A very comprehensive book on science, technology and society that cover the syllabuses of various tertiary institutions' courses on the subject which is unmatched by available international or local authors. The book has unique discussions on achievements of women in science and society and a contextual approach was adopted to elucidate facts about African science and technology activities and their challenges by giving numerous local examples. The book is up to date in discussions and provides copious statistics to support arguments. It is a necessary read for ministries of science and technology, communication, education, among other relevant institutions in developing countries and an invaluable guide for developed countries' planning and understanding of the many problems of science and technology with reference to Africa.It is an unputdownable book for students, teachers, researchers and governments.

The author has contributed a book chapter published by Wiley-Scrivener, U.S.A. and has taught science and society course at the College of Education level for eight years.He has many scholarly publications and, has won national research grants and supervised many postgraduate students. His latest book chapter is to be published soon.

978-613-9-85509-4

Science, Technology and Society

Ahmadu

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The functional role of science in society

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Imprint

Cover image: www.ingimage.com

Publisher:
LAP LAMBERT Academic Publishing
is a trademark of
International Book Market Service Ltd., member of OmniScriptum Publishing Group
17 Meldrum Street, Beau Bassin 71504, Mauritius

Printed at: see last page
ISBN: 978-613-9-85509-4

SCIENCE, TECHNOLOGY AND SOCIETY

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Foreward

The understanding of the relationship between science and society is very vital to the development of any given society.

Going through the contents of the book one will find almost all vital aspects of science in relation to society has been torched. The book will go a long way in minimizing the lack of indigenous texts in this course.

Mr. Umar's experience in teaching this course for over nine years has given him the know-how of teaching this course. Therefore I will recommend the use of this text by all students undergoing GSE in NCE course. It is therefore a worthy experience in promoting the educational development of the country.

Alhaji Ibrahim Akuyam

Dedication

This work is dedicated to the students of Aminu Saleh College of Education, Azare, Bauchi State, Nigeria, who inspired me to carry out this work.

Preface

Science, Technology and Society is a collection of essays which have been thoroughly researched and written on different thematic aspects of science and technology as they interface with society and drawn from various sources ranging from official documents, books, magazines, newspapers and discussion with relevant stake holders in the education sector at different levels, amongst others. The essays are original with reviews at the appropriate places in each chapter. They include narrative, descriptive and argumentative approaches as necessary while the topics are a kind of cocktail of various subject matter. No single book exists on science and society that encompasses the broadness of the topics which have been presented in here in such a manner as to be a balance between a book and a textbook targeting the general reader, student and lecturer. The essays provide information, debates, commentaries, and handles subtly sensitive political issues underpinning some topics in order to provide context that cannot be found in the existing local literatures in use as standard texts at the various tertiary levels. The chapters meet the yearnings and aspirations of students offering General Studies (GS) courses both at the universities and Colleges of Education and other institutions of higher learning where no standard texts exists. Until now, lecturers have to use their general knowledge and spend a lot of time reviewing various texts in order to gather the necessary information to teach the course which broadens at higher levels of studies. This collection of essays fills this gap by bringing everything to one point. It is not meant to *teach per se* nor is it a *how to* book rather it provides facts, augments and their counter arguments and adequate details on issues which are open for deductions where necessary. It is invaluable reference material for lecturers teaching the course to science education undergradutes and NCE (National Certificate in

Education) holders and the general reader who is interested in the interaction of science, technology and ssociety. The need for a publication of this genre was long overdue and necessary due to lack of indigenous texts that cover the topics within the specific needs of tertiary institutions and appropriate local content infused. Hitherto, lecturers had been teaching the course with different approaches due to lack of a harmonized instructional content, that is to say, the course had been taught subjectively. Adoption of this book will bring about harmony, objectivity and consistency in its teaching. The specific originality is the harmonizing of the details obtained from various authoritative sources into organized, well-sequenced and contexualized presentation suitable for teaching purposes or independent reading and research. The book more than meets the National Commission for Colleges of Education (NCCE) minimum requirements for General Studies in Education (GSE) course at the Colleges of Education level (specifically, GSE 103-Introduction to Science and Technology, formerly Science and Society) and to great extent, those of NBTE (National Board for Technical Education) courses in science and technology. The topics more than meet two thirds of the course EDU211 in Universities of Technology (History and Philosophy of Science, Technology and Mathematics, three credits units-3C), and at different degrees, for those of the National Open University of Nigeria (NOUN) run courses (*Science Technology and Society* (SED 413-2C); *Science and Technology in Society* (SED 834-2C), *History and Philosophy of Science* (GST 105(2C), a core course) and also some universities run *science and society* courses at the postgraduate level (for example, Usman Danfodio University). Although it is acknowledged that many books have been written on science, technology and society, the peculiar feature of this book is that it is comprehensive and replete with local examples which are concomitantly situated within an international context and interesting debates that inspire, all integrated into one book. It exposes students and readers to knowledge about scientific procecsses, institutions, history and their complex interrelationships with society and education in general. The chapters are generally moderately detailed and logically linked based on issues at stake and their relevance with appropriate perspectives which cover the most current issues in the worldof science and technology. Important features include introductory material on computers, Internet, ICT, science and politics, technology transfer, amongst others, all linked to the Nigerian education system as a special case, *vis-a-vis* the international community and the African diaspora. This is deliberate attempt to give the student or reader the necessary perspectives to contextualize the scientific enterprise within and outside the country and the overall educational superstructure. The book is therefore a tribute to the need to motivate local authors on the desirability to produce such a book and to harmonize its teaching. The book is a necessary read for the Ministry of science and technology in Nigeria for science and technology policy formulation and research and development programme. There are also very important discussions and proposals for the TETFund (Tertiary Education Trust Fund) on its Ph.D. and research grants progrmmes. The Federal Ministry of Communications also has much to gain from the book, amongst other instutions within Nigeria and outside. Ultimately, the goal of the book is to cover all the scope of science and society syllabuses as currently run in the tertiary institutions but this will always be subject to revisions based on the dynamic nature of science and technology. The principal targets of the book are srudents, lecturers and most importantly, researchers owing to the depth at which issies have been treated.

Chapter 1 is an overview of the historical development of science and gives a brief account of the early Greek philosophers and their works. Some characteristic features of this period were briefly elaborated. There is a summary of the Islamic civilization's contributions to the development of science and society in terms of its personalities and some of their relevant works. A unique feature of the book is the essay on African contribution to science and technology, a concept rarely featured in standard textbooks with all its revealing themes, presented at the end of this chapter.

Chapter 2 is general philosophy, a prelude to the philosophy of science. Main schools of philosophy (idealism, realism, etc.) were described briefly with their main features and proponents. The implications for the philosophy of science and science in general were pointed out.

Chapter 3 discussed the philosophy of science proper and answers questions such as what are the criteria for calling any given inquiry science? What meaning do we attach to scientific explanations, theory and observations? What are the inherent limitations of science as a result of its nature? These and more were thoroughly analysed.

Chapter 4 discussed the meaning and elements of the scientific method, its limitations and the implications of its various components. Basic concepts such as theory, hypothesis, laws, etc., were explained.

Chapter 5 examined the relationship between science and politics. The nature and dynamics of the relationship in terms of benefits and otherwise were discussed as evident in the science-politics interface, such as environmentalism, genetic engineering, agriculture, nuclear energy, among others. The political nature of science was then portrayed within the context of today's realities.

Chapter 6 is a prelude to chapter seven and contextualizes our science education programme within the overall educational enterprise. The chapter reviewed the general characteristics of Nigerian education system starting from its philosophy and how it subsequently gave birth to the National Science Policy. The philosophy, spending, intake and output, history and problems were reviewed briefly.

Chapter 7 examined critically, the spirit and implementation of the Nigerian policy on science and technology within the committee of developing and developed worlds on a general level. The impact of the policy statements were analysed at all levels of our educational system. The role of women in science was also highlighted.

Chapter 8 assessed the nebulous concept of technology transfer for developing countries, its definition, pitfalls, reality and problems were highlighted. An alternative approach, AT (Appropriate Technology) was discussed together with its inherent subtleties and limitations, while the experience of Nigeria in this regard was brought to mind.

Chapter 9 is a summary of the development of the computer and its integration with ICT.Various types of computers and their hardware features were discussed and defined. The meaning of computer education and its application to various sectors of the economy were presented, pointing out their impact on the society. This was linked to the Information Technology boom.

Chapter 10 discussed and emphasized the problems facing the mechanisation of agriculture in Nigeria. Some inputs necessary for proper mechanisation were identified and analysed within the politico-social and economic contexts. The effects of the chemicals used for crop protection and development and the uproar it has generated were explained.

Every chapter of the book ends with a summary which is a synopsis of the essential arguments of the chapter in which some of the highpoints have been enumerated. This is followed by review questions in each chapter meant for evaluation, although further reading might be necessary in some cases to competently answer the questions, or for further work by researchers. It is a deliberate attempt meant to stimulate the student or reader to widen his/her scope in understanding the concepts in question. References are also provided at the end of each chapter to enable students and researchers have access to original material and to carry out further research. The objectives of each chapter are clearly stated at the beginning of each chapter and with running heads of quotations from eminent scientists, philosophers, essayists, amongst others, all through the chapters. Efforts were made to ensure each chapter can be read independently of the other without losing the necessary links or full gist of the matter.

Acknowledgement

Acknowledging people by name who have contributed to the development of this book, one way or the other, since 2002 to date is almost impossible task to achieve. I therefore beg for pardon for omitting some names in spite of my appreciation of the worth of their goodwill. Consequently, I acknowledge with profound gratitude the valuable suggestions and criticisms made on the initial draft manuscript by the late Professor N.I. Hariharan of the Department of Physics, Ahmadu Bello University, Zaria, Nigeria. For going through both draft and final manuscript, I'm indebted to my colleagues at the Federal University of Technology, Minna, including, Professor (Mrs.) I.N. Mogbo, Dr. Rabiu Bello, Prof. D.I. Wushishi, Dr. R. W. Gimba and Dr. A.A. Hassan (all of the Science Education Department) for their valuable inputs in reviewing the work; and to Dr. R. O.Okwori of the Introductory Technology Education (ITE) department for his critical review of the section on technical education, amongst others. I thank Dr. Ibrahim Mohammed Gana of the Federal Polytechnic, Bida for a thorough

review of the chapter on agricultural mechanisation (chap. 10). I am grateful to Professor O.B. Awojoyogbe, my colleague in the Department of Physics, for his suggestions for the inclusion of some thematic areas that made the book comprehensive and distinctive.

Special thanks to my former Provosts, Alhaji Ibrahim Akuyam (currently Council Chair, Federal University Dutse) who wrote the Foreward to this book and during whose tenure this work began. Others are Drs. Garba Ibrahim and Abdullahi Mohammed Isyaku, all of Aminu Saleh College of Education, Azare, for the support, encouragement and understanding they displayed at various times. I also thank the former Registrar of the College, Alh. A.B. Shehu . I must mention my former collegues, Alh. Shehu mamman, Alh. Ado Musa, Mal. Babangida Alkali and Dauda Dogo for all the good times we had.

U. Ahmadu,

12th July, 2018.

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A science is said to be useful if its development tends to accentuate the existing inequalities of wealth, or more directly promotes the destruction of human life-**Godfrey Harold Hardy**

Chapter 1

INTRODUCTION: AN OVERVIEW OF THE HISTORY OF SCIENCE

At the end of this chapter you should be able to:

1. identify some early Greek philosophers of science and their works.
2. discuss the important stages in the organisation and development of science.
3. identify and list the contributions of Islamic civilization to science.
4. Identify and discuss the African contributions to science and technology.

1.0 Introduction

Science and society is a subject at the frontiers of socio-political debates, seething with activity and evolving due to the nature of scientific advancement. From a seemingly neutral subject confined to the laboratories carried out by some *initiated* practitioners who can only talk to themselves, it is now so much integrated into our daily lives to the extent that it has reshaped and redefined the relationship among members of society and the values: politicians, culture, communication, etc. It has revolutionized the relationship between man, society and the whole universe. In recent times, science and technology have drawn on the wrath of society due to their destructive potentials for man, the earth, ethical considerations and the social and criminal vices they induce. They have thus entered into the political realm. Various legislations have been enacted to limit scientists' activities within acceptable practices for the benefit of the human race. The chapter makes an in-depth analysis of the various factors that define science as it is practised today, its history, the scientific method, philosophy, contributions of the Islamic civilization and the concept of *African science*, among others, have been presented. These issues interact in a very subtle, complex and preeminent manner with eachother and the society. Attempt has been made to provide only a sketch of the issues involved, further reading is suggested in some cases.The general impression is that modern science is linked to the European civilization and by extension, to Judeo-Christian origins. It is common to hear words like *Western science*, which is a reference or pointer to it. Later, it will be stressed that a large portion of science was also rooted in other civilizations' history. Within Europe, modern science is credited to the voluminous intellectual activities of the Greeks, between the second and particularly, the fifth centuries B.C. Notable originators were the works of Aristotle, Plato, Democritus, Aristachus, Galen, Diascorides, among others. Early science was dominated by speculative philosophy amongst other characteristics. There were no areas of specialization, everything in the universe was within the purview of their discourse and arguments were primarily based on logic and reason. There were no physical methods of approach toward finding answers to scientific questions. Observation using instruments were unheard of due to the level of advancement of the society. The ability for one to defend his proposition logically is proof of workability. The early and most fundamental disciplines in science were mathematics, astronomy and biology, other branches followed later. All other branches of the sciences or fields of applied science were derived from these. Thus one who specializes in mathematics is called a *mathematician;* one who specializes in physics, a *physicist*; one who specializes in chemistry, a *chemist*; and in biology, a *biologist*, and similar appellations. Many other indices that define science as it is practised today were non-existent then. Most of the earlier calculations and theories had to be revised or completely jettisoned due principally to increasing sophistication and accuracy of equipment, theory and thorough approach at observations which were not available to the pioneers, not out of lack of intellectual prowess. For instance, Aristotle's (384–322, B.C.) views on motion dominated for almost 2000 years before it was dethroned. Apart from the codification of scientific practices which we have today in terms of ethical and other value requirements for scientists, even laboratories were unheard of. This state of affairs continued for a long period into the Roman era and hence the Judeo-Christian influence in science. Apart from hostorical exigencies, it may be argued whether early science was science at all, based on modern definition.The formation of the Roman Empire brought the work of scientists under the influence of the Church. Scientific activity became constrained and subject of scrutiny since all scientific explanations of phenomena have to suit the ecclesiastical or papal interpretation. Many scientists were thus persecuted for their scientific explanations, inevitably bringing science to a standstill in Europe. Christianity would later support science more than any nation to this day. The other civilization that contributed most significantly is the Islamic civilization. In contrast to Christianity, the then Muslim empire encouraged search for knowledge and did all it could to support it. This was evident in muslim rule of Spain which lasted for about 800 years. Muslim caliphate encouraged and honoured all scientists and learned men of all faiths and creeds and no restriction were laid on the works in the natural sciences. Furthermore, Islam itself has a non-restrictive attitude with regard to freedom of thought as it encouraged observation and investigation of nature (Kotb 1951). The author further showed that it was the Prophet of Islam, Muhammad

(P.B.U.H) who emphasized on science when he instructed that listening to the instructions of science and learning for one hour is more meritorious than standing up in prayers a thousand nights. There is no religious authority in Islam apart from revelation, an attitude that is essential for approaching reality in science. In order to fully appreciate science as it is practised today, we must go back to its historical roots. A subject that grew out of the isolated speculation of man in order to understand the complexity and awesome nature of the universe, has grown into a gigantic enterprise which the whole human civilization is built upon, depends upon and to which there seem to be no alternative and turning back. Every product of science and technology (internet, computer, mobile phones, nuclear energy, amongst others) is associated with some negative aspects which the society has to live with.This is the basis of the science and society irony. Attempt to isolate every aspect of the interaction of science and society for full discussion and analysis is not made as they require socio-psychological studies and expert analysis, rather the objective is to give general information, provide discourse and idea of the complexity and central position science has assumed in our polity so that it can be accommodated with minimal inconvenience to all through a better understanding.

