Therefore, the advancement of science relies on open-mindedness to new ideas and willingness to refine old beliefs in face of strong credible evidences.

2.2 Science Asks Answerable Questions

Science asks answerable questions without a value-seeking component. Science doesn't directly address moral, religion or ethical issues. Questions like "Does God exist?" cannot be answered empirically as the terms cannot be defined in terms of measured quantities or physical quantities, and therefore is not answerable with the evidences collected. To address the problem, we can convert it into empirical questions like "does the belief in God strengthens with the advancement of a man's age?" Science can hereby inform ethical decisions by identifying the likely consequences of particular actions. Isaac Newton also stated clearly in "The Mathematical Principles of Natural Philosophy" that discovering patterns of natural phenomenon is more important than finding out causes (54). By bypassing the discussion of reason which may spark controversy in religion, politics or philosophy and focusing on observable objective phenomena, the growth of science can be facilitated.

2.3 Science Extends Beyond the Observable

Contrary to our everyday commonsensical knowledge, science deals with abstract entities and the unobservable. Scientists infer unobservable underlying mechanisms from observable phenomena. Newton's breakthrough in mechanics can be attributed to his shift to abstract thinking. Unlike Cartesian mechanics without action at a distance, Newton's law of universal gravitation recognized action at a distance in which objects can attract each other without touching. Also, the American astronomer Edwin Hubble did not actually observe the expansion of the universe with his finite life span before announcing such a remarkable discovery. He reached this conclusion just by observing the receding galaxies, with receding speed proportional to the distance and by applying the Cosmological Principle. In addition, Sir Charles Sherrington concluded that binocular vision was produced psychically rather than mechanically by the Flicker experiment without any open-brain surgery. Thus, the advancement of science depends on the unbounded imagination of scientists beyond observables, authorities and common sense.

2.4 Experimentation

Scientific emphasis on experiment allows verification of beliefs in an unbiased manner with objective evidences. By conducting experiments, specific effect of a variable on another variable can be singled out and examined with confounding variables strictly controlled. Oswald Avery conducted an experiment on pneumonia bacteria, showing that DNA is the transforming principle of living cells. Galileo Galilei also carried out experiments to make accurate measurements and conclusions about the speed of a falling body, e.g. ball and ramp experiment. Experiments therefore make theories falsifiable, i.e. possible to be refuted by results that are not consistent with the theory. If a theory is not possible to be falsified by experiments, the general public and the scientific communities cannot examine it vigorously, calling the validity of the theory into question.

2.5 Facilitation of the Expression of Scientific Models by Mathematics

Mathematics provides a universal language for science by describing relationship between variables. Science produces public knowledge that can be verified. Thus, mathematics allows clear and quantified description of research that allows replication, keeping the wheel of scientific development rolling. Newton's law of motion provides a quantitative relation between force and acceleration. Edwin Hubble also discovered a linear relationship between the distance of galaxies from the Earth and their velocity, establishing the Hubble's law. Thus, mathematics is extremely valuable in expressing scientific model unambiguously, allowing precision in science.

2.6 Scientific Appreciation of the Beauty of Simplicity

Science seeks to develop simple and straightforward theory, i.e.

explaining the greatest amount of observations with the fewest assumptions or constructs. If other things being equal, simpler theories are generally better as the more generalizable a theory is, the greater its predictive power. Henri Poincaré also acknowledged the beauty of simplicity by stating that "the more general a law is, the greater is its value." Newton's three laws of motion clearly exemplify this idea as they can explain parabolic trajectories of falling objects on Earth as well as Moon's orbital motion. He also cleared the distinction between celestial region and sublunar region, and between violent motion and natural motion as proposed by Aristotle and established a new set of simple rules governing the whole universe.

2.7 Collaborative Efforts as the Key of Success in Science

Collaboration of different scientists from different fields is vital in facilitating exchange of intellectual ideas and accelerating the growth of science. Many accounts of success of scientists could not be possible without collaborative efforts from different scholars. The expansion of the universe was discovered by Edwin Hubble with the help of prior research on Doppler effect by Austrian Christian Andreas Doppler, the shifting spectral lines of nebulae by Vesto Melvin Slipher, and Leavitt's formulation of the period-luminosity relationship of Cepheid variable stars. "If Henrietta Leavitt had provided the key to determine the size of the cosmos, then it was Edwin Powell Hubble who inserted it in the lock and provided the observations that allowed it to be turned," commented by David H. Clark and Matthew D.H. Clark in their book *Measuring the Cosmos* (98). Francis Crick and James Watson's discovery of DNA structure also lies in their exploration of many laboratories and researchers' ideas. They invited Maurice Wilkins and Rosalind Franklin from the King's laboratory to exchange ideas about their

DNA structural studies. James Watson also read papers by scholars such as Erwin Chargaff and Linus Pauling who specialized in gene studies as well.

2.8. Stress on Inter-Disciplinary Communication

Modern science has been split into disciplines like Physics, Chemistry, Biology, Zoology, etc. Such organizational structure sometimes drags people to focus on one discipline solely without considering the others. In fact, different disciplines come together to give a more complete picture to the understanding of the same phenomenon. Having different disciplines is advantageous in fostering research by a kind of collaboration of research efforts. However, such division may make inter-disciplinary communication difficult, hindering scientific development. For example, the integration of mathematics and physics were only possible in the 19th century due to the limited interaction between mathematicians and experimentalists in the 18th century. In fact, different disciplines should be considered as supplementation of each other working together for scientific endeavor. For instance, “the most beautiful experiment in biology” was made possible by the combination of centrifugation in Physics and isotope in Chemistry.

3. Conclusion

As Francis Bacon once noted, “If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties” (293). It is vital to hold a correct attitude in learning science, such as imagination, open-mindedness, fairness, curiosity, and skepticism. Effective learning of science could also reinforce such general societal values, which can be extended to other academic fields of enquiry as well as to everyday life, molding us into men of integrity.

Works Cited

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Teachers' comment:

This essay discusses the nature of science from different perspectives such as the limitations, scope and methodology of science, and also the community of scientists. Different parts are coherently connected and are well balanced in length. This makes the conclusion more convincing. Creativity can be seen from the thoughtful use of examples taken from texts to illustrate abstract concepts. (Chan Chi Wang, Szeto Wai Man, Wong Wing Hung)