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A Critique of the Scientific Method

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Abstract- In an attempt to bring to the fore the strengths and the weaknesses inherent in the scientific method; this paper starts with an analysis of the concepts; science and method. This is followed by an enquiry into the evolvement of the scientific method from the Muslim thinkers to its advent in Europe and Renaissance,and also to the modern day idea of scientific method. The paper further examines the definitions and descriptions of what scientific method refer to, while highlighting the steps that make up the scientific process.

Keywords: Science, method, scientific method

Introduction

Science is a methodical approach to studying the natural world; it asks crucial questions like how does the world work? How did the world come to be, what was it like in the past, what is it like now; and what will it be like in the future? These questions are answered using observation, testing, and interpretation through logic. Scientists may probably not be able to assert with certainty that science can give us truth, that science can lead the way to truth. Science, however, helps in determining what is most likely to be correct at the current time with the evidence at hand. [1]

Etymologically, the word science has its root in *scientia* meaning knowledge. In Medawar's opinion, the "knowledge alluded to is knowledge hard-won, in which we have much more confidence than we had in opinion, hearsay or belief"[2]. To certain scholars, science is a body of knowledge which means that, all that will qualify a discipline as science is that knowledge claims be made in accordance with socially and academically accepted methods of doing so. This may be what Robert Morgan tried to capture when he writes: "science is any activity resulting in knowledge and understanding about the world around us"[3]

Method according to Encarta English Dictionary "is a way of doing something or carrying out something according to plan; is also the body of systematic techniques used by a particular discipline, especially a scientific one"[4]. Method is synonymous with procedure, function, or routine. It can be described as an established, habitual, logical or prescribed practice or systematic process of achieving certain ends with accuracy and efficiency, usually in an ordered sequence of fixed steps.

How It All Began?

Muslim Scholars and the Scientific Method

In the past millennia, there has been some understanding by leading thinkers that the acquisition of knowledge can be performed in such a way as to minimize inconsistencies in their conclusions[5]. To answer the question of who invented the scientific method may not be an easy one because it is difficult to pin down where exactly it started from. However, it can be said to have evolved over a period of time with some of history's greatest and influential minds making inputs to it and refining the process. Aristotle the Greek philosopher is generally acclaimed to be the prime mover behind the development of the scientific method, but this can be said to be too much of a leap because, while it is true that the Greeks were the first western civilization to adopt observation and measurement as part of learning about the world, there was no enough structure then to tag it scientific method[6].

Despite this nonetheless, it is just fair to credit the beginning of empirical science to Aristotle, but research has shown that the development of the scientific process resembling the modern method was actually developed by Muslim scholars during the golden age of Islam and made sophisticated in the enlightenment by the scientist-philosophers. Muslim scholars between the 10^{th} and 14^{th} centuries are said to be the prime movers behind the development of the scientific method. It is said that they were the first to make use of experiment and observation as the basis of science and it is regarded by many historians that science started during this period.

Al-Haytham is singled out among the array of great Muslim scholars to be the architect of the scientific method. His model of scientific method involved the following steps

1. Observation of the natural world
2. Stating a definite problem
3. Formulating a robust hypothesis
4. Test the hypothesis through experimentation
5. Access and analyze the results
6. Interpret the data and draw conclusions
7. Publish the findings

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The steps above are very similar to the modern scientific method and they became the foundation of western science during the renaissance. It is even said that Al-Haytham insisted on repeatability and the replication of results and that other scholars added such ideas as peer review and made great leaps in understanding the natural world.

Europe and the Renaissance

The enquiry in to who invented the scientific method moved to Europe as the Renaissance began and the wisdom of the Greeks and Arabs helped Europe out of the Dark Ages. Roger Bacon (1214-1284) is recognized as the very first scholar to promote inductive reasoning as part of the scientific method. The findings from experiments are generalized to the wider world, process that is being used by all modern scientist. His version of the Islamic scientific method comprises of four major steps which lie at the basis of our modern method. They are:

- Observation
- Hypothesis
- Experiment
- Verification [8]

Francis Bacon (1561-1626) and Rene Descartes (1596-1650) continued this process with the Enlightenment. The former continued the work of his Renaissance counterpart strengthening the inductive process. His method became

- Empirical Observations
- Systematic Experiments
- Analyzing Experimental Evidence
- Inductive Reasoning [9]

Bacon's inductive method was a way of relating observations to the universe and natural phenomena through establishing cause and effect.