Science is normally associated, at least in terms of its origins with the superfluous works of the early Greek thinkers for the simple reason that they were first to lay such a foundation of organized discussion of nature and phenomena, and to a great extent of which the records are available. Some have argued that the only other civilization that contributed such organized knowledge about nature is the Islamic civilization because many contributions were made by Muslims in various fields of science, some of which are original while others are developments of the classical Greek works and commentaries most of which formed standard texts in Europe up to around the 16–17th century. Others have held that the Islamic civilization enabled science to flourish rather than stifled it. We begin with the history of early Greek philosophers and their works and then sketch those of modern scientists and their characteristics before moving on to the Islamic civilization and science, including a perspective on African contributions. Principal sources have been Losee (1972) and Fowler (1962).

1.1 Early Greek Philosophers of Science

1.1.1 Thales

Thales (C.624–565 B.C.) lived in the Greek city of Miletus in Asia Minor and was discontented with the practical knowledge with which the Egyptians calculated the size of their pyramids and led him to discover the general principles of the geometry of the triangle, apart from the success in predicting the eclipse of the sun in 585 B.C. (Flower 1962). During the period, the Greek had accorded the study of science and philosophy as one entity, i.e., the study of the *essential* nature of things which was called *phusis*–from which physics was derived. In Thales' philosophy, the underlying nature of things which are perishable was to be determined by a rational system called *logos* (from which the word logic and psychology were derived, among others), he thus arrived at the conclusion that there was one element, water. Water lay at the basis of all beings and due to its mobility connects a life cycle passing from the sky to earth through all living things and then back to sky again.

1.1.2 Anaximander

Anaximander (611–547 B.C.) was one of Thale's pupils and proceeded with inquiry into the nature of *phusis* arriving at the conclusion that it could be identified. He was the first Greek thinker to make inquiries into Astronomy by propounding a theory of the earth as a flat disc at the centre of the universe, which was elaborated upon by his successor, Anaximanes (C. 570 B.C.). He also returned to Thales' theory of a basic element underlying the nature of all beings. He believed that this element was air rather than water due to the observation that air is necessary to support life on earth. He thought air contained an essence called *pneuma* and that this essence supports the universe in the same way that air supported human existence. Anaximanes thus became the earliest philosopher to hold a theory of organism–that the universe possesses some kind of life analogous to human life.

1.1.3 Pythagoreans

The Pythagorean (582 B.C.) view of nature had been very influential on science. In this view, the philosopher-scientist of this school believes that nature is mathematical and harmonious and that this harmony of nature rings all through it; that the knowledge of this mathematical harmony of nature will reveal her fundamental structure-the structure of the universe. His followers discovered that musical harmonies could be correlated with mathematical ratios and that the ratios hold, regardless of whether the notes are produced by vibrating strings or resonating air columns. They now extended these musical harmonies to the universe at large.

1.1.4 Plato

Plato (428/7-348/7 B.C.) was born into a distinguished Athenian family and founded an academy in 387 B.C. His centre pioneered a research in mathematics, science and political theory. Plato contributed to the *dialogues,* which deals with the entire nature of human experience. For instance, in his *Timaeus*, he presented a picture of the universe based on geometrical harmonies. In time, Plato was accused of discarding the study of the world as revealed by sense experience in favour of contemplation of abstract ideas. His detractors would point at the *Republic*, one of Plato's works, were Socrates recommends a shift in attention from transient phenomena of the heavens to the timeless purity of geometrical relations. Plato was concerned with the study that favoured development of abstract thought and was of the belief that *mere empirical* knowledge of the succession and coexistence of phenomena must be transcended in such a way that the underlying rational order become manifest. Platonist natural philosophers believed in the underlying rationality of the universe and the importance of discovering it. They are convinced that this was also Plato's conviction. Platonism served as a counter to the denigration of science within religious circles and the pre-occupation with the disputation, in academic circles based on standard texts. Plato's philosophy tended to reinforce Pythagorean orientation towards science. The marriage of Plato's *Timaeus* with Holy Scripture made it popular in the west. In the *Timaeus*, Plato ascribed the creation of the universe to a *demiurge* that impressed a mathematical pattern upon a formless primordial matter. Christians assimilated this by associating the pattern with divine plan and thus repressing the theory based on primordial matter. For those who favour this theory the task of the philosopher is to discover this in mathematical pattern. In the *Timaeus*, Plato further suggested that five elements–four terrestrial and one celestial may be correlated with five regular solids: to the tetrahedron he assigned fire, a three dimensional triangle; he assigned cube to earth, as earth is the most solid of elements; the octahedron to air and dodecahedron to matter. He further suggested that transformation occurs within them.

1.1.5 Atomists

A section of Plato's followers took the world to be an imperfection of an underlying reality. Democritus and Leucippus, both *atomists* suggested a radical departure in that they believed that objects and their relations in the real world were different in kind from the world we know by means of the sense. In the view of atomists, phenomenal changes are as a result of association and disassociation of atoms. For example, they associated a salty taste of some foodstuff to the setting free of large atoms and the ability of fire to penetrate bodies to the rapid motions of tiny spherical fire atoms. Reduction of observed changes to processes occurring at a more elementary level of organisation became characteristics of this group. Seventeenth century philosophers believed in this so much. For Pythagoreans, scientific explanations might be given in terms of geometrical and numerical relationships. The philosophy has been castigated for its uncompromising materialism because it reduces even sensation and thought to motion of atoms (a *mechanical philosophy*). Atomists do not seem to have room for spiritual experience. The ad-hoc nature of atomists' explanations also drew criticism since they offered a biased picture, a way of looking at phenomena but not how to check its accuracy.

1.1.6 Aristotle

Aristotle (384-322 B.C.) was born in Stagaria of Greek colony in Asia Minor and came to Athens at age seventeen as a pupil of Plato. At one time he was a tutor to Alexander the Great and had a school known as Lyceum in which he gathered round himself a group of thinkers called *Peripatetic*. From modern point of view he is believed to have extraordinary powers of observation. He also had interest in logical arguments and divided the possible spheres of knowledge into sections: logic, natural philosophy (science), metaphysics, ethics, politics, rhetoric and poetry. Aristotle's primary interests were in biology which led him to develop *classification* in botany and biology. His biological theories led him to formulate a new theory of causation which he applied to the phenomena of the physical world, called *doctrine of the four causes*. These are stated below:

a) the material cause: this is to be thought of as a matter which is at the basis of all occurrences: e.g. the stone with which the sculptor works.
b) the formal cause: this is the basic law governing all phenomena– that is the platonic idea which inspired the sculptor in his use of the stone.
c) the efficient cause: this is the antecedent state of affairs that triggered off the phenomenon: it is the activity or will power that motivated the sculptor.
d) the final cause: the aim, purpose or end of the phenomenon: it is what the sculptor is trying to achieve, i.e., the complete statue.

For Aristotle, the whole universe was purposive or teleological in nature. He helped in the *theory of method* (scientific method) development, as he was the first thinker to distinguish between deductive and inductive reasoning (Fowler 1962). He however was quick to realize the limitations of the deductive system in the physical sciences when he said that in the world of nature, it is always possible for things to be otherwise than they are and that it is only in the realm of logic and pure mathematics that purely deductive systems which cannot be otherwise are possible (Fowler 1962). Aristotle conducted an extensive inquiry into the nature of reasoning and developed the *science of reason* as opposed to Socrates and Plato who had developed *the art of reason* (dialectic). He formulated what are known as the laws of thought as enumerated below:

a) whatever is, is, this is called law of identity.
b) nothing can both be and not be, this is called the law of contribution.
c) everything must either be or not be, this is called law of excluded middle.

1.2 Milestones in the Development of Modern Science

Some characteristic features of modern science in terms of scope, method, attitude, application and relation to society are novel ideas. In the early days there was no real demarcation between the sciences and art: everything was within the realm of philosophical speculations, interpreting texts of old is dominant characteristic. The attempts of the philosophers were to reconcile what they read with that of the ancients, such as Aristotle and Galen. The basic distinction of early science is the lack of relationship between reality and ideas. Apart from Alchemy, there was no linkage that practical (experiment) work comes from understanding as obtained today. The emphasis on authorities is too pervasive, as all knowledge had to conform to one or more of the early Greek philosophers. One of the greatest philosophical minds, St. Thomas Aquinas set the stage when he opined that the final happiness of man lay in the contemplation of the truth. Thus attempt of early thinkers was to confirm what had been written in records rather than innovative ideas. Another important feature which is observable is the dominance of the church, scholars, and clergy or monks which strengthened the ecclesiastical or Papal influence, since every explanation had to be constrained to fit into the *worldview* of the church, else, it be declared a heretical opinion punishable by death. Before the 16^{th} century, there were relatively few books on science, even during the *Renaissance*. Priority was given to translation of books on theology and literary texts, for example, the *Almagest*, Ptolemy's work, was not printed in Latin until 1538 (Brown 1986). Most literate persons were found in the church. Learning was therefore a monopoly of the church and religion. Man's relationship to God was deemed greater than his relationship to nature. For example, St. Augustine remarked that scientific knowledge was more likely to encourage pride than to lead people to God. The ultimate aim should be salvation and not material gain. The monopoly of the church was however broken in the 16^{th} century due to the development of printing and in due course, the concept of liberalism. The humanist scholars during this period were interested in this world than in the next. Development of merchandise also brought in material rather than spiritual merchants. In the 16^{th} century, there were advances in mining, treatment of metallic ores, working of glass, etc., which were more of craftsmanship than any systematic study of nature. It was the culmination of strong material motive, better methods and tools, unshackling from the scholastics' tradition and asking the right questions that would lead to beneficial aspects of science and society to develop. The departure from speculation and the subsequent metamorphosis of science from hitherto theoretical and dialectic to a practical dimension can be pinned down to the work or contributions of the following scientists, beginning early in the 17^{th} century. This, arguably, marks the beginning of modern science.

1.2.1 Francis Bacon

The basic philosophy of Bacon was the restoration of the exact power and dominion of man to himself and of the human race over the universe (Brown 1986). He held a supreme principle which emphasized that the purpose of all knowledge, including natural sciences was power to improve life by useful inventions. He believed that people should work together to achieve a better future through applied knowledge. Bacon disparaged the science of his day as being of very little practical use. He based his arguments on the following (that):

a) they substituted talk for experiment
b) they substituted contemplation for action.
c) they are satisfied with pure verbal solutions to real physical problems.
d) they confused science with religion.
e) there are always final causes and doctrines which would explain physical phenomena once and for all.

On the contrary, Bacon proposed that:

i) the truth and value of knowledge should be tested by its utility–the worth of any system of philosophy should be judged by its contribution to human welfare.
ii) to advance human welfare is to serve God; both faith and science should be judged by their efficacy.

Bacon dethroned the authority of the ancients for scientific progress when he put forward his *new method*, precipitated on the idea that scientific knowledge is cumulative and that it can be increased in time by methodical hard work. Thus Bacon gave society a powerful motive to pure science–utilitarianism.

1.2.2 Evolution of Scientific Tools

The invention of equipment and tools gave Bacon's ideas impetus. Astronomy progressed due to the invention of telescope, whereas medical science and biology owe their progress to the invention of microscope. Galileo used the newly constructed telescope to observe the sun and established a new astronomy for the solar system–the heliocentric model put forward by Copernicus. The invention of the microscope was fundamental to our understanding of nature such as bacteria, spermatozoa, capillaries (which carry blood from arteries to veins) through the work of Robert Hooke and others. The invention of thermometers, barometers, pendulum clocks, all about this time, helped in making precise and objective measures of fundamental physical quantities such as heat, pressure and time.

1.2.2.1 Mathematical Framework

The development of mathematical techniques in the 17th century turned qualitative speculation of quantitative science, to solve unsolvable word problems. About the same time, Newton in Britain and Descartes in France invented the science of Calculus with which Newton explained the motion of the solar system. Similarly, the 16th and 17th centuries saw the introduction of algebraic notations, decimals, logarithms and co-ordinate geometry. For Descartes, all the laws of nature were deducible from mathematics, if mathematics is to have concrete meaning. Mathematics should explain all the order in our universe. He strongly believed that scientific knowledge is couched in mathematical metaphor; here is the fundamental relationship between mathematics and science.

