C. George Thomas

Research Methodology and Scientific Writing

Second Edition

Springer

Contents

Chapter 1
Research: The Search for Knowledge

We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power.
Bertrand Russell (1872–1970)

Human beings have been curious from the very beginning. Primitive humans observed matters concerning the universe, and changed their way of living, settlement, food habits, social institutions, and many others over time. In fact, these were the results of 'research' done by our ancestors on the processes happening in nature, which helped them to learn many lessons and draw several conclusions. Our ancestors used observation as the primary means to understand various phenomena. They invented many devices and tools by trial and error. Discoveries or inventions by accident were galore. Nevertheless, the pursuit of humans to unravel the mysteries of the universe had to face many challenges.

Earlier efforts of our ancestors to explain the operation of the universe paved way for primitive religious concepts; and for many phenomena, they attributed the cause to supernatural powers. This gave birth to religions and priests. At least for some part of history, religions became the authority on everything, even on science! Yet, there were many 'researchers' among them who could observe cause–effect relationships for various phenomena and processes. They also discovered that under certain conditions, events could be predicted with reasonable accuracy. The saddest part of the story is that often these findings and explanations were simply rejected, if they seemed to conflict with the prevailing religious dogmas. Nobody was allowed to question religious authority, and those who dared faced the consequences—sometimes even death! In course of time, however, humans could break the religious hold on matters concerning science. This emboldened them to have a quantum leap in science and technology, and they succeeded in offering accurate explanations for innumerable phenomena. In fact, the accumulated knowledge over the centuries was the result of 'research' done by our ancestors.

This process of research in search of more and more scientific knowledge is still going on in all the scientific disciplines.

C. G. Thomas, *Research Methodology and Scientific Writing*,
https://doi.org/10.1007/978-3-030-64865-7_1

1.1 Acquiring Knowledge

What is known is knowledge. From the day we are born, we begin to acquire and refine knowledge in many ways. Acquiring knowledge and sharing it with others are widely recognized as the basis for improving one's power, especially reputation and influence in the society. Every addition to scientific knowledge is an accession to human powers. Francis Bacon (1561–1626), considered as the 'father of scientific method', recognized this power of knowledge and said, 'Knowledge is power', implying that with knowledge one's capability to succeed in life would surely increase. Bertrand Russell (1872–1970), a renowned philosopher of the twentieth century, recognized the power of knowledge; he said: 'We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power'.

Knowledge can refer to both theoretical and practical understanding of a subject, which includes facts, descriptions, information, and skills acquired through experience or learnt through books or other means. In other words, knowledge can be *implicit knowledge* as with practical skills or *explicit knowledge* as with the theoretical understanding of a subject. *Information* is knowledge communicated through any media such as sensible statements, opinions, facts, concepts, or ideas. Information becomes knowledge only when it is conceived and understood.

The knowledge we acquire may be a priori (a Latin term, meaning 'prior to') or a posteriori (posterior to). Note that the knowledge known independent of experience is a priori. It is non-empirical or arrived at beforehand without experience. In contrast, a posteriori knowledge is knowledge known only by experience. It is empirical or gained only after we have firm experiences.

We consider a priori knowledge as true, because *deductive reasoning* is used to arrive at that conclusion using valid arguments. For example, the knowledge that 7 plus 5 is equal to 12 is known without direct experience. Anybody with some arithmetical understanding will be able to tell the answer. In other words, we acquire a priori knowledge not through experience but by reason alone. Most of the equations in mathematics are examples of a priori knowledge, as they are self-revealing. Similarly, the statement, 'all dogs are mammals' is an a priori truth. By knowing the definitions of the word 'dogs' and 'mammals', one can use reason to establish that the statement, 'all dogs are mammals' is true without the need to examine all dogs for mammalian characters.

From *inductive reasoning* based on empirical evidences, we gather a posteriori knowledge. For example, a statement such as: 'this rose flower is fragrant' cannot be considered true through reason alone. You cannot be sure whether the rose flower in question actually possesses fragrance through reason; for that, you must have direct experience—you have to smell the flowers. Note that unlike a priori knowledge, this type of a posteriori statements can be faulty; the rose in the statement may not have fragrance! Although certain scientific disciplines such as physics treat all knowledge as empirical or a posteriori, some disciplines such as mathematics use logic and reasoning. Rationalists suppose that knowledge is primarily attained by a

priori processes or is inherent, but for empiricists knowledge is a posteriori. Most scientific disciplines now utilize both a priori and a posteriori knowledge.