Rene Descartes like past scholars established some form of framework for the scientific method in 1619. His first step is seen by many as a guiding principle in the field of science today

> …never to accept anything for true which I did not clearly know to be such; that is to say, carefully to avoid precipitancy and prejudice, and to compromise nothing more in my judgment than what was presented to my mind so clearly and distinctly as to exclude all ground of methodic doubt. [10]

He broke away from the model of induction and reasoning and again proposed that deduction was the only way to learn and understand, harking back to Plato. His method was almost the reverse of induction, they are:

- Establish First Principles
- Deductive Reasoning
- Interpretation
- Mathematical Analysis [11]

Newton and the Modern Scientific Method

Our discussion of the inventor of the scientific method will not be complete without mentioning the role of Isaac Newton who refined the process that formed what we use today. It was him who first realized that the scientific discovery needed both the inductive and the deductive reasoning; a revolution in the scientific method that launched science into the modern age. Other thinkers nevertheless further made the scientific method better; these include such great thinkers like Albert Einstein, Bertr and Russell, Karl Popper, Paul Feyerabend and a host of others. All these scholars and several others have had a great influence upon determining the course of modern science as we know it today. Scientific method therefore, is a process that evolved over a long period of time.

What is Scientific Method?

Scientific method simply means the series of steps that scientist use to answer questions and solve problems. It is a process that is used to answer questions about the world around us. It can be said to be a mode of learning or a process of using comparative critical think.

The scientific method in the actual sense is not a sequence of procedures that must happen, although, it is sometimes presented as such. Irrespective of how many method it has, a scientific method must contain elements that are applicable to most experimental sciences, such as Physics, Chemistry and is usually taught to aid students in their understanding of science. Scientific method is usually subjected to review and independent duplications in order to reduce the degree of uncertainty. It may include some or all of the following steps in one form or the other:

Observation

This comes as the first step in the scientific method; in making observation one makes use of the senses to gather information. Sometimes one may use instruments such as microscopes, and telescopes to extend the range of the senses. It entails studying or examining a phenomenon, event or a "problem". The finding of such a phenomenon may occur as a result of the interest the observer has, a suggestion or assignment, or it may be a puzzle one wishes to resolve, the discovery may even be accidental even though it is unlikely the observer will be in the right frame of mind to make such observation. History has it that, Albert Einstein as a boy was curious as to what it will be like to ride a light beam. This inquisitiveness was with him in the course of his education and it eventually led to his theories of electromagnetism. [12]

Question

Questions drive the scientific method. As one observes, one discovers that one has more questions than answers; the questions which need to be answered to satisfy human curiosity. Questioning beginning with *what,why,how,* and *when* are very important in focusing an investigation and they

often lead to hypothesis. Questions such as how or why this event happened or what it is like…something. In order to develop these questions, observation may involve taking measures to quantify it in order to better describe it. Scientific questions need to be answerable and lead to the formation of a hypothesis about the problem. [13]

Hypothesis

This is an educated guess about how things work. It can be represented in schemata: If I do this, then this will happen. Educated in this instance, means that no good hypothesis can be developed without research into the problem. Hypothesis is a clear statement of what you expect the answer to your question to be. Hypothesis is generally consistent with existing knowledge and is conducive to further enquiry. A good hypothesis should be testable and has to be falsifiable, that is, there must be ways of making the hypothesis fail. The hypothesis should also contain a prediction about its variability. For example, if the hypothesis is true then dependent variable should happen when independent variable is manipulated. The former variable depends on what one is doing, while the latter one is the one that is manipulated to get a reaction. [14]