1.2.3 Laboratory Experiments

The first requirement of science was in the harvesting of reliable facts. In the 15^{th} and 16^{th} centuries, astronomers endeavoured to improve on their observations. Later, Biologists and Anatomists began to see for themselves and men such as Andrea Vesalius began to do things to see what will happen. This was the final step towards experimentalism. The idea of experimentalism began to gain grounds around 1590 with the physicist William Gilbert who devoted his life to study of magnets. Gilbert carried out experiments on magnets rejecting the opinions of the ancients. He came out with conclusion that the earth is itself a magnet with poles near but not co-incident with geomagnetic poles and that the compass needle was attracted to these and not as previously supposed, to some northerly star, for example (Taylor 1949). Galileo Galilei (1564–1643) was the first to employ the scientific method in its fullness (Taylor 1949) and is often called the *first modern scientist* (Brown 1986). His main achievement in physics was founding of mechanics. However, his work spreads across physics and astronomy. He dethroned the Aristotelian view that the speed of falling bodies was proportinonal to their weight; on the contrary, his experiments proved that bodies fell with an accelerated motion which can be expressed by a mathematical formula. In his view, research must start from quantities to be measured and their relationship established. In a beautiful harmony, he showed how observation, experiment, speculation and mathematical analysis, as typical in modern days, could be integrated. Nevertheless, others are of the belief that it was Isaac Newton who gave the world the most powerful, influential and most convincing demonstration of the scientific method. For example, he completed the revolution began by Copernicus and Kepler by mathematically demonstrating that all the observable motions of the solar system could be explained and predicted in a few simple laws. He thus demonstrated that observational data, speculation, theory and mathematical analysis, could be harnessed to solve extraordinary difficult problems. It was thus a great elaboration on the foundations of Galileo. In 1615, Harvey discovered the circulation of blood which was subsequently published in 1628. In the standard view of antiquity, blood ebbed and flowed in the veins, which is chiefly operated by the right ventricle of the heart. Harvey however, described the course of the blood, by partly reasoning from anatomy and study of the living heart in cold-blooded animals.

1.2.4 Science Technology and Industry

The provincial areas of society were the first that stimulated scientists to the problem of industry. In the 18th century, these were chiefly in the area of chemicals and textile industry. Lovoisier laid the basis of quantitative chemistry in the 18th century. At the end of the 18th century chemistry had reached a point where it could be applied to solve problem of industry and led to the production of leaching powder and soda (Taylor 1949). Steam engines were later developed to meet the urgent needs for better method of pumping water out of deep old mines, instead of use of horses. At the end of the 17th century, this early engines owed little to science, until in 1765 when James Watt invented the condensing steam engine. In the 19th century this revolutionized transport and industry.

1.2.5 Production of Electricity

The practical usefulness of science was more evident in the electrical industry. The phenomenon of static electricity was known since ancient Greece. Subsequent experiments led to the phenomenon of lightning conductor. Alessandro Volta in 1800 invented the electric battery, while H.C. Oested discovered that electric current produced magnetic fields which subsequently led to the production of electric telegraph. Michael Faraday was responsible for the most comprehensive and revolutionary work in this field when he demonstrated the connection between electricity, magnetism and motion and led to the invention of the dynamo, the alternator and transformer.

1.2.6 Evolution of Scientific Institutions

The recognition of the importance of science to the society started with the invention of the word *scientist* in 1840 by Reverend William Whewell (Brown 1986). One of the principal ideas which inspired the French revolution was the belief that the use of reason and hence science would lead to a better society. This would subsequently lead to the teaching of science in schools and the establishment of a Polytechnic. Germany followed this French initiative with the establishment of a most successful school of chemistry by the chemist, Lieberg at the University of Geissen in 1826. Science thus gained a place in the academic world and universities and training could begin in recognized fields. Germany was the most successful in these, both in teaching and research, it thus dominated the academics for almost 100 years (Taylor 1949). It was only after the Second World War that this edge was blunted. A further strengthening of the scientific institution is the founding of specialized scientific associations or societies. For example, between 1800 and 1900 societies were formed for botany, zoology, chemistry, physics and microbiology, amongst others. Their relevance is in the social services they provided for science.

1.2.7 The Road to Modern Science

For the most part of the last century wealth had increased tremendously at dramatic rate. Particularly acute is in Western Europe and the U.S. where it increased by 5% per annum, that is, total number doubles every 14 years

(Brown 1986). Also the number of scientific journals published had grown to over 100,000 (Brown 1986). Concomitantly, the amount of money spent on science has been climbing at a geometrical rate, a subject to be discussed in detail in section 7.2. World War I propelled the British government to support science as it exposes her defficiencies in various fields compared to the Germans. The Second World War also gave further impetus to the development of radar, jet engines, penicillin, rocket, etc. The atomic bomb development had no rival in actually projecting the need for increased scientific support. It implied that science could be used for good or bad. In 1935 U.S. spending on R & D was only 0.1% GNP, whereas fifteen years later it increased to 1% GNP (an increase of 100%). Similarly, some 300 largest firms account for 92% of total expenditure on research in the U.S. Similarly, 97% of all R&D is carried out in developed countries which have 10 times more engineers and scientists per head of population than the developing countries (Brown 1986). One can conclude that the Europeans dominated the history of science in the past and at present. Nevertheless, enormous contributions were made by other civilizations. There is thus a historical mismatch in terms of R & D in favour of the developed countries, and in terms of overall exploitation of the benefit of science.

1.2.8 Political Leadership and Science

The history of science showed that it permeated society through relevance. Those at the helm of affairs, the church, state or Muslim Caliphs have always patronized science. In 45 B.C. for example, Julius Caesar and Pope Gregory XIII in 1582 ordered astronomers to reform the calendar, a purely scientific job. In Portugal Prince Henry the navigator, established an observatory charged with research into navigation, and 250 years later the

British Government set up the Royal Observatory at Greenwich. It was not, until the twentieth century that the real featuring of systematic and organized support for science by governments, industry, public, health, and agriculture was started. Between the 8^{th}–13^{th} century A.D., governments began to lend all forms of support to general knowledge seekers, particularly science.

1.3 Islamic Civilization and Science

In the introductory remarks, it was hinted that just as the Judeo-Christian civilization was involved in one way or the other with the institution of science, so also was the Islamic civilization. In literatures it is often reported as Arabs' contribution to science. The birth of Islam created this impetus through various races that formed the Muslim Empire.Therefore the discussion here has been christened Islamic. Unlike the church that tried in vain to tailor scientific findings toward ecclesiastical designs, the caliphate (muslim leadership) under the Islamic civilization gave great impetus to the development of science and knowledge in general, even though at some later stage there were some restrictions, particularly, on philosophical speculations as it conflicted with the Islamic worldview. These contributions, during which science flourished in the Muslim empire spanned over centuries, but was prominent around the 8^{th} and 12^{th} centuries. However, this blossoming radiance in knowledge was dimmed for various reasons, toward the end of the 13^{th} and mid-14^{th} centuries. A feel of the impact on the renaissance in Europe was provided by Clark (1992) who noted that muslim thinkers enriched the stream of knowledge with their original contributions which provided the foundation for the renaissance. The following is a brief profile of some of the notable contributors and their works.

1.3.1 Developement of Mathematics

Anawati (1970) quoting Ibn Khaldun showed that Arithmetic (*Al-lissaf*) was the first of the mathematical sciences used by the Muslims principally for religious reasons. Muslims borrowed from Greeks and independently developed or improved on other areas. For example, Muslims defined certain arithematic progressions and methods of calculating the sums, the aggregate of equal numbers and of certain unequal numbers without explaining them in general terms, as would have been the case today. For example, Al-Karaji (died 1029 C.E.) gave a real solution of the progression, $1 + 2 + 3 + 4$ .... Muslims also made one strong observation: that numbers which ended in 2, 3 and 7 or in odd number of zeros were not perfect squares. They constructed *abaci* (abacus) for making calculations easier by using ratios. Another characteristic of Muslim arithmetic is their accuracy. Archimedes' best inequality gives π correct to two decimal places, whereas Al-Kashi's for instance, is correct to 16 decimal places. Let us look at typical contributions in some branches of mathematics.

1.3.2 Development of Geometry

Muslim geometry was founded on deep knowledge of prior Greek works, particularly those of Euclid, Archimedes's and Apollonius and was also influenced by the Indian, Siddhanta. Muslims however, made original contributions and used intersecting conic sections in construction of regular polygons that were used in the design of certain Arabesques. Abu-layth constructed a regular nine-sided polygon. Muslims are also credited with the creation of plane and spherical geometry (Wickens, 1976). For example, Abu'I Wafa was the first to point out the generality of the sine theorem in relation to spherical triangle (Wickens, 1976).

1.3.3 Development of Algebra

The word is from Arabic *al-jabr*, which refers to the restoration of something broken, but more often it is associated with balancing of two sides of an equation (*Mugaballah*). Draper, as quoted by Nagvi (1973) opined that Muslims take the undisputable credit for the invention of algebra. Muhammad Musa Al-khuwarizmi (9th century C.E.), the Latinized algorithm, was chiefly responsible for the foundations of algebra (Anawati, 1970). He wrote a thesis on quadratic equations, algebraic multiplications and division, numerical measurements of surface and distinguished different types of quadratic equations; laying down the rules of solving them verbally (algebraic notations were not invented then). Umar Khayyam solved equations having negative and imaginary numbers that were unknown at the time (Anawati, 1970). Wickens (1976) opined that Umar was limited by lack of co-ordinates and mathematical notations. Recall that it was around the 17th century that Descartes formulated co-ordinate geometry.

1.3.4 Developemnt of Trigonometry

Carra *de* Vaux showed in Anawati (1970) that the Arabs were unquestionably, the creators of plane and spherical trigonometry because it did not exist in the early Greeks. They elaborated on the popular trigonometric functions: sine, cosine, tangent and called sine, *jayb* (opening), i.e., the opening of an angle. Anawati (1970) asserted that Abu'I–Wafa was probably the first to demonstrate the popular sine theorem. His mode of constructing sine tables gave the value of sine 30^{o} accurate to eight (8) decimal places. An outstanding achievement was presented by Al-Battani, uniting the three sides and one angle of triangle, which has no equivalent in Ptolemaic mathematics; he also introduced the secant and cosecant. In the view of carra de Vaux, following Moritz Contor (Anawati, 1970), it was Abu'I' Wafa and not Copernicus who invented the secant when he called it the diameter of the shadow.

1.3.5 Development of Physics

Optics is one of the most important areas that enjoyed Muslim patronage. A remarkable practitioner of this art is Al-Hassan bin al-Haytham (died 1039 C.E.), the popular Alhazen of the Europeans. Alhazen distinguished himself as an eminent scientist by proving mathematically that light emanated from illuminating objects when people were arguing that it came from the eyes. Nagvi (1976) and Anawati (1970) showed that he discovered the laws of reflection, although not explicitly stated as such, and what is now called *normal ray* which he called *centric ray*. He applied geometry of refraction to the eye and investigated the phenomenon of atmospheric refraction from which he calculated the height of the atmosphere; he studied lenses and mirrors of different shapes and sizes (convex, spherical, etc.) and described various experiments which he performed on starlight, rainbow and colours. Thus Wickens (1976) wondered why he did not discover the telescope given the breadth of his work in optics. Using observation of the image cast during eclipses for instance, he produced the first known instance of the camera obscura-pin-hole camera. Alhazen and other Muslims practised the inductive method of science, although not explicitly couched in the modern language. He emphasized their use and said one who does not do so will never attain mastery (Nagvi 1976). Shustery (1968) reported that al-Biruni gave the exact specific weights (relative density) of eighteen precious stones and metals.

1.3.6 Development of Alchemy and Chemistry

Chemistry developed from the practice of alchemy, an attempt to convert pure metal to gold or silver through the use of elixir which is supposed to have some powers. Draper opined (Nagvi, 1976) that it was experimental observations that made the Muslims the originators of chemistry and led them to the invention of all kinds of apparatus for distillation and sublimation, amongst others. Jabir b. Hayyan (Geber) was excellent practitioner and wrote several works on chemistry. Wickens (1976) gave him the credit for the discovery of nitirc acid, sulphuric acid and the distinction of separating lead carbonate, Arsenic and Antimony from their sulphides. Jabir further explained the separation of steel, polishing of metals (electroplating), dyeing of clothes and leather and the distillation of vinegar into concentrated sulphric acid. He provided the exact description of processes such as, crystallization, sublimation and reduction. Jabir was born 721 C.E. and his laboratory was discovered two centuries ago, near Damascus gate and a golden mortar was found. Al-Razi was another good chemist and in his book *Sir-al-asrar* (*Secretum Secretorum*) he described apparatus that fits modern picture, such as flasks, pots (with glazed covers inside), water bath, funnels, etc.

1.3.7 Developement of Astronomy

Muslim lunar calendar gave impetus to the development of astronomy. Yahaya Khalid translated Ptolemy's work, the Arabicised *al-magest*. Muslims contributed in the construction of observatories for observing stars and planets, for example, the work of Nasiruddeen Tusi (died 1274 CE). Also it was claimed that the system of creating observatories was imitated from the Muslims by Europeans who improved it on a large scale (Shustery, 1996). Muslims discovered different constellations of stars such as Virgo, Germini, Scorpio, etc., in the 8th, 9th, 10th and 12th centuries, C.E. (Nagvi 1976). Examples are *Mirfak* (αper), *Hamal* (α ori), *el Nath* (β Tau), amongst others (Evans, 1992). They elaborated on the Astrolabe, an instrument for measuring the position of the sun and stars and used *quadrants,* with which they identified wobbling (*Chandler Wobble*) of earth's axis and the revolution of the planets in elliptical orbits round the sun, much before Tycho Brahe, Copernicus or Kepler. Albiruni, for instance, suggested the possibility of the centrality of the sun in a solar system with the earth both revolving round it and turning on its axis (Wickens, 1976). Alfarghani (Ahmed B. Muhammad) believed in the value of precession and held the view that it affected not only the stars but also the planets; precession is the slow movement of equinoxial points causing the equinoxes to succeed each in less time. Alkujandi (died 1000 C.E.) also made astronomical observations from which he determined the obliquity of the ecliptic (Shustery, 1968). Erasthothenes (230 B.C.) gave the value as $32^o\ 15'\ 20''$ and was assumed to be constant; but al-Battani got a lower value of $32^o\ 15'$ and insisted that it was correct and was later vindicated, that is in the 13th century C.E. (Anawati, 1970).

