Scientific Method for Research and Project

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Scientific Method for Research and Project

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Projects and dissertations are an essential part of the academic curriculum whereas research has become a modem phenomenon of development. From antiquity man has traversed a long path of development making discoveries and undertaking researches to seek out the deep hidden truth of the universe, to reach this stage of modem life. How has this become possible? Karl Pearson is very right when he says **"There is no short cut to truth,** no way to gain knowledge **of the universe except through the gateway of Scientific method."**

Well, before discussing the Scientific Method, let us briefly discuss what 'Research', 'Dissertations' and 'Projects' are, and what are the major differences and similarities among them. Fundamentally, all three terms bear the same meaning. Research aims to seek and establish some fundamental or elemental truths by furnishing enough evidence and proof. It also aims to review or to re-establish what has already been established as a fundamental truth, to find out new patterns from the authentic Scientific theories and to further modify existing notions. A water-tight demarcation of differences is not possible among the three terms — they are frequently **used** for the same concept. The only major difference among them is that of scope. Projects are smaller than dissertations in scope, and dissertations from researches. A project may be regarded as the execution part of a research with a limited scope. In fact the aim of academic curriculum projects is to make the students acquainted with laboratories and prepare them for future scientific researches. Dissertations aim at adding a new dimension to already explored phenomena. In the case of some researches, ideas are developed towards absolutely new and innovative outcomes. Such researches are called 'pure researches.'

Science is generally defined as the systematic study of a given subject field to gain knowledge. Thus the goal of science becomes knowledge whereas systematic study becomes the process through which the **defined goal is** obtained. In fact, the goal of any kind of study is to obtain knowledge or truth. It -is only this systematic process which distinguished science from other methods of obtaining knowledge. Lundberg has rightly remarked "All that the term science is applied to a particular field comes to mean, is a **field which has been studied according to** certain principles i.e. according to **scientific method."**

Now we need to see what **'Scientific Method' is. Simply stated, it is systematic observation,.a classification** of ideas which have been accumulated through observation, organisation of these classified ideas into data and lastly,, interpretation .of the data. Karl Pearson says, "The **Scientific Method** is marked by the following features : a) Careful and accurate classification of facts and observation of their correction and sequence, b) the discovery **of scientific** laws **With the aid of the creative imagination, c) Self** criticism and the final touch stone of equal validity for all normally **constituted minds."**

Analysing this definition, it becomes clear that scientific methods have two aspects: one that deals with the methods employed and other with the results achieved. In fact both are equally important. But the latter has been regarded more important by Wolf who says, "Any mode of investigation by which science **has been built up and is being developed is entitled to be called a scientific method." So it is a matter of opinion. But both seem 'to be of equal importance. If one does not employ the right method, one will certainly not get the desired results.**

Characteristics of Scientific Method

A **summary of the chief characteristics of the Scientific Method will help delineate different steps of scientific study. The chief characteristics are :**

1. Verifiability: **The conclusions drawn through a scientific method are subject to verification at'any time. Verifiability presupposes that the phenomenon must submit to being observed and measured. This will bring greater exactitude to our verification. For example, we know that matter expands on** heating. In order to verify this we **can heat matter and** see **whether it expands. Again, the rate of expansion in all the matter is not the same. Thus from th.e general scientific law that matter** expands on being heated, we **can proceed to find out** the exact degree of **expansion of each kind of matter. This is only possible** when **the expansion of matter be measured.**

2. Generality: **Scientific laws.are•universal. They are primarily concerned with the types,** kinds or classes of objects and events "of which the individual

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a difific method can c ie. , e ..:racy. For a. ample car. cc said accuracy that water will change into ice, at zero degree celsius. But it should be kept in mind that predictability is based on two factors, viz. fixity of relationship between cause and effect and the stability of the causative factors themselves, On the one hand predictability depends upon the nature of the phenomenon itself and on the other, upon our knowledge of various causative factors.

4. *Objectivity:* "The first requisite of all sound knowledge is the ability to get naked facts and not be influenced by mere apppearance or by prevalent notions or by one's own wishes." Thus when a phenomenon is observed in its true form without being affected by the observer 's own views, it may be termed as an objective' observation. "The main criterion of objectivity is that all persons should arrive at the same conclusion about the given phenomenon. It is also essential for verifiCation. Objectivity is fundamental to all sciences.