The discussion on knowledge leads us to recognize that acquiring knowledge is through acquaintance and through the description of characteristics of materials or phenomena. We learn many things through perception and sensation. However, most of our knowledge is by description. Knowledge may also take the form of beliefs and judgements. Some beliefs may be supported by evidences, but many are simply beliefs! The beliefs that are supported by evidences are 'justified beliefs'. According to the great philosopher Plato, knowledge is 'justified true belief'.

Kerlinger (1986) quoting Charles Sanders Peirce (1839–1914), a renowned American philosopher, described four methods of acquiring knowledge or fixing beliefs.

Method of tenacity: Probably because of our upbringing and socialization pattern, we believe and accept certain things to be true. These are being taught or thrust upon us from early childhood. Among the public, the more frequent the repetition of the belief, the more the enhancement of its validity. It is difficult to change such beliefs even in the face of conflicting evidences, and sometimes, fresh ideas may evolve from false beliefs or superstitions! For example, most religious beliefs, spirituality, omens, superstitions, and astrology existing in the society are through the method of tenacity or beliefs. People adhere to such beliefs, and it is very difficult to change them. The root cause of many superstitions in the society is because of this human habit of clinging to such dogma.

Method of authority: In olden days, nobody was allowed to question the authority. The authority might be kings, priests, or other leaders. People often take for granted the information passed on to them based on authority. Even now, the authority has some sway over the people. For common people, a statement must be true, if it is in the religious books. Most people also accept as true without questioning what the kings (now, political heads!), judges, priests, oracles, celebrities, leaders, or teachers say. The authority is considered infallible.

Although the 'method of authority' has several problems, it is considered to be superior to the 'method of tenacity'. Acquiring knowledge through authority is common among people because of some reasons. Most people are conditioned from birth by their parents with suggestions to listen, trust, and obey authorities. In most cases, authoritarian method is the fastest and most efficient method of transmitting knowledge. However, authoritarian knowledge should be corroborated by evidences and reasoning to consider it reliable. As far as science is considered, if we accept the authority of politicians or public figures like poets, artists, or other celebrities, that would be the end of science! The norm must be to accept only 'experts' in their own fields as authorities in science.

Method of intuition: The method of intuition or a priori method of acquiring knowledge is considered to be superior to the two already mentioned. As already discussed, it is called a priori method as reasoning is done from what is 'prior' or 'before'. The propositions accepted by the method of intuition are self-evident. However, in intuitive propositions, reason is considered as the criterion of truth rather than experience. It attempts to reason from cause to effect or from observed

fact to another fact or principle not observed. However, if two reputed individuals reach different conclusions based on intuition, it would be difficult to decide for sure whose judgement is correct.

Method of science: The method of science or scientific method is a practical methodology of acquiring knowledge by framing specific questions and systematically finding answers. Among the four methods of acquiring knowledge, scientific method is the most reliable. In this method, the questions formulated and answers predicted are scrutinised based on observation, measurement, verification, and evaluation. The method of science is based on empirical and measurable evidences rather than beliefs or arguments. This unique characteristic distinguishes science from other methods of faith, authority, or intuition. Scientific method has also the rare characteristic of self-correction, which no other method has; in science, theories and laws are revised based on new evidences (see Sect. 1.8).

1.2 Science and Technology

Can you define science exactly? In fact, the word 'science' is from *Scientia,* a Latin term, meaning knowledge; and it was originally used to mean simply knowledge. In Sanskrit, the word for science is *Vijnana*, which is associated with the processes of discernment and understanding. However, science as we understand today is much more than simply knowledge.

A major distinguishing feature of scientific knowledge in comparison to other kinds of knowledge is that it is not static. Scientific knowledge is constantly revised or expanded through the processes of observation and experimentation. Therefore, one can say that science includes a 'content' part and a 'process' part of acquiring or improving this content. Scientific knowledge hitherto known to us developed as the content of science. This 'content' is what we usually read and learn from science textbooks comprising of descriptions, facts, principles, theories, laws, and their relationships (Sect. 1.7). The 'content' of science develops through the 'process' of science involving repeated observation and experimentation done in a methodical manner. This 'process' is nothing but *research* using scientific method (Sect. 1.8). The stipulation of methodical approach to acquire knowledge in science is important because this distinguishes science from other knowledge systems prevalent in the society.

The above discussion leads us to define science as follows: Science is a body of knowledge attained through repeated observation and experimentation done methodically, which is always amenable to correction, modification, or improvement upon getting better evidences.

Science is closely related to *philosophy*. For a considerable period in the history of science, both 'science' and 'philosophy' were considered the same. Some distinctions between philosophy and science, however, began to surface during the late modern period. By eighteenth century, the use of the term 'science' in the sense of