1.3.8 Medicine and its Icons

The science of medicine among the Muslims made headway in Baghdad in the 8th century C.E., during the caliphate of al-Mansur. But it was al-Ma'mun who took the first initiative when he called the genius Hunain B. Ishaq (873C.E.) to translate classical texts on medicine, notably those of Hippocrates, Galen and Diascorides. The greatest clinical doctor of Islam and most eminent physician (Anawati, 1970) was Abubakar Al-Razi (Rhazes) who died 925 C.E. In his clinical daybook he described each malady and the results of treatment. His most famous book was, *De.*

Variolis at morbilis was the *first treatise on infectious diseases in existence* (Anawati, 1970) and deals with small pox and measles. In examining the course of a disease, he advised paying great attention to pulse, breathing and excrement. He wrote many books covering anatomy, surgery, fevers, skin disease, etc. Within 100 years of the Islamic civilisation it had reached Spain. Muslim civilisation in Spain would last until about 800 years. During this period Muslims contributed a lot to the intellectual development of the state. Muslim physicians and pharmacologists in Spain introduced, in conjunction with botanists, useful plants, date palms, and other medicinal plants. Some illustrious Muslim physicians in Spain were Ibn Sina (Avicenna, 11^{th} century C.E.); Ibn Zhur (Avenzoar, died 1162 C.E.) and Ibn Rushd (Avveroes, died 1198 C.E). Abdul-Qassim al-Zaharawi (Abdulcasis, died 1013 C.E.) was a leading Muslim surgeon and his work *al-Tasrif* was the first medical work to contain surgical instruments (Anawati, 1970). In it he described operation carried out with the aid of scalpel, ocular and dental surgery, and operation for stone, obstetrics and extraction of arrows. With Ibn Sina, Muslim medicine reached its peak. His great medical work is called *Cannon of medicine* (*al-Qanun fittibb*). In it, he talked about muscle, nerves, veins, anatomy, diseases and their causes and several other diseases and their causative agents. It has been reported that in 1924 an Egyptian doctor, Dr. Tatawi, in his medical thesis demonstrated that Ibn al-Nafis, in his work called *al-Mujaz* gave an almost exact description of the small or pulmonary circulation, nearly three centuries before its discovery by Micheal Servetus (1556) and Ronaldo Colombo in 1559 (Anawati, 1970).

1.3.9 Seeds of Technology

Muslims had contributed in the invention of ingenious devices, techniques and theoretical propositions. Clark (1992) reported that al-Biruni was able to guess from observations that the desert of Arabia was at one time a sea, an assertion that has been confirmed today as a result of the preponderant oil found in the Gulf States. During Muslim rule in Spain (Andalusia) they introduced excellent and functional irrigation schemes for the dry plains of Andalusia (Burke, 1985) as they turned the dry plains of Andalusia into an agricultural cornucopia. Perham (1993) showed that the arrival of Muslims in India in 1001 C.E. solved the perennial water problems through the building of a unique type of well called the *Baoli step wells*. Muslims were also reported to be the first to manufacture paper *successfully* in Baghdad in 800 C.E. Even the present system of writing numbers (1, 2, 3, 10, etc.) called Arabic numerals, though arguably borrowed from India, have also been credited to the Muslims (Wickens, 1976; Bronowski, 1973).

Environmental science is today seething with activity, yet new as it may seem, was long practised by the Muslims. Eigland (1992) for example, reported that various prophetic traditions supported this and that Muslim law makers formulated laws which covered, among other things, the conservation of forest, prevention of overgrazing, protection of water resources and animal rights. This brief survey demonstrates the relevant works of early Muslim scientists, amongst others, in spite of the pervasive literature attributing the origins of science to Judeo–Christian and Greek origins. Enormous contributions came from the Muslims during the European *dark ages* which no doubt changed and enriched the manner of doing science. The present science is therefore cumulative, the Japanese, Indians, Chinese, Africans, etc., all have contributed their quota one way or the other.

1.4 Africa, Science and Technology

A major missing link in the impact of science teaching in Nigerian schools, indeed African countries' educational systems is the absence of any reference to contributions made by Africans in the history and evolution of science and technology. This has serious ramifications on the socio-psychological, political psyche and pride of the African student and thus necessitated research into this matter. The African sense of pride had been one of humiliation and surprise, juxtaposed with Africa's position as the origin of man and civilisation. No single name of a classical African scientist or contribution can be found in any field. The discussions on science and society would therefore be incomplete without commenting on this hotly debated matter which affects the African continent. African contribution in this context encompasses contributions made by all peoples of the geographical continent, largely based on early contributions until the advent of slavery in the continent. The debate whether Africa had contributed to science or not is a complex one involving political, historical, socio-cultural and methodological discourse.Thus it is impossible to disentangle such knotty issues in this essay for the above reasons. However, recent efforts in this area by historians has revealed much and it has thus become untenable to uphold the standard view that Africa had not contributed to the evolution of science and technology. The factors that affected and stifled the develpment of "African science" are both internal and external to it. This essay therefore addresses these issues through the following questions:

i. is there anything worthy of note in African science?

ii. what is the nature of this African science?

iii. why has it been obscured?

iv. what are the specific contributions?

1.4.1 African Science

Bajah (1980) asked whether there is anything like African Science, because as we know there is only one science, Western science. However, if science is defined methodologically, there should be no Japanese, Chinese, or Arab science, *et cetera*. This is the consequence of the fact that Western science has been adopted as the standard method of investigating nature due to its various appealing characteristics as we have discussed earleir and chiefly due to the fact that it can produce tangible products, is verifiable and repeatable, among others. Bajah (1980) defined African science as a systematic, complex and exclusive traditional process in which attempt is made to describe, understand, predict and control nature. Whereas Ezeabasili (1977) says that African science is African overrating nature and how it is working, arguing that every culture has its own science which is part of its total symbolic expression which cannot be separated from its culture, art, sculpture and even religion. The problems that face scientists of a particular culture, the questions they ask and the methods through which they choose to address them has a bearing on the cultural orientations of the people and the way in which the observer presents and comprehends it. The same problem could be addressed through different methods by different cultures. Choosing any method as standard is political or cultural in thought or motive in spite of the outstanding successess of the scientific method. African science has also been defined as a way of describing and explaining nature which arose within an African context and experience and which is diametrically opposed to the vaunted objectivism of science. The basic difference between African and Western science is principally in methodology and the object of study: whereas the one concerns itself with both inanimate and animate matter, the other concerns itself with animate.

1.4.2 Nature of African Science

According to Asante (1988), in African Science, the self is the science of the world, animating it and making it living and personal in which neither materiality nor spirituality are illusory. African Science is spiritualistic and bureaucratic. Western science considers progress in terms of more technique, how to do it better and with richer explanation which is fundamental to a technological–scientific future; whereas to the African, it is related to development of human personality which is the source of life for the material and spiritual (Asante, 1988). A major sticking point with regard to the legitimization of African science is the question of lack of contributions. Bajah (1980) explains that one of the reasons is the exclusive nature of African science which makes nonsense of any notion of freedom of information, a principal tenet of science. Also, the effectiveness of many processes now classified as African science depends on the personality. Parents are expected to passs on their knowledge of traditional herbs to some carefully selected members of the family. The amount of knowledge that would have perished through this method is enormous over the ages. The argument advanced for this exclusivity of African science is the need to protect against wide-spread and uncontrolled use of the knowledge. African science is concerned with diseases, mental illness, social affairs, e*t cetera*, with less interest in mechanistic manipulations. Little wonder that records of African science achievements are difficult to access. Researchers are working hard on these questions and more. Proponents of African science have blamed slavery and colonialism during which Africa fell victim, as part of the problem that obscured its contributions to science. Africa made scientific and technologial contributions, among others but due to stereotyping, these accomplishments were ignored or unreported alltogether. In our discussion of the philosophy, nature and methods of science later (chaps. 2-4), we describe its principal features such as rationalism, empiricism, objectivity and the mechanical philosophy. It is from these perspectives that some of the differences between the two sciences, so to speak, may be appreciated.

1.4.3 African Contributions to Science and Technology

By stretching the definitions of science and technology and that of *research,* lossely, it will allow us to show that Africa had indeed contributed immensely in this area, even though standard text writers and literatures have neglected them. Enormous research work in this area has been carried out by many researchers, notably Ivan Gladstone, Van Sertima, Cheikh Anta Diop and Pappademos. Recent work on the issue in an edited volume is very compreshensive (Mavhunga, 2017) with several examples and philosophical perspectives, among others. Many Africans have contributed immensely, particularly from the late 19th to 20th century science. African Americans have also carried out a lot of research into this topic which revealed many facts hitherto unknown in order to boost their image and overturn this negative impression about Africans. The following are some selected contributions by subject, and are not exhaustive or in any special order.

Astronomy

1. The Dagon of Mali had an excellent understanding of the solar system and the universe 700 years ago. For example, they detailed knowledge of the *white–dwarf*, companion star to *Sirius A* which was not visible to the naked eye (Sertima 1984).
2. The pyramids of Egypt are an epitome of the maturation of poor African technology, from poor mud bricks to huge stones (Lumpkin 1984a).

Agriculture

1. Africans were the first humans to plant maize crops and to domesticate cattle, 15,000 years ago (Sertima 1984). Between, 17,000 and 18,500 years ago, with ice still covering most of Europe, African peoples were already raising crops of wheat, barley, lentils, peas and dates, among others.

Chemistry

1. 1,500 to 2,000 years ago near Lake Victoria, carbon steel was made in blast furnaces. A temperature of 1,800 ^{o}C was reached, much higher than what was used in Europe until modern times (Sertima, 1984).
2. Iron minning occurred in Swaziland 40,000 years ago (Zaslaisky, 1984).
3. Evidence of 2,900 to 5,500 year old Iron slag and charcoal, showing smelting, among the ancients of NOK culture in Nigeria (Zaslaisky, 1984).

Mathematics

1. A woman in Egypt from Alexandria called Hypathia designed an astrolabe, a water still instrument to measure water level and hydrometer. She also tried to prove concepts about the geometry of planes, such as what happened when a cone is intercepted by a plane (Lumpkin, 1988; Alice, 1986;Lumpkin, 1984b), among others.
2. Around 1000 AD, people in West Africa in particular, Nigeria, among the Yorubas were using the number system, partly in base ten and partly in base twenty (Sertima, 1984).
3. Examples of distance, area, volume, weight and time were all used by the Egyptians. They also used standard units and methods of measurements (Papademos, 1984).

Medicine

1. Africans developed their aspirin from Kaolin to treat diarrhoea (Sertima, 1984).

2. African Doctors carried out autopsies and were asked to treat psychosis (Sertima, 1984).

3. In cosmetic science, African women wore wigs, used breathe fresheners, polished mirrors made of copper and jewelry, made perfumes, scented oils and pomades and used henna to stain finger nails and toenails (Yar'brough, 1984).

4. In Kaleen (Egypt) medical papyrus, women diagnosed pregnancy, guessed at the sex of unborn child, tested for sterility and treated dysmenorrheal (irregular menstruation). Women surgeons also performed Cesarian sections, removed cancerous breasts and set bones with spiritual aid (Alice, 1986).

5. In Egypt, Cleopatra wrote on gynaecology, obstetrics, cosmetics and skin diseases (Alic, 1986).

Critics of African science have argued that if it were adopted it could not lead to practical products of science and technology: automobiles, mobile phones, computers, among other real benefits of science and technology. African science does not provide for independent investigation and provision of information but peruses which is not respectable, verifiable and objective; it cannot lead to a physical change in the world. On the other hand, appologists of African science argue that the known good results should be adopted and legalised inspite of the method, since it is efficacious. This is particularly true and effective in the area of medicine and social issues. Western science is materialistic, expensive and remote from human values. It has been suggested that Western science needs to engage with African science in order to be complete. African science solves spiritual and human problems while Western science is mechanical, that is materialistic and mechanistic; whereas the worldis both materialistic and spiritualistic. With greater flexibility, African science can be open to questioning and scientific method. The difference between the developed and developing world, particularly, Africa, is technological development. Aspects of African technology such as, textile industry, arts and crafts and music and food technology can be used to leverage African technology. Culture is the driving force that fuels and inspires technological accomplishments in human society; it is a phenomenon which encompasses all the materials and non material expressions of a people (Adebayo, 2011). The achievements of African science and technology should be reflected and interpreted in standard science textbooks and not be ignored or relegated, say apologists.Unfortunately, lack of development of unique writing by Africans has been a great impediment to the storage and transmission of the records of their history and achievements.

Chapter Summary

The history of science is replete with contributions from various philosophers in the Greek pioneers work. They were responsible for making intelligent discussions about the origins of matter, reality, ideas, concept, etc. and laid a foundation for their intelligent and logical discussions. They organized these discussions into the branches of philosophy that we have today. The utilitarian aspect of science was emphasized by Francis Bacon and since then science and society have become inseparable. The development of instruments for observation, mathematical frameworks, etc. helped in no small way in codifying and allowing more accurate results. Islamic civilization contributed in many ways through original works and improvements on the classical writings by expanding the Greek works which eventually led to the emergence of Europe from the *dark ages* into the *Renaissance* period. Thus the necessity imposed by the physical environment and its challenges have integrated science into our daily lives since then. The African continent had made contributions to science and technology but these have been obscured due to a conbination of reasons both internal and external to it such as its human centred philosophy, methods and sphere of infleunce which are spiritual and humanistic. Its exclusive perusal and subjective nature is an impediment that restricts information and knowledge and consequently to loss of enormous knowledge due to lack of written records. There are the issues of slavery and colonialism, twin evils which have been blamed as draw backs to the practice of science and which have led to loss of culture and products emanating from them . The definition of science does not only largely exclude African science but any other science distinct from Western culture. This has alienated people from useful knowledge resulting from the experiences of these cultures which certainly are a reflection of overall human experiences and aspirations. Many problems are spiritual and not physical. African science also has its many draw backs from its practice and administration of its solutions. It is a great irony that achievements of a continent which has been acclaimed to be the origin of the human race and civilization and which has the privilege of holding the two most oldest fossil records of early man, as found in Kenya (~1.5 million years) and Ethiopia (~ 2 mllion years) have been downplayed.

Review Questions

1. Discuss the importance of the Pythagorean philosophy of science.
2. Explain any two of Aristotle's *doctrine of the four causes*.
3. Discuss the contributions of Francis Bacon to the use of science for solving human problems.
4. Enumerate any two important milestones in the metamorphosis of modern science.
5. Discuss briefly the contributions of Galileo to experimental science.
6. Argue that Muslim scientists are *chiefly responsible for the development of algebra* and *...the originators of chemistry*.
7. Enumerate three definitions of African science and explain them.
8. Criticize the methodological difficiencies of African science.
9. List and discuss three contributions of African science in areas other than those presented.
10. Suggest and discuss five ways of integrating African science into mainstream science and technology.