5. *System:* The four characteristics discussed above deal with the result obtained. This last one perealiis. to the method of arriving at the result. Scientific conclusions, are not only true but also born of a systematic mode of investigation: It is only under such circumstances that the results can be verified. This is what Lundberg calls "Formality and Rigorousness". Every science has an accepted mode of investigation and inferenceS which must be adhered to. The result arrived at by means of haphazard methods, even if.true, cannot be called scientific because theiri,accuracylis purely- accidental. Wolf avers that not resiablit,the mode of investigation too is important.

We have already stated that scientific method implies sYsternatic study. But what should be the system,'from general to specific i.e. from broad to narrow or vice versa? It has been the most discussed phenomenon pf 'the scientific method. Because of the 'nature of study, type of phenpmena under study and the researcher himself, the procedure to be adopted in a scientific method may differ. However, the basic principles and steps laid doWn below have been found quite successful. They are capable of showing the proper way from very inception of a research to its completiOn.

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__.ea ing a asiic., or the topic. The basic challenge in front of me was to provide a clue as to how one should approach projects. What are the necessary requirements? And the result of this efforts is presented here. The aim is to point out that before starting any plan, an idea, however vague it may be, should be kept in mind. Only then can one proceed to find out whether the ideas conceived are true. They may be totally or partially correct or altogether false, but they do help to get going. For new discoveries, one cannot proceed in complete ignorance. These primary ideas which guide us in our study may be termed as hypothesis.

According to Good and Hatt, "a proposition which can be put to test to determine its validity" is a hypothesis. A more elaborate and clear idea of a hypothesis has been given by Lundberg: "A hypothesis is a tentative generalization, the validity of which remains to be tested. In its most elementary stage the hypothesis may be any hunch, guess, imaginative idea, which becomes the basis for action or investigation." What is more striking is that a hypothesis and a theory are not the same, although they are closely related. A theory is an elaborate hypothesis. A hypothesis some times emerges from a theory. It is a generalization drawn from the theory and when it has been tested and found correct, it becomes a part of the theory itself. Thus a theory in its early form is only a hypothesis and the two are interdependent.

The importance of hypothesis can hardly be overrated in any scientific research. In fact it is the very foundation of scientific research. A good hypothesis which is clear, simpld and scientific makes the enquiry more specific and to the point. It helps in deciding the direction in which to proceed, in selecting pertinent facts and moreover it helps in drawing specific conclusions. "Without hypothesis the research is unfocused, a random empirical wandering". The results cannot be stated as facts without clear meaning. Hypothesis is the necessary link between theory and investigations, which leads to discovery, or to addition of knowledge.

There are various sources of hypotheses. This bulk of primary idea i.e. the hypothesis, which may strike the researcher's mind in his day to day work is important. Take for example, the famous incident

of apple falling from tree, which puzzled Newton. Culture proves a good source of hypotheses. Indian culture, for instance, has a metaphysical basis for hypotheses. Scientific theories also lead us to form further generalizations or corollaries. These corollaries or generalizations form a part of the hypothesis. Sometimes a hypothesis is formed from analogy too. However, the formation of a hypothesis is affected by the way in which an individual reacts to each of these sources. Sometimes the facts are there, but only the right individual sees it in a right perspective and formulates a hypotehsis. It was only Newton who could formulate the idea of the force of gravitation from the falling of an apple.

Observation and Collection of Data

After the hypothesis has been formulated, the next step is to test its validity. This requires observation of facts and collection of data. Data is the raw material of information. When data is processed it becomes information. Data can be in various forms viz. tabular, graphics, etc.

In this respect the first thing to be decided is the nature of the information that would be necessary to establish the validity of the hypothesis and wherefrom this information can be collected. There are various methods of collecting data. For all theoretical investigations i.e. where hypothesis have been derived from existing scientific theories, a rich library will certainly be useful, While collecting data one should ensure that the data are related to the subject under study. They must be adequate and accurate. Adequacy of data deals with the sufficiency of information to test the validity of a hypothesis and its accuracy.

Analysis and Synthesis

The data, related to the hypothesis, which is collected, must be processed and analysed to draw proper inferences. "The discovery of order in the phenomena of nature, notwithstanding their complexity and appparent confusion, is rendered possible by the processes of analysis and synthesis which are the foundation of all Scientific Methods". The earliest and simplest method of discovering order in a confused mass of data is by classification. Classification, the first step in the analysis of data, means arranging data in different classes or groups according to their similarities or dissimilarities. The mass of data may be similar or dissimilar. They are arranged or grouped together on the basis of these similarities or dissimilarities which are pertinent to the hypothesis.