Experiment

As soon as the hypothesis is established, the next step is to test it. The procedure of experiment is what sets science apart from other disciplines, through it, discoveries are made every day. An experiment is carried out to prove or disprove the hypothesis. If the prediction is correct, it will not be possible to reject the hypothesis. Testing and experimentation can take place in the laboratory, on the field, on the blackboard or the computer. The result derived from testing must be reproducible and verifiable. The data should be available to determine if the interpretations are unbiased and free from prejudice. As the National Science Education Standards state:

> In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work towards finding evidence that will resolve their disagreement. [15]

Evaluation

Evaluation which is usually the last is integral to the process of scientific method. Here all evidences and conclusions are analyzed in a bid to ensure that biases or inadequate effort do not lead to incorrect conclusions. Qualitative and quantitative mathematical analysis may be applied. Scientific explanations should always be made public either in print or presented at scientific meetings. The importance of peer review to science and the vigour and rigor in which it is carried out cannot be over emphasized. The evaluative process in science truly makes it necessary for scientists to be accurate, innovative and comprehensive. [16]

Critique

Strengths of the Scientific Method

Having made an exposition of what the scientific method is all about; it is pertinent at this juncture to make an appraisal of the method. One important advantage of the scientific method lies on the idea that all data and interpretations are empirical, that is, it is grounded on what is measurable and observable. All the data is collected from direct observation and experimentation. It is based solely on fact; nothing is based on hearsay or other forms of indirect or revealed authority. The methods can also be said to be unprejudiced to a certain extent, in the sense that, the data from experiments and/or observation is the sole arbiter of whether a hypothesis or theory survives. The scientific method does not require superhuman powers. Any person with the patience and the resources to perform the experiment can test the reliability of a theory. [17]

Secondly, the scientific method is universal and generally applicable in the following sense: its primary goal is to formulate laws of nature which "hold" at all times in all space and for everybody. This is the reason why modern technology has been so successfully based on scientific rationality. Based on this universality, we can for instance build complicated machines like airplanes and computers which can be operated by virtually everybody who is willing to learn the relatively simple rules. The behaviour of these machines (in the absence of defects and defaults) can be predicted precisely from the laws of nature. Furthermore, scientific method is usually well defined and relatively free from contradictions. A consequence of this is that one can define "right or wrong" by a set of laws and hence no responsibility (in the true sense of the word) rests on the decision maker. Rather he/she has to be very careful to avoid errors. [18]

On another note, the scientific method attempts to minimize the influence of bias or prejudice in the experiment. This is so because; even the best intentioned scientists cannot escape bias. Biases results from personal beliefs as well as cultural beliefs which means that any human filters information based on his or her on experience. The scientific method provides an objective, standardized approach to conducting experiments and in so doing improves their results. By using a standardized approach in their investigations, scientists can feel confident that they will stick to the facts and limits the influence of personal, preconceived notions. [19]

In addition, the intellectual and practical applications of the scientific method make it important for the public to have a basic understanding of the manner in which scientific theories are obtained, tested and accepted. With this type of knowledge, the public can protect itself from scientific quackery, and may even impress upon the government the need to create and enforce policy against scientific charlatanism. [20]

Most of the tremendous strides in understanding the world around us have been made possible by the use of the scientific method. It lies at the foundation of science and some scientists would agree that the best part of our science is based on its use, that is, the use of the scientific method. In this light, the development of science and the scientific method led to the demise of the geocentric conception of the solar system. Although it initially strongly appeared to the naked eye that the sun and the moon go round the Earth (geocentric); between the 16th and 17th centuries however, observations made about the stars and the planet with the aid of Galileo's newly invented and improved telescope detect the phases of Venus as seen from the Earth. With the application of mathematics to their precise measurements, it became obvious to astronomers that the planets and Earth must revolve around the sun (heliocentric). [21]