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Advances in medicine and agriculture have saved vastly more lives than have been lost in all wars in history-**Carl Sagan**

Chapter 2

GENERAL PHILOSOPHY

At the end of this chapter you should be able to:

1. describe briefly the subject matter of of philosophy
2. explain the features of the principal schools of philosophy
3. discuss the limitations of the various schools of philosophy
4. compare and contrast between religion and philosophy

2.0 Introduction

The subject matter of philosophy is relevant to the understanding of science and is a brainchild of philosophical speculations of the ancient Greeks, as far as records prove. All the relevant schools of philosophy, idealism, realism and pragmatism, are important in the understanding of science, scientists and their relevant concepts. A sketch of idealism will be provided from which the philosophy of science will be developed, this is in spite of the lack of universal definition of philosophy by philosophers. Philosophy is generally believed to have originated from the ancient Greek city of Miletus around the 5th or 6th century BC. Though this view has been criticized and rejected by African philosophers. Records show that Ionian philosophers such as Phytagoras and Thales visited Egypt and got educated by African teachers in various fields of knowledge (Onyewuenyi, 1987). Philosophy is the *love of wisdom, that* is *philo*-love and *sophia*-wisdom. It is defined as the study of the methods and principles used in distinguishing good from bad reasoning (Copi, 1972) or an attempt to distinguish between correct and incorrect arguments (Kahane, 1968). The principal source for this discussion is from Yusuf (1996).

2.1 Idealism

This school believes that whatever exists is not real but mental; that ultimate reality has a spiritual nature and not physical, mental or material. The real can never be perceived. Plato, the foremost idealist, argued that due to the inherent imperfection of our sense perceptions we can never be trusted if the issue of reality is to be comprehended. In the view of this school therefore, all physical objects are mere manifestations of a more fundamental non-material reality. For instance, the sun, the moon, rocks, etc., are just appearances reflecting a deeper spiritual, immaterial reality which we can never comprehend. Based on this principle, religions are favourable to idealist philosophers. Both Muslims and Christians for instance, trace sources of all physical beings to Allah or God. In the idealists view, man is a spiritual being, i.e., a spiritual animal. Idealism emphasizes or affirms the spiritual nature of a man. Man had had to worship one god or another at different times in history. It is in the realm of ultimate reality and is therefore described as idealist's metaphysics. As will be discussed later, epistemology deals with the realms of knowledge. Socrates and Plato had maintained that any knowledge obtained from the sense must always remain doubtful and partial. The material world they say is a distortion of the more perfect sphere for spiritual being. Thus, we cannot rely on such knowledge. They maintained that it is only through reason that we could acquire true knowledge; that only reason can transcend the physical form of things into the realm of the spiritual. Most modern philosophers, accept the factor of reasoning introduced by Plato, Emmanuel Kant and Hegel, since they argued that the essence of knowing is to impose order and meaning on any information gathered by our senses. Idealists are of the view, when it comes to ethical or moral issues (i.e., axiology), that values and ethics are absolute and not relative. What is good is good and what is bad is bad from generation to generation all through society; they are pervasive and unchanging in their essence. They are not man-made, but inherently embedded in the nature of the universe; they exist independently on their own. For instance, telling lies is bad anywhere and condemnable, but beauty is appreciated everywhere and for all times. The aim of idealist education is to emphasize the search for truth. Plato had argued that we could not find the truth in our ever-changing physical world. The conception of true ideas is the highest aim of education in his view. Thus, the platonic idealists suggested the study of arts and science subjects, with abstract subjects such as mathematics and astronomy that could stimulate speculations, as the only way of arriving at the truth. Plato thus suggested the dialectic method, that is, critical analysis of mental processes, which supports lecture method.

2.2 Realism

This philosophy takes almost a diametrically opposite view to that of the idealists. In their metaphysics, realists believe that matter is the ultimate reality, nothing is beyond it. The sun, trees, cars, etc., are not distorted and imperfect mental ideas in the minds of those who perceive them, but exist in and of themselves, independently of the mind. Realists are further divided into two:

1. Rational Realism: this could be broken down into *classical* and *religious* realists. Classical and Religious realists agree in the independent existence of the world. However, religious realists add that both matter and spirit were God's creation. The fact that God created the universe proves its reality; for divine creations must be real.

2. Natural or Scientific Realists: these believe that the real existence of the world imposes responsibility on science to investigate and not on philosophy. Natural realists are skeptics while scientific realists are experimental in behaviour. The most important aspect of the universe in their view is that it is permanent and enduring. Change occurs according to permanent laws of nature. Natural realists are not in consensus on the spiritual nature of the world. In the view of scientific realists, free will does not exist and it is determined by the impact of physico-social forces on our genetic structure.

Realists' epistemology believes that the physical world is not a mental creation, but a true existence. Ideas or propositions are true as long as they correspond with those features of the world which they claim to describe. True knowledge must therefore have correspondence. In the course of our history we have gathered plenty of knowledge about the worldwhose truth have been confirmed time and again.

Realist axiology agrees that fundamental values are permanent, though for different reasons for the Classical. For example, they argue that there is a fundamental moral law for every rational being. Religious realists agree with the classical and add that this moral law can be comprehended by applying reasoning and that it is God who had made us rational beings to understand that created the law. However, Scientific realists deny this supernatural connection and argue that good adapts us to our environment, whereas evil estranges us from it. The principle of the constancy of human and physical nature demands that values are also constant. Thus basic values remain intact the world over, in spite of differences in social institutions and practical orientations. For the Scientific realists, the concepts of right and wrong are not intrinsic to religious principles and that morality should be based on the result of investigations of science which should have found them beneficial.

In their aims of education, religious realists downgrade the importance of matter in itself, unless it leads to something beyond. They believe that the study of nature should transcend matter as its essence. Thus they believe that only by careful study of the world in order to unravel its order and regularity that knowledge of God could be achieved. This is the prime purpose for which God created them so we could know Him.

For Scientific realists, the purpose of studying the world should be to use it for man's benefit. A lot facts and ideas are learned by the study of the physical world in their opinion, they therefore emphasized that the fundamental purpose should be the survival of man and the advancement of knowledge. That education should be biased towards technical expertise. Whereas Scientific realists maintain that science provided for moral as well as intellectual education because of its very nature and requires some ethics such as integrity, self-sacrifice, courage, etc in order to succeed. Realists stress the use of critical reason, observation and experiment in education, while Scientific realists, emphasize technical education.

2.3 Pragmatism

The pragmatists school, also known as *Instrumentalism* or *Experimentalism* take almost intermediate position within the philosophical realms. In their metaphysics, they believe that the world is neither dependent on nor independent of man's ideas. That reality is a product of the interaction between the human being and environment, our total experience. It is man that gives meaning to the world. If there is any meaning not known to man, then it is hidden, and therefore what man cannot experience cannot be said to be real to him. Pierce and Dewey for instance, believed that only experts, especially scientists, could establish the facts about reality. Pragmatists put change at centre of all things. They argue that we must always be prepared to change our way of doing things. In their view, human nature is fluid and changeable.

Pragmatists' epistemology emphasizes the active role of the mind which has tendency to explore, as against a passive and receptive one. That truth does not lie solely in the correspondence between reality and ideas due to the nature of the content of the ideas used. Problem solving is a better means of understanding.

For pragmatists, values are relative and not absolute, in contrast to the realists and idealists. Values must be culture and society-dependent. The worthiness of our values must be tested, just as we test the truth of ideas. Human interaction problems should be considered objectively and scientifically and appropriate values that befit them must be chosen, and that are most likely to resolve them. Values should not be imposed by higher authorities but must be out of consensus, after informed deliberations based on objective evidence. There are of course other philosophical Schools of Thought such as Falsificationalism and Relativism, amongst others, which have been properly treated elsewhere (Chalmers, 2013; Singh, 2002; William, 1996; Frank, 1992). Falsificationists, for example, freely admit that observation is guided by and presupposes theory and are pleased to abandon the claim that theories can be established as true or probably true in the light of observational evidence. On the other hand, the Relativist denies that there is a universal, ahistorical standard of rationality with respect to which one theory can be judged better than another; that the most important factor with respect to scientific theories would vary from individual to individual or from community to community.

This is thus a brief rundown of the fundamental and relevant philosophical thoughts that are at the roots of scientific philosophy. In chaps. 3&4 it will be shown that scientific practice and culture are mostly based on one or more of these views. In the practice of science, all these ideas are used at differing degrees, depending on the situation. For instance, science is more realist-pragmatist oriented and relegates religious philosophers to the background by arguing that science could not be done based on religious philosophy.

2.4 Philosophy and Religion

The objectives of religion and philosophy are fundamentally opposed even though there are some similarities. Whereas philosophy is always critical and investigates from the vantage point of intellectual neutrality, irrespective of personal sympathies, seeks knowledge for its own sake, is anti-magic and does not entertain miracles; religion, on the other hand, is critical only to a point, as reason is used to interpret dogma derived on grounds of faith. In the religious philosophy knowledge is sought to achieve human kind's happiness or destiny; it is characterized by symbols such as religious ministers, pastors, imams and amongst others. The relationship is very complex and defines the framework of scientists' work which had led to great debates in the past. The basic elements or attributes of religion and their interrelationships are summarized in the conceptualized schematic in Fig. 2.1 and indicates philosophy is a component part of religion, a kind of idealist perspective. A practical example is the debate that ensued following the publication of Charles Darwin's *on the Origin of species*. The publication sparked controversies within the scientific and religious circles based on rationalism of the day. The famous physicist, Lord Kelvin had argued that creative power was needed to account for the existence of objects which are unlikely to form through the fortuitous concourse of atoms, and wondered if anything could be more absurd as to believe that a number of atoms by falling together of their own accord could make a crystal, a sprig of moss, a microbe and a living animal (Ivan, 2004). Although Kelvin later removed the reference to a crystal and limited the question posed to living things to reflect the objective of the publication and its import. Also, historically, the separation between science and religion during the scientific revolution has been described by the Nobel Laureate Steven Weinberg as a *divorce.* Weinberg asserted that it was brought about by the need to outgrow a holistic approach to nature. However, he argued that classically, the shift had more to do with the desire of Bacon, Galileo, amongst others, to remove personal bias from scientific endeavours despite their having religious convictions (Paul, 2015).

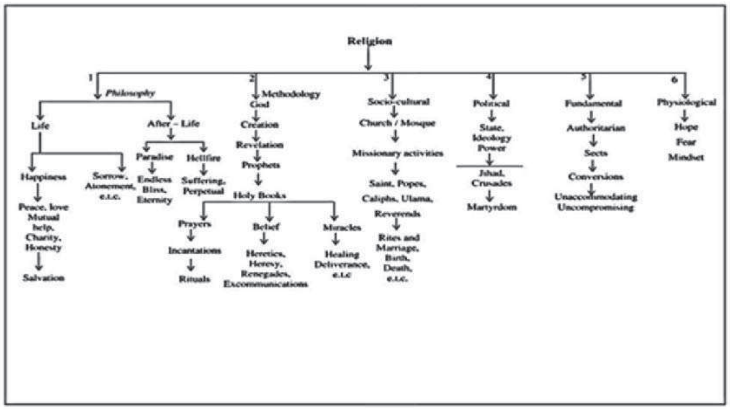

Fig. 2.1. The author's summary of the concept of religion and its different characteristics. Religion consists basically of six components whose attributes have been enumerated based on the two most populous religions as examples. Religion is defined by its philosophy, methodology, socio-cultural, political, fundamental and psychological dimensions.

Chapter Summary

The subject matter of philosophy is important for the understanding of any conceptual analyses, particularly in science, where it is necessary to be unambiguous about concepts and how they are used. The main branches of philosophy, realism, idealism, etc., are all relevant for value, metaphysical and epistemological discussions in whatever philosophy. This is the necessary foundation of any philosophy of science. Science is about human experience, both matter and otherwise, it is necessary to demarcate this border through the use of philosophy. Philosophy gives meaning to all scientific activity by spelling out aims and objectives and limiting itself to measurable variables. This discussion also hints at the demarcation between religion and science. Idealist philosophy is most befitting for religion. Darwinian Theory sparked a great debate between religious scientists (idealists) and rational idealists.

Review Questions

1. Idealist philosophy is totally incompatible with science, discuss.
2. Distinguish between *rational realism* and *scientific realists*.
3. Enumerate and discuss the basic ideals of pragmatism and how it is related to experiments in science.
4. Discuss any three other philosopies relevant to scientific understanding.
5. The publication *on the origin of species* by Charles Darwin sparked a great debate between religious scientists and rational idealists. Discuss within contemporary context.

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After all, science is essentially international, and it is only through lack of the historical sense that national qualities have been attributed to it-**Marie Curie**

Chapter 3

PHILOSOPHY AND THE MEANING OF SCIENCE

At the end of this chapter you should be able to:

1. state any two definitions of science
2. state the aim and objectives of science
3. enumerate some limitations of science and
4. list the fundamental assumptions of science.

3.0 Introduction

Many people have harped on the so-called failures of science in situations where it seemed to have offered little help or its predictions failed, thereby justifying the supremacy of moral, social and religious institutions as the most reliable and immutable sources of knowledge to fall back on. This is the result of ignorance of the philosophical projections of science. The aim of this chapter therefore is to give an insight into the underlying framework of its philosophical dimensions, even though no detailed attempt is presented.

As a subject matter, science study begins at the primary school level but it significantly starts at the secondary school level. Some of its fundamental subjects are Physics, Biology and Chemistry which are called Natural or Physical Sciences since they deal with the study of nature or the physical environment and natural phenomena. At the advanced level, subjects like political science, Library science and many others also incorporate the word science in their names. But are these subjects, strictly speaking, amenable to being classified as science? What about archeology, paleontology, etc.? These questions can only be answered correctly if we understand the philosophical meaning of science which defines its borders and any value we may attach to it. We shall learn later that the real torch-stone for deciding what is or is not science lies in the *scientific method* of inquiry. The definition of science is very fluid, due to daily emerging new fields of study that in turn branch off into others. Basic science has branched off into various fields of study some of which are arbitrary, others historical, whereas others are deliberate. The interface between science and technology is also being blurred due to their interrelationship and increasing harmonization (chap.3.9). A combination of science subjects would lead to engineering subjects which in turn has branches (mechanical engineering, electrical engineering, software engineering, etc.).

Natural science is concerned with the characteristics and operations of any and all natural things and happenings (Beck,1960). The word science comes from the Latin word *scire* which means, *to know*. At the very heart of all definitions of science the search for knowledge is the cornerstone. Defining science is not an easy matter (Kotb, 1951; Ziman, 1980). However, attempt will be made to give various definitions that will be comprehensive enough to cover the broad picture. Science is as an attempt to survey and classify the phenomena of the world in the pure dry light of the intellect, uncoloured by feeling (Thompson, 1953). In the view of Taylor (1949), it is a systematic method of describing and controlling the material world. Based on an operational definition Mohr (1977) described it as a disciplined and systematic attempt of the human mind that aims at genuine knowledge. Other definitions looked at aspects of science like its verifiability and universality. For Kotb (1951) it is the study of those judgments concerning which universal judgments can be obtained. Although Oguniyi (1986) conceded that there can be no definition of science that would be complete, he nevertheless defines it as an attempt by human beings to organize their experiences about nature into meaningful systems of explanation. Among other competing definitions, one finds that by Beck (1960) introduces a controversial notion of objectivity when he said it is a body of tested objective knowledge obtained and unified in principle by inductive methods. This definition evidently begs the question whether science is objective. In summary, science is an attempt by humans to understand, explain and manipulate the world through universally agreed methods. The essential thing is a definition that captures the essence of science because scientific explanations are more interesting and illuminating (Ed, 2014).