When the data has been classified it is to beipUt in proper form. If the data is statistical in form it has to be placed in the form of tables in order to facilitate comparison. Again if the.'ciata isin a riathericabiorm various measurements like averageS; peftent_*S'etc will have tote completed
son. The elements obtained by andlySi'S of different objects or events may also be synthesized in such a way so as to form combinations, the likes of which have never been observed at all.

GeneralisatiOn -

The last step in the scientific method of research is generalisation or drawing of iriference.'Aftdi l-lecting, analysing and processing the dita;broad conclusions are drawn which may be, later used for the purpose of deduction. This method can be broadly classified into two groups : Logical Methods and Statistical Methods.

Logical Methods

The important logical methods frequently used to draw inferences are: Method of agreement, Method of difference, Joint method including methods of agreement and difference both, Method'of residues, Method of concomitant variation etc. All these methods are basically logical processes to draw'inferences. *The method of agreement may* either be positive* negative. In the positive method when two or more cases of a given phenomenon have one and only one condition in common, then that condition may be regarded as the cause (or effect) of the phenomenon. In negative cases the absence of a particular condition is regarded as the cause (or effect) of the phenomenon. Symbolically it may be expressed as :

Positive case

A + B + C — Produce — X

C + D + E — Produce — X

Therefore C -- Produces — X ,

Negative case

A + B + non C — Produce — Non X

Non C + D + E — Produce — Non X

Therefore C — Produces — X

The method of difference is a combination of both positive and negative methods of agreement. In this method, all other iactors being common When the presence of a factor is associated with the presence of another factor, or the absence of it, the factor may be said to be;causally connected. Symbolically itmay be represented as :

! -+[1]B + Produce — X

A +B + Non C — Produce — Non X

Therefore C — Produces..— X

The joint method for drawing inference is an amalgamation of the methods of agreement and difference. According to this method, if two or more causes in which a phenomenon occurs have something in common, others in which the phenomenon does not occurs have all other things in common except the cause or effect on the phenomena.- The first part of this method is the method of agreement while the secondis the method of difference. Symbolically it may be,presented as :

A + B + C — Produce — X

A + P + Q — Produce — X

M + N + non A — Produce — non X

G + H + non A Produce — non X

Inference': A and X are causally connected.

The method of residues is that if a, phenomenon occurs under:certain circumstances and it is known on the basis of previous knowledge that a part of phenomena is causally, connected with some of the circurnslances then it will be assumed that the remaining phenomena, ate also causally connected with the remaining circumstances. The discovery of the Planet Neptune was made in this way. It was seen several times that Uranus deviated from its path. People tried to ascertain its cause, but in the absence of any valid cause it was thought that this, could be another planet. This led to the discovery of Neptune. This method, however, was first of all used. by Sir John Herschel, an astronomer of the 18th century. In this method previous knowledge of a phenomenon and its causative factors are essential and it is on the basis of these factors that we proceed to_predict the phenomenon. If the actual results differ from the predicted results we try to find out particular circumstances which cause the difference. Symbolically this method cart be represented as :

AB CD— Produce —W X YZ

B C 1), — Produce — X Y Z

Therefore A — Produces — W

The method 'of concomitant variation is also known as method, of quantitative induction as we base our inference on quantitative change in the two factors. In this method the inference is based upon the change in the two inter-related factors. If the change in two factors is in the same direction and an increase in one is followed by an increase in the other and a fall by decrease, the two factors may said to be causally connected.

These logical methods are however, sometimes unreliable due to plurality of causes and inter mixture of effects. The statistical method of drawing inferences tries to solve this problem.

Statistical Methods

The statistical methods are mathematical in nature. In addition to establishing a causal connection between two variables these also try to establish a mathematical relationship between them. As for example, it is not enough to say that poverty causes delinquency. These methods also try to find out a numerical measurement of the extent of this relationship. Co-existence or co-variance of two or more variables can at best be proved by statistical methods. But they can never differentiate between the cause and effect, nor can they ascertain why a particular factor produces a certain result. Thus in these methods too, early part of the inference is similar to that of the logical methods. The only advantage of the *statistical* methods is that these can prove the degree of co-variance.

To sum up, conceiving a proper hypothesis is the first and most important step to begin a research, whatever be the process i.e. from general to specific or vice-versa. The formulated hypothesis is tested by collecting and analysing pertinent data or by the systematic observation of facts. And lastly the hypothesis is verified. Logical or statistical methods may be used for this purpose. It should be noted that the two methods are not mutually exclusive. Sometimes, for a correct inference, both methods may be necessary. If, in a research process, the hypothesis is not fully proved, it may be amended and a fresh hypothesis adopted. This process should go on till a perfect hypothesis has been evolved which can stand all the tests.

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