Limitations of the Scientific Method

Inspite of the importance of the scientific method, there are some shortcomings inherent in it that has made it a subject of constant criticism. Among such is the accusation that scientific method cannot be used to study everything there is. If something cannot be studied using the scientific method then it cannot be studied by scientists. Science deals with what our senses tell us about the world around, not simply that, also that if it can be observed it must be more than ones, which is known as repeatability. What sort of things that science may not be able to study we may one to ask? The constraints of the use of the senses and repeatability limits science in a number of ways; this is because there are numerous ideas we have about the world that cannot be studied with the aid of the scientific method, and the fact that they cannot be studied via this method does not mean that such ideas do not have values; on the contrary, they are often significant areas of our lives. Some of such issues that scientific method does not help to solve can be seen in the following: [22]

Science Deals with Hypothesis and Not Truth or That Science Sometimes Confuses Theory with Truth:

If you probably believe that truth is unchanging then the scientific method may not appeal to you because it is a process. In other words, it is always open to changing its hypothesis and theories about the world; this means that the scientific method cannot deal with truth as you believe it. That a tortoise can run faster than a rabbit is true. It is however not necessarily true to say that a rabbit than beat a tortoise in a running race; a scientist can hypothesise that rabbit will always win, but the day the tortoise wins disproves the hypothesis that is the hypothesis is proven to be false. [23]

Science Does Not Incorporate the God-factor

There are divergent views about God, while many people believe that there is a God, some deny the existence of such being, while others express the ignorance of not knowing, that they don't know what to believe. The scientific method is not helpful in assisting any of these categories of people to confirm or deny their belief. The idea or study of God is outside the purview of scientific method. The existence of God to a scientist is just a hypothesis that cannot be proven or disprove with experiment. The belief or disbelief of people in God is an act of faith. [24]

Government and Special Interest

It is a known fact that a number of scientific researches in recent times are funded, this makes scientists tailor their agenda and even sometimes their findings accordingly, or be out of work. This is particularly unfortunate in countries where there is a very high level of favouritism and corruption. Similarly, large corporations like pharmaceutical corporations hire scientists to prove that their products are safe to use or superior to their counterparts and competitors which may not necessarily be so. In this kind of situation, we can hardly expect an unbiased report of their findings. [25]

False Assumptions

All of science is based on various underlying assumptions. If these assumptions turn out to be wrong then the whole edifice built upon them could fall. For example, for several millennia, it was assumed that the plane geometry of Euclid was "true", but then Einstein and others proposed "curved space" which has proven to be a very fruitful theory. In the same vein, space and time were believed to be absolute and matter was believed to be different from energy. Again, it was Einstein who argued convincingly otherwise. When the underlying foundations are wrong, it often requires rebuilding the entire scientific edifice, as was the case with Einstein. [26]

Not-yet-measured Equated to Non-existent

This is the tendency of science; ignoring the observation of those who can see something which you cannot. It is the inclination of science to declare that something does not exist if it cannot be measured with instrument. This extra stem into ignorance compounds the problem

Moral Decisions and the Scientific Method

Moral decisions cannot be made using the scientific method; it cannot help one to decide whether something is good or bad it can however reveal something about the world that will present one with a moral problem. For instance, the discovery of how AIDS is transmitted has caused many people to face the decision about their sexual behaviour. [27]

Conclusion

In this paper we have tried to define what science is and also what the scientific implies while looking at some of the process of the scientific method itself. In addition, we examined what can be considered to be the strengths and the weaknesses of the method; this is in a bid to give us a balanced assessment of it. From the foregoing, we want to conclude by stating that the method of science or any other method at that especially those that involve fallible beings like humans cannot be foolproof. Lapses and loopholes are bound to always happen. Some of what constitute the limitations of the scientific method does not diminish its importance. Besides, what viable alternative do we have that will take cognizance

of both the importance and the inadequacy of the method discussed?

At this juncture, we want to submit by saying that we should double our efforts at ensuring that those procedures like peer review, independent publications among others, that can help lessen to the barest minimum such things as prejudices, biases and uncertainties about scientific method are painstakingly and meticulously carried out. This is to lend more credence and integrity to the whole process.

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