3.1 The Nature of Science

Earlier, it was stated that philosophy is fundamental to the understanding of science as it tells us what value or degree of faith we should attach to our results of investigations or products of the interaction of our investigations and the manipulation of the results in order to control the environment. Philosophy's subject matter is divided into logic, epistemology, metaphysics and axiology. Science is based on a consistent and systematic reasoning. Logic being the principle of correct reasoning is therefore relevant to the subject matter of science. Our theories, arguments, propositions, etc., in science must be logical, even though at some higher level scientific theories may seem illogical and unpredictable, as is the case in in quantum physics.

Epistemology is the theory of knowledge where the question is whether any part of scientific knowledge that we claim is certain and not liable to revision under any conceivable circumstance. *Episteme* means knowledge and *logos mean* study or reasoning. It is a critical philosophy which investigates the scope, source and limitation of human knowledge. It attempts to chart the path for discovery of what knowledge is, as distinct from mere opinion or belief. Sometimes it is called theory of knowledge. Typical questions defining its subject matter may include: what is the relationship between knowledge and belief? Is the human mind capable of knowing at all? Is it possible to know anything with certainty or must we have to do with mere guesses and opinions? Is there anything like truth? Is all knowledge dependent on experience or independent of it, and to what extent? Can we really say our knowledge of the working of nature which we gained through mental activity and sense perception of the environment is really the truth? Can we really claim complete knowledge of anything, matter or phenomena? The safe way that science chooses is that we cannot swear on our theories or explanations, but if they work for our purposes then they are right. So we do not mean that scientific theories are *the whole truth and nothing but the truth*. Rather, they are our consistent and agreed explanations about nature and they work. We accept that the knowledge is imperfect and we continue to review them tending towards the ultimate truth.These revisions are what seem to others as the failures of science.

Metaphysics deals with concepts and their relationships. It is the only theory that deals with the basics of the theories of the universe. It is defined as the science of the first things or of the most real (Mann *et al* 1966). It deals with the totality of the observable universe, the visible and invisible as it studies existence and reality. It is etymologically derived from the words *meta*-after and *physika*, i.e., physics or *nature*. It asks questions such as, is the universe self-caused or do we have to invoke the concept of a Creator? Does God exist? Are men free? What is mind? Is reality essentially spiritual or material? Examples include our concepts of time, space, motion, creation, etc. How are they related to the real thing, the ultimate thing, that is the ultimate reality? Is time continuous or reversible? Is there anything like space with three dimensions in reality? How or why was the universe created and how will it end? All these are metaphysical questions. Scientific philosophy asks *how*, *why*. For *why* cannot be answered incontrovertibly without invoking religion or other philosophies. Ooccasionally, however, science has to conjecture answers to such problems.

Axiology or ethics deals with the realms of values and aesthetics. It is the branch of philosophy that deals with the morality of human actions on society (Omoregbe, 1989) and is traceable to the Greek word *ethos*-character. It has been described as *moral philosophy* and systematized by Socrates who proclaimed that *the unexamined life is not worth living*. Its primary concern is that of human conduct, those actions which are carried out conciously or willfully and could be descriptive, prescriptive or normative aesthetics. Classically, science used to be thought of as objective, neutral, with no morals, feelings, devoid of all forms of sentiments, safe search for truth. There was thus no value consciousness in science. However, the dropping of atomic bomb in Japan and the advent of genetic engineering and similar sienctific adventures have made this traditionally valueless, ethicless notion of science to break down. Scientists and governments now bear the onus of moral and ethical considerations, even legal, in their search for ultimate truth. For example, scientists produce contraceptive pills to prevent unwanted pregnancies or for family planning. Some argue that there is a moral question there, as you are indirectly killing the unborn baby. There is the issue of genetically modified foods, so-called GM foods. Some fear the consequences of eating or planting its seeds around the natural ecosystem in the long run as we have not and would probabaly not be able to study the long time implications. Should one even tamper with nature to that extent, they would ask? As long as we confine our attention to the phenomena which our senses can comprehend and thus restrict our inquiry, examine our mental picture in relation to its parts, test their correspondence, or want of correspondence, we are studying natural science (Dampier–Whetham, 1927). In contrast to speculative philosophy and other philosophies, a general consensus of scientific opinion upon fundamental points has been reached. This is not to say that the results of science have no metaphysical import. Science is therefore not the epitome of truth but a dubitable revisionary enterprise (Oguniyi, 1986) and *does not pretend to be a complete view of the world but working towards such a complete view in the future* (Dampier–Whetham 1927).

Science is systematic study of nature and involvees both method and theory formulation. What meaning do we assign to our observations or methods? There are different views on the nature of science. The most simplistic (Driver, 1983) view is that of the empiricists who hold the view that knowledge is essentially based on observations. We arrive at scientific knowledge by an inductive process through the *facts* of some data. According to this view, observations are objective and facts immutable (unchanging). This view also shows that science will produce cumulative knowledge: that the truth about the natural worldwould be gradually unveiled. This idea was first put forward by Bacon and was criticized; however, it later reasserted itself early in the last century.

Another pertinent position is that of the Inductivists. The limitation of the inductivists' position had long been acknowledged by philosophers of science and scientists. They emphasize and acknowledge the role imagination plays in the construction of scientific concepts and theories on the contrary. The *constructivists* approach, discussed in sec. 4.5.2, argue that theories are not related by induction to sense data but are constructions of the human mind which are linked to the world of experience.

Scientists and philosophers of science are not in accord about the nature of the philosophy of science, including its subject matter. This idea is very insightful and revealing for this discussion and has been discussed according to Losee (1972).

3.2 Perspectives on the Philosophy of Science

In his analysis, Losee (1972) divided the various groups in disagreement into four, based on their feelings about subject and content:

a) in the first view, the philosophy of science is considered a formulation of worldviews that are consistent with and to a degree premised on important scientific theories. It is thus the task of the philosopher of science to expatiate on the wider implications by speculations.
b) the second view is that philosophy of science is about the expressions of the presuppositions and predispositions of scientists. Here the philosopher may point out that nature is not random and

has harmonies of sufficiently low complexity which would be accessible to the investigator. Further, he could uncover the predisposition of scientists for determinate rather than statistical laws of nature or mechanistic, based on the view that everything can be reduced to a mechanical motion and teleology (the view that everything is made to serve a purpose) explanations.

c) in the third view, the philosophy of science is concerned with the discipline in which concepts and theories in sciences are analysed and classified. It is not essential to reduce it to mere exposition of new theories, rather a matter of being precise about meaning of terminologies, such as wave, energy, potential, momentum, power, etc., defined within scientific range as distinct from other fields. That is, that definition and proper use of concepts is emphasized. This view has been criticized by Gilbert Ryle who argued that it carries the implication that it is as if the philosopher would explain the meaning of scientific concepts to a scientist. Moreover, not every analysis of scientific concepts qualifies as being a philosophy of science, though some conceptual analyses do.

d) in the fourth view, the philosophy of science is considered as *second order criteriology* in which the philosopher of science seeks answers to questions such as:

a) distinctive characteristics of scientific inquiries compared to other types of investigations.
b) what are the proper procedures for investigating nature by scientists?
c) what are the fundamental conditions that satisfy a correct scientific explanation?

d) what status should we accord scientific laws and principles at the cognitive level?

When the fourth view is analysed, it would be found to incorporate elements of the second and third views. For example, should we inquire into the disposition of scientists it would be relevant for evaluation of scientific theories, likewise, analysis of the meaning of concepts would be relevant to a delineation of scientific inquiry from other fields. It should be borne in mind that though categorized as these views may be, in reality their borders are thin. Consider for example, the relative adequacy of Maxwell's electromagnetic theory and Young's *wave theory of light* in Physics. The scientists would be responsible for judging Maxwell's theory to be superior, while the philosopher investigates the general criteria for acceptability.

3.3 Goals and Objectives of Science

Man is a curious thinking being. In his interaction with the environment he has always longed for explanation of natural phenomena and control and tried to modify his environment to overcome some harsh realities. This he does through developing ideas which would be consistent with his observations. It is such thinking and ideas that led to philosophy. The objectives of science can be stated therefore as follows, to:

a) fit together consistent and harmonious models which shall represent to our minds the phenomena which acts upon our sense (Dampier–Whetham, 1972).
b) gain genuine knowledge about the real world(Mohr, 1977)
c) satisfy material needs, which in turn contribute to pure knowledge (Taylor, 1946).

d) compare man's strategic position in the world, by means of dependable methods for predicting and controlling events that occur in it (Hempel, 1968).
e) realise man's desire to know, his insatiable intellectual curiosity to explain and thus to understand (Taylor, 1949; Hemple, 1968).

3.4 Fundamental Assumptions of Science

At the base of the study of science are certain fundamental assumptions which enable its study to be possible. As enumerated by Oguniyi (1986) and Beck (1960) they include:

(i) nature is understandable
(ii) all of nature is subject to the same natural law (i.e. unity)
(iii) all natural events have natural causes-science does not accept spontaneity, that is cause and effect exists.
(iv) nature is simple and orderly
(v) space is real and has finite dimensions
(vi) time is real, continuous and practically irreversible (quantum mechanically, thermodynamically, they are possible in physics)

In their pursuit of the study of nature scientists have implicitly assumed that nature would expose herself when thoroughly subjected to investigation, without this assumption it would be futile to attempt to study an entity that is unintelligible and haphazard. Implicit in the above assumption is the fact that nature is also assumed to be simple and orderly. There must be order and harmonies in the rhythm of nature to enable us discern its behavior. This pattern or rhythm is generally unchanging and enables us to formulate theories and laws in science which work. Another valid and pertinent assumption about nature is that there is unity in the laws of nature, a kind of natural law. All the laws of nature are true from which ever point of the globe, indeed the universe, you may wish to measure them (that is, invariant). Science works through *cause and effect*. Everything has a *cause* leading to an *effect*. The sun shines because of some *cause* inside the sun (nuclear fusion), some people are racially black while others are white due to some *cause* in their genetic constitution, some chemicals have smell of rotten eggs others of pungent smell due to a *cause* (chemical composition), etc. Note however, that science does not accept that something can *cause* itself spontaneously, in principle. The last two assumptions have fundamental implications for physicists and mankind as a whole. We believe or rather assume that we live in a three dimensional space and continuously flowing irreversible time. Initially, it was thought that space and time were separate entities. However, the great scientist, Albert Einstein showed in his *theory of relativity*, that space and time form one entity of space-time. That is, space is inseparable from time and vice-versa. If you change the structure of space, time is affected. Time is no longer thought of as a continuously flowing entity separate from space. With these assumptions we are able to understand, explain and manipulate our environment. Though our assumptions may not be correct or true but they work and that's what matters.

3.5 Logical Limitations of Science

From the above discussions, we may deduce the boundary to which science has been confined by its very nature.

a) science is derived from reasoning. Aristotle and other idealist philosophers have argued about the correctness or otherwise of our sense perceptions. What is evident is that our sense perceptions and reasoning abilities are limited by our very nature.Therefore all our theories and understandings are limited to our reasoning ability. Thus anything that is not reasonable is outside the purview of science.

b) Assumptions. Our scientific theories, laws, formulae, etc., are subject to certain subjective assumptions, despite the overriding fundamental assumptions. We predict future and learn about the past under these conditions that are assumed unchanged. Once the assumed conditions changed, our explanations fail. All the variables in a problem cannot be taken into consideration, thus the need for assumption.

c) we can never know past and future events with any dependable degree of certainty.

3.6 Socio-Political and Cultural Limitations of Science

Science is an attempt to unravel the secrets of nature through a systematic study. The knowledge we gain is always imperfect. Some of its socio-political limitations as enumerated by Ziman (1980) include that:

a) science is not an end in itself. Science is only a tool towards achieving some aspects of human experience. It is only a facet in the range of experience. There are other needs which science cannot help: belief in science as an end in itself is dangerous and destructive because the human being is made of matter and spirit, whereas science is concerned only with matter. The Church of scientology, for example, believes in science.

b) science is not the only source of knowledge: the poets, lawyers, traditional healers, etc., give us more meaning and taste to life.

c) It is never absolutely objective and cannot be known to for certain to be true.

Philosophers are divided with regard to knowledge (sec. 2.2, 2.3) of anything.The skeptics maintain that knowledge is partial and never complete; the agnostics are doubtful whether we have any knowledge at all, whenever we claim to. For the idealist philosophers on epistemology, knowledge is only a sense perception. But the human being as a whole is inherently limited even in mind. Therefore whatever we claim to know is very limited by our being and can therefore never be the ultimate. This is not to talk of how our social, cultural, historical, among other experience, colour and stereotype our thinking.

d) scientist's preparation or experience is poor for social responsibilities, such as politics and business. In politics, the success of the scientist depends on attributes like cunning, charisma, patience and moral rectitude, which in general have no effect on a scientist's work. However, in recent times many scientists have become successful politicians in many parts of the world: former present Goodluck Ebele Jonathan, Ph.D Zoology (Nigeria), Chancellor, Angela Merkel, Ph.D. Physics (Germany) and former US Defense Secretary, Ashton Carter (Ph.D Physics), among many others.

e) the reliability of scientist's knowledge is over a relatively very small portion of the known universe, particularly the physical and biological sciences. There are so many facts that we have no theory for them.

f) every product produced by science has some imperfections: negative social effects and biological side effects. Think about the car, aeroplanes, Television, mobile phones, computers, internet, nuclear power, drugs, among others. Their problems can only be minimized and not eliminated.

Such philosophical inclinations and similar considerations have led some scientists to be accused of atheism as a result of *fanatical science*. Scientists have been accused of sticking uncompromisingly to the scientific philosophy and scientific method to deny the existence of God, and hence religion (see sec. 2.4). For others, like Einstein, science led him to affirm the existence of a God of creation, i.e., from the extraordinary nature of the universe, its simplicity, harmony and intelligibility, among other awesome qualities (Slote, 1969). The fundamental difference between religion and science is thus, whereas the former requires unquestionable belief in some authority based on revelation or otherwise, the latter questions and demands proof through a standard method accepted universally based on obervations and measurability.

3.7 Acknowledged Sources of Knowledge

Is science the only means of obtaining knowledge about our universe? How is it that the *scientific method* of acquiring knowledge is preferred and often emphasized? This should have been clear by now. However, the following list is a summary, though not exhaustive (Bassey, 1968), which further highlights the difference as alternative sources of knowledge:

a) appeal to the supernatural (God, religious knowledge, etc.)

b) intuition–answers to problems are formulated by the mind, usually is a thought to which no conscious reasoning can be attached. Examples include hunch, inspiration, and inner feelings.

c) common sense-this depends on experience and a combination of logical and intuition reasoning.

d) appeal to worldly authority-people, books, radios,internet, etc.

e) logic-a disciplined system of thinking from which conclusions are drawn from factual statements (premises) to be shown to be true or false.

f) scientific method-embraces all of the above and emphasizes evidence. This shall be treated fully in chap. 4.

Note that there is unanimity in the answers to problems in the last case and the method of arriving at the answers is repeatable and verifiable anywhere, anytime.

3.8 Objectivity and the Nature of Science

At several sections earlier, the notion of objectivity in science was mooted without further qualification, now is the time to do so. The survival of the myth of objectivity has been challenged by scientists and has been found to be in conflict with the nature of perception as it ignores organisational influence in science. The context in which people work is relevant since our concepts and beliefs are moulded out of our culture which tends to limit our ability to imagine outside the box any alternative possibility. In the opinion of Head (1985), objectivity persisted due to a) misunderstanding of a perfectly sound case and b) a strong emotional commitment to the belief. Political beliefs, personal interests, and personal life-styles may affect the work of a historian, sociologist or artist, in so far as objectivity is concerned, but would have no effect on a scientist studying the structure of DNA, or a chemical molecule, for example. For instance, attempts to impose on the scientists an outside belief system, incompatible with the available scientific evidence, as with the inquisition and Galileo or the church in the last century, had all led to the discredit and discomfiture of those who made the imposition (Head, 1985). Thus to a greater extent, a scientist's prior belief or disposition cannot and should in principle not colour his investigation of nature, since the results of his investigation have to be reinvestigated by others and there has to be unanimity in whatever conclusions he might arrive at. Misunderstanding of some philosophers of science is also responsible for this belief. For example, the philosopher Popper's stress on objective knowledge was wrongly misconstrued. He had argued that worthwhile scientific theories should yield hypothesis which are open to testing and regulation by empirical experiment; and that in the testing process, the open, objective mind is necessary. But even in that context Popper was being *prescriptive* not *descriptive* (Head, 1985). Persistence of objectivity is also believed to be due to scientist's emotional attachment to that belief. The reality is that both scientific facts and theories also represent a particular worldview, which is a model which we hold of the world and can therefore not be said to be objective. Further work on the meaning and philosophy of science and the nature of knowledge can be found in a book edited by the philosphers Imre Lakatos and Alan Musgrave (Imre and Alan, 1979).

3.9 Distinction between Science and Technology

Before concluding this chapter it is important to make a distinction between science and technology, a concept which even student-scientists find difficult to distinguish, not to talk of non-scientists. From all the philosophical discussions about the meaning and philosophy of science, this should be apparent. However, let us be more precise and sum up everything. Although the two are used interchangeably in this book occasionally, and in general discussions, they are subtlely different. They are so much intertwined these days that their borders have become blurred. Nevertheless, there are differences in spite of their intricate relationship.

In the same vein that definition of the concept of technology transfer (sec. 8.0) and its constituent parts have eluded experts, so also is the term technology. The United Nations played a key role in helping developing countries define this concept to help them in negotiating technology transfer to bridge the technology gap between developed countries and the developing ones. Various definitions have been proposed by the receiving (developing) and source (developed) nations, aside from those of experts and independent observers, such as the United Nations who has even tried to codify it, but without consensus and thus failed. This is principally the result of the irreconcilable and diametrically opposed viewpoints of the two parties who try to see it from perspectives that would favour them each. Some examples of definitions of technology as found in literature have been discussed below. The United Nations viewed it from a broad perspective by referring to technology as a combination of equipment and knowledge while others said it is a systematic application of scientific or other organized knowledge into practical tasks (Haug, 1992). The Organisation for Economic Cooperation and Development (OECD) in Europe sees it as a systematic knowledge for the manufacture of a product, the application of a process or the rendering of service, including associated managerial and marketing technologies. Although this definition captures developing countries' aspirations, nevertheless, it signifies the cultural implications or packages that technologies are usually cloaked in.

The word technology is from the root *techne* (art or craft) and–ology (branch of learning) (Mavhunga, 2017). The goal of technology is to change or improve the real world for the sake of man (Mohr, 1977). For Aminu (1986) technology is the product of resourcefulness; while Ukoli

(1985) affirms that science and technology reinforce each other. Video players, television sets, mobile phones, trains, aeroplanes, etc, are all products of technology. However, the understanding of the working of the components that make up some of the products is science, through research. Though some products came to being purely on the basis of scientific investigations, others, however, came on independently of science, i, e., technology. Technology deals with applications of knowledge (science) in solving a particular problem. People who graduate from polytechnics, for example, belong to the technology class (skill emphasis) but a physics, chemistry or biology graduate is a scientist (theoretical emphasis).Technology does not emphasize on intellectual development and could be a technique, process (for example, that of mass production) or method; it is craftsmanship and not necessarily obtained out of research. It draws on imaginativeness, ingenuity and skillfulness which are brought to bear on a particular problem in order to produce some material things (product or device) or a way of doing something that has utilitarian relevance for man. Technology provides all the comfort we live in and has a bearing on diverse fields of our life: economic, military, social, political, etc. Science on the other hand, deals with investigation (research), understanding and explanation of the working of material things or natural phenomena. It is only through science that innovation is brought about and encouraged and the frontiers of knowledge are pushed further. Understanding of the principles of things or phenomena will lead to its manipulation. Without science, innovation will be very slow. When it is applied to solve specific problem it becomes applied science, that is, applied research, which is favoured by companies and industries. However, innovations and new products can generally only be obtained through research. Science and technology and very important in establishing what we can be done and provide the ability for us to generate new options but neither of them can tell us what we should do (Zoller, 2013). Further treatment of the differences between science and technology can be found Brooks (1994) and Bybee(1998).

Chapter Summary

The definition of science has been presented from various points of view and has been shown to be contexual and universal. The goal and objectives of science is defined by its philosophy. Science offers a universal explanation of phenomena which can be verified at any time and anywhere. It is not the only source of knowledge, there are others that are equally necessary for proper living. Science is not spiritual, though spiritualism is part of human history and culture which cannot be divorced from it. Science cannot offer solution to those types of problems, it is basically materialistic in nature, it is about knowledge. It is operable due to fundamental overriding assumptions and limited in scope due to its very nature and its lack of socio-cultural solutions, in comparison to religion. Science cannot bring peace, though in principle it can. Religion ought to bring peace and happiness, contrary to current happenings. It was also argued that today's science has lost its claim of objectivity as its results are subject to socio-political debates, restrictions, manupulations and the notion is inherently inconsistent with itself.

Review Questions

1. Discuss any three definitions of science.
2. Explain any one viewpoint in the philosophy of science.
3. List any three social limitations of science and explain their importance.
4. *Nature is simple and orderly*. Explain.

5. Criticise the notion that science is *objective*.
6. Philosophers and scientists disagree on some interpretations of science. Discuss.
7. Scientists are ill-prepared for politics. Discuss.

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Almost everything that distinguishes the modern worldfrom earlier centuries is attributable to science, which achieved its most spectacular triumphs in the seventeenth century-**Bertrand Russell**

Chapter 4

THE SCIENTIFIC METHOD OF INQUIRY

At the end of this chapter you should be able to:

1. list any five definitions of the scientific method of inquiry and criticize each.
2. list and explain the components of the scientific method of inquiry
3. identify and discuss any three limitations of the scientific method
4. distinguish between the scientific method and that of a named religion.
5. discuss the degree of conformity or otherwise of scientists to the ethical component of science and its implications for society, cite relevant examples.

4.0 Introduction

The scientific method is the only criterion that could be used to distinguish between what is science and what is not (pseudo-science); it is a way of understanding nature that is preferred with respect to the other methods of seeking knowledge. Some writers even assert that science is really about a method-the *scientific method*. This is because the scientific method plays a major role in determining the nature of scientific knowledge (Beck, 1960). There are two basic approaches that are normally applied in the course of scientific investigation which are part of the scientific method: inductive and deductive science.

4.1 Inductive Science

All science depends on facts drawn from observations. The process of drawing conclusions from a set of particular observations is called inductive science. In this view of science, concrete evidence precedes scientific generalisation. The conclusion always follows from the premises with only a degree of probability. An example from Oguniyi (1986) will suffice: the probability of children exposed to measles to catch it is high (premise); John was exposed to measles (makes highly probable); John caught measles (conclusion). An inductive logic or science proceeds from individual case to generalisation. Although the premises may be true the conclusions drawn may be false. As a result, some like Medawar (Oguniyi, 1986) faulted it technically. It must be noted that if we had to study everything individually before reaching a conclusion, then science may never have been possible. Thus it is widely used method.

4.2 Deductive Science

This is simply the reverse of inductive science and involves accepting a general idea to be a fact and then judging individual cases accordingly, that is from general to particular. In this case the conclusions come from the premises. An example: all girls from Adamawa State are beautiful (premise); A'isha is from Adamawa, (therefore) A'isha is beautiful (conclusion). Note that defining science through method is not enough. Inclusive in the scientific method are the attitudes or ethics required of scientists to observe. Scientific method has been defined as the series or sequence of steps taken by scientists during the course of their investigations.

4.3 The Scientific Method

Scientific method or process refers to those activities carried out by scientists during investigations. The list below is from Oguniyi (1986) and is not exhaustive and includes: observation, classification, measurement, prediction, problem identification, testing, hypothesis, experimentation, collection of data, analysis of data, synthesis of data, interpretation of data and drawing valid conclusions.It should b noted that the actual details of the method are different for physics, chemistry, soil science, agricultural science, amongst other. However, they all fundamentally have to fulfill the general elements of the scientific method.

4.4 The Products of Science

The results of the various activities of scientists are usually packaged as: facts, concepts, laws, theory and hypothesis. Further, eventually it leads to the development of technology which ultimately becomes devices and processes.

4.4.1 Facts

These are undeniable, evident observations which are there for everyone to see (philosophically, instrumentally), they speak for themselves. Observation is defined today based on instrumentation (from miscroscopes, telescopes and beyond). Example: the sun rises from the east and sets in the west; a pregnant woman delivers a human child; night follows day, etc.

4.4.2 Concepts

This is a very ambiguous term (Oguniyi, 1986) because to some they are terms, symbols, ideas or names; while to others, they are summaries of related facts, composite knowledge, exclusive or relational terms, mental picture of some kind, such as design, etc. It can as well be taken as any conceived explanation given to a thing or phenomenon which is consistent with observations and predictive. For instance, in physics, there are concepts such as magnetic and electric fields, charge and energy. In Biology, there are concepts of cell, nucleus, cell division, amongst others, all in an attempt to explain some facts.

4.4.3 Laws

A scientific law is a brief statement of mathematical formula which quantifies the relationship that has always been found to exist between a number of observed quantities of a special kind (Taylor, 1949). Wenham *et al.* (1972) defined a physical law as a summary of observed physical behaviour. These definitions summarize the answers to the appropriate *hows*. Examples of some laws in chemistry include the laws of *multiple proportions* and *constant composition* which may also be represented by mathematical formulae (Kokoin and Kokoin 1987). In physics, there are laws of Gravitation, Newton's laws of motion, etc. A law is a verifiable generalisation about nature (Oguniyi, 1986). It is a statement about the relationship among variables investigated and may be expressed mathematically. It testifies the regularities in nature and can be used to describe, explain and predict it.

4.4.4 Theory

Oguniyi (1986) asserts that a scientific theory is a generalisation requiring further investigation.While Beck (1960) sees it as the best idea as to how a group of separate facts are related to each other. For Kotb (1951), on the other hand, a true scientific theory merely means a working hypothesis. That is the building of imaginative pictures of the processes which give rise to the observed behaviours (Wenham *et al.,* 1972). A scientific theory includes a mental picture or model and some mathematical or logical relationship. It must have passed rigorous experimentation, reexperimentation, verified and be consistent with existing knowledge regarding the matter, though not necessarily a perfect fit. It is an explanation that is generally consistent with known facts in the relevant field (physics, chemistry, etc.) within an internationally accepted scientific framework (though not always necessary as had happened several times in physics), for example. There is always room for improvement. Examples are theory of Evolution in biology, Relativity and Kinetic theory of matter in physics, amongst others.Theories are construed as tentative conjectures or guesses freely created by the human intellect in an attempt to overcome problems encountered by previous theories and to give an adequate account of the behaviour of some aspects of the world or universe (Chalmers, 2013). Some observations presuppose theory while observations and experiments are carried out in order to shed more light on the theory such that only those observations considered relevant to the relevant task are recorded (Chalmers, 2013). However, in so far as the theories that make up our scientific knowledge are fallible and incomplete, the guidance they offer as to what observations are relevant to some phenomenon under observation may be misleading, as some factors may be overlooked. The philosopher Kuhn sees theory as a form of scientific structure based on the revolutionary character of scientific progress, where the revolution involves the abandonment of some theoretical structure and its replacement with another incompatible one. See more discussion in secs. 4.5.2. and 3.8.

4.4.5 Hypothesis

A hypothesis has been described as an intelligent guess; a tentative explanation to a problem; the first flash of idea that comes to mind before beginning scientific investigation in earnest. It has to be subjected to testing, experimentation and reexperimentation to confirm the hypothesis or otherwise. It is a tentative idea of how observation is to be interpreted (Beck, 1960). An inquiry into nature which employs these concepts in tandem with the other components can bear the name science, as long as it is within the scientific ethics. The scientific method encompasses all three components (laws, theory and hypothesis). In summary, a hypothesis is an intellectual construction developed to explain facts and intended to represent in some preliminary manner, a certain section of reality (Mohr, 1977).

4.4.6 The Ethical Component

The other fundamental method of defining science is through the code of conduct of scientists, that is the standards of attitudes and behaviours they are expected to observe during the course of their investigations. The range of these ethical requirements are many and a kind of platonic idea of virtue. They include intense curiosity, skepticism, objectivity, open-mindedness, humility, honesty, determination or doggedness, patience, consciousness, amongst others. Further, strict regulative principles such as careful observations, accurate reporting and recording of data using available skills, models, programs and discussion at various levels (Oguniyi, 1986) are inclusive. Psychologically, attitude may be positive or negative; scientists need both. According to John Dewey (Kotb, 1951), negative attitude is freedom from control by routine, prejudice, dogma, unexamined tradition and sheer self- interest. On the positive side, it is the will to inquire, to examine, to discriminate, and to draw conclusions only on the basis of evidence after taking pains to gather all available evidence. Professional quality of a scientific research encourages intellectual and moral qualities which could be equally useful and transferable into other fields. There is no spirit of authority; anybody can be challenged on any matter. However, this gives the impression that science has no morals and is blind (that is, as per socio—cultural-political) pursuit of knowledge for its own sake, in so far as the matter at hand is concerned. This is where science runs into troubled waters neck deep with the political establishment and social institutions. For our society is a socio-political set up in its broadest sense, any attempt to pretend otherwise would have a price tag. Thomson (1953) concluded that such a separation in the long run is impossible. There will be more to say on these in chap. 5. It must be borne in mind that the scientific method as defined by its three components has not always been so clearly defined. Science started as a philosophical speculation by notable philosophers such as Aristotle, Empedocles, Democritus, Heraclides, etc., who hammered out arguments to which no verifiable answers could be given. The arguments were more metaphysical and idealistic, until the 17th century and after during which the scientific method gained footage. For example, it was Galileo, who proved experimentally that all objects fall toward the earth with the same acceleration due to gravity that pioneered the scientific method and made the observation that the sun is at the centre of the solar system (heliocentric view), contrary to the view held that it was the earth (geocentric). An idea earlier proposed by Al-Biruni and Nicolas Copernicus. Thus, eminent personalities of the time, e.g. Francis Bacon continued to advocate for the scientific method.

4.5 The Process of Learning Science

Literature reviews have revealed a lot of information concerning the feelings of students about science. Science is perceived as difficult, incomprehensible and not related to experience. Research also shows that it demands cognitive ability to succeed. Indeed psychological studies have shown that it requires a certain threshold of I.Q. (Inteligent Quotient) in order to succeed. Many theories have been propounded on the nature of the process of understanding scientific concepts. The most prominent ones are the *Piagetian* and *Constructivist* approach. These have have subsequently spun a lot of techniques that emphasize some activity–oriented studies for science students and the respect for their own personal construction. Philosophy has emphasized the need to be very unambiguous about the use of concepts, which is highly emphasized by teachers to ensure that their pupils and students are precise and accurate on the use of scientific words (terminologies). For instance, Care' (1981) has shown that progressive teachers build their courses around a background of practical experiences in which you would find children clicking batteries and bulbs together, digging up worms, amongst others. But the values of these experiences in themselves mean little unless they relate with pupils thinking. Thus it is necessary for lessons in science to be related to pupil's background experience as a means of facilitating learning.

4.5.1 Jean Piajet's Studies

The fundamental theory which attempts to unravel the nature of understanding of concepts that are relevant to scientific concepts is the work of the psychologist Jean Piaget. According to his studies, each individual in maturing develops mental capacities relevant to each stage to enable the individual to handle increasing difficult forms of knowledge which are a necessary consequence of maturation. Different individuals have different rates of maturation. However, the individual may be helped to master each of these steps when he is *ready* to do so, the individual must be *ready* for the particular mental task at hand. Among the hierarchies in the Piagetian knowledge ladder and which are of fundamental importance to science education is the progression from *concrete operational* thinking to *formal operational* thinking. In Piajet's view, these stages allow the individual to think more in abstract and complex ways and that it characteristically develops in the early adolescent age. Thus, the teaching of science from the primary school to the university reflect the different tasks commensurate with the ages of the pupils and students and experiences that will induce or evoke the right response. The nature of science is such that thinking at abstract level is a necessary precondition to generate mental picture that could be correlated with the learner's experience. It is necessary for the students to be able to imagine and conceive ideas in abstract. In recent times, this view has been criticized for various reasons, including the allegation that it does not give room for the individual to have any prior experience or idea about the nature of things or concepts. Thus reflecting the constructivists' perspective is one of the new paradigms.

4.5.2 The Constructivists' Theory

This work, related to Kelly is the main opposition to Piagetian view and its adherents are called *Constructivists*. The thrust of his argument is that each individual has some personal constructs on the way he views things or phenomena. Here the emphasis is on the individual way we make sense of the world. Kelly's main suggestion is that we are naturally mentally active, and thus we develop a set of personal constructs (picture) based on our experience of the world with which we anticipate how people and things behave. Thus the importance of the learner experience or involvement is emphasized, not that the learner has no contributions to make, rather, his state of mental preparedness to receive an *external* picture as suggested by the Piagetian view. Consequently, many science educators today have accepted this as the new paradigm for science study. Curricula have been designed to take cognizance of these factors. Methods such as reformulation (reconstructing the pupil's mental picture); application, through practical lessons; making use of prior knowledge of students, and involving the learner in the teaching strategy, amongst others, are being used. The aims of science education run through all our educational levels. The general aims however, reflect very much that of the British Association for Science Education. For the purpose of comparison, we enumerate them as follows (Head, 1985):

a) understanding science concepts
b) development of cognitive and psychomotor skills
c) ability to undertake inquiries
d) understanding the nature of scientific enterprise
e) understanding the relationship between science and society and
f) the development of personal worth.

Most of these are found in our educational objectives at various levels, and correspond with the nature and philosophy of science. But there are questions about the capacities and preparedness of teachers to achieve these objectives. There are other relevant concepts that need to be stressed to science students on which some philosphers have divergent views. For example, the philosopher Karl Popper hinted to *a world of objective knowledge*. Whereas the writings of Polanyi, on the one hand, and those of Lakatos and Kuhn, on the other, suggest the importance of commitment of an individual to a theory may be an influence on him, other than logic; that the criterion of acceptance of a scientific theory is that it be scrutinized and approved by the community of scientists (Driver 1983). Thus in the teaching of science therefore, teachers have to incorporate these sort of diverging views on objectivity of knowledge versus the criteria for assessing theories. This is achieved through recognition of pluralism in scientific theories. Students should be made to acknowledge the revolutionary nature of science: that progress in scientific knowledge is made only through changes in scientific theories. No theories are final and no scientist has the final word, or unchallengeable authority. Grounds or paradigms in science keep on shifting as we move toward unraveling the ultimate truth about matter and phenomena. Science teachers therefore should only teach consensus without turning into orthodoxy in class (Driver, 1983). Secondly, the students should be told, and this must be emphasized, that no longer are scientific observations seen as completely objective but are influenced in the least by the theoretical perspective of the observer. According to Popper, we are prisoners who have been caught in the framework of our theories (Driver, 183). The implication is that it will prepare the minds of pupils and students to accept the permanency of change in science as an inevitable necessity for scientific progress to be guaranteed, and not as a result of any imperfect nature of science, a fact accepted by consensus right from the outset. It shows that the door is always open for contributions and revisions to scientific knowledge to be made.Finally, given the discussion on the distinction between science and technology, it is also important that teachers not only distinguish between them conceptually but they should also defined them by relevant activities depicting and projecting each as explained by Bybee (1998).

Chapter Summary

Scientific method of inquiry is a series of steps taken by scientists during the course of an investigation. These steps make a particular investigation scientific or otherwise. We have emphasized the difference between inductive and deductive science with the inherent limitations of the latter. The value aspect of science in terms of the utopian attitude required of scientists have been enumerated and have been shown to be easy to uphold in all cases despite its different elements, in terms of method having been highlighted, Laws, Theory, Hypothesis, amongst others. Also two prominent learning theories of science have been presented which their complementarity in a way. Science has been shown to be only a human activity which tries to understand nature and that its conclusions will always be limited and inconclusive due to its very nature as reflected in its methodology by means of which it arrives at the truth about nature. The products of science were shown to be concepts that are well-defined within the scientific frame work or field in which they are used.

Review Questions

1. Distinguish between inductive and deductive science
2. List any two elements of the scientific method of inquiry and discuss them.
3. Distinguish between a scientific concept and theory
4. To what extent do scientists uphold the lofty ideals of objectivity, honesty and accurate reporting of data? Discuss.
5. Make a critic of at least five identified weaknesses of the scientific method.
6. Contest the futility of the notion of objectivity in science.

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And even should the cloud of barbarism and despotism again obscure the science and libraries of Europe, this country remains to preserve and restore light and liberty to them-**Thomas Jefferson**

Chapter 5

SCIENCE AND POLITICS

At the end of the chapter you should be able to:

1. identify and discuss three key areas of engagement of politics in science and *vis-versa*.
2. analyse the implications of the relationship between politics and science.
3. identify any other potential areas of the science-politics saga.
4. argue that politics is both dangerous and necessary for science on the issue of Weapons of Mass Destruction (WMDs).

5.0 Introduction

The role science plays in our everyday life cannot be overemphasized. Science has pervaded all aspects of our lives: social relationships to religious beliefs and practices have been affected. But from the various definitions of science presented earlier, it is clear that science is impersonal, has no feelings, biasless and independent search for pure truth or knowledge, irrespective of its subject matter or whatever prior notions the investigator or scientist may have. It was argued that this is almost impossible task to achieve as we now elaborate further. Increasing criticism of scientists and their activities in recent times has been coming from within and outside the scientific establishment, particularly the society. This is because scientific activity can no longer be regarded as the realm of scientists alone due to its impact on the people, environment and the very survival of man in general. Politicians no longer turn their faces the other way, lest they do so at their own peril. It has thus put science, indeed the scientists in a difficult position, between their desire to do true science freely and *objectively*, and the pressure to limit their activities for the sake of the values for which man exists. In 2009 six scientists were convicted-though later acquitted- on manslaughter charges based on the advice they gave during an earthquake which turned out to be disastrous as it led to the loss of hundreds of lives (Michael, 2004). This is an extreme demonstration of the legalistic aspect and a head-on collision with the political establishment. On the party politics side, six physicists were elected to the UK House of Commons from different parties out of at least 36 candidates with a physics background during general elections. This was also the case in the 2010-2015 parliament where five members of the House of Commons had degrees in physics (Michael, 2015), that is aside from scientists from other disciplines who might have been elected and demonstrate the respectability and acceptability of the role of scientists in the society. Is science being redefined, constrained or lossing its hitherto priviledged unlimited freedom as pointed out by the extreme example? What are the fundamental turning points that led to such change of attitude towards science on the part of the politicians and the public? Can science balance the two opposing forces of freedom of doing science and upholding of socio-cultural values without paying a price? Before these questions and more are answered, let us make clear what is meant by *politics* and *science* in this context. A very narrow definition of politics that suits this presentation is *the interrelationships between the people, groups, or organizations in a particular area of life, especially insofar as they involve power and influence or conflict or the use of tactics and strategy to gain power in a group or organization***.** In a nutshell, politics may be defined as a system of government that takes into cognizance the values and aspirations of the people. By politics and science, we mean the maneuvers, overt and covert, taken by governments, international bodies or legally recognized pressure groups to legislate or enforce the restriction of scientific investigation, dissemination of its results or a ban on or possession of certain of its products, including the restriction of scientific knowledge to a select few. The promotion of science in terms of providing a favourable environment is not part of this discourse, in any case it is dealt with in chap. 7. Being near a textbook, politics is a very sensitive, passionate and subjective issue, thus every attempt has been made to give a balanced view in the presentations that follow.

We begin by identifying key factors that incarcerated science in this imbroglio. In the early years of science, it dealt with the formulation of theories, accumulation of data and later, experiment, under Galileo Galilei, to discover the relationship between matter and phenomena.Thus, many do not feel affected by these activities of the scientists, including political leaders, but increasingly scientists began to run into problems with the establishment. For all practical purposes however, they were free. Politics and science are at two extremes of power (politics) and truth (science), respectively (Restivo and Vanderpool 1974); one therefore naturally expects a clash. What follows is a discussion of the prominent events that involved politics in science and vice-versa.

5.1 Science and Military Adventurism

Since the First World War, the image of science as an impersonal, biasless search for truth has become untenable. As nations fought each other, their scientists were under pressure to enlist their talents in the war efforts as a mark of their patriotism. Even the exchange of scientific information between warring countries was stifled, something that is vital for the progress of science, it was thus inevitable that the scientists had to contribute their quota in terms of creating lethal explosives and harmful gases (Lokoff, 1977) which were deployed indiscriminately during the war. Consequently, the war was described as *chemists' war*. The deployment of these weapons not only was a telling of how scientific knowledge could be used to wreak havoc on the enemy, but also underlined the power of science. The Second World War between 1939 and 1945 also marked another watershed which once and for all convinced even the doubting Thomases that there is power in science. At the instance of the re-known scientists, Albert Einstein, the U.S. President, Roosevelt charged a team of scientists with the so-called *Manhattan Project* which led to the creation of atomic bomb that was dropped on Japan to end the Second World War. The monstrous and unimaginable power of the bomb and the consequent destruction of life and landscape could be better imagined. Up until today the Japanese people are still suffering from the effects of that bomb explosion. From this time onward no one needed to be told, particularly, political leaders, that they need to harness science both for security purposes and as an offensive weapon. Consequently, the era of arms race majorly between the U.S. and the U.S.S.R.(now Russia), under the aegis of the *cold war*, led both to amass so much deadly weapons (conventional, biological and chemical) that everybody wondered whether the world would live on in the next second. Since then a new field of military science has developed. In America most scientists are involved in military research with Pentagon or some other defence agencies. This period was characterized by development of bballistic missiles, nuclear warheads, F16 Fighter planes, etc. Thus most countries spent billions of dollars in military research and became a source of revenue for countries largely in Europe and America. It is clear that from this point on the marriage between science and military and by extension, politics, can only be strengthened further to other fields.

5.2 Science and Medicine

If the activities of scientists with regard to war evoked horror and disgust, in medicine, it elicited wonder and moral or ethical questions and revulsions. Medical science has brought about dramatic improvement in public health, longer life span and reduction in mortality rate of children. Many diseases have disappeared and many more are on their way out. All these were possible through research and improved facilities. However, the most important and revolutionary discovery for biology and medical science is the discovery of the structure of the double Helix which led to the unraveling of the structure of DNA and eventually to *Genetic Engineering*. Let us consider the following cases which form the bases of our argument and can be addressed by medical science:

a) Test-tube babies: by taking the sperm of a man putting it into a test tube and carrying out some scientific manipulations in other to fertilize it and then returning it into the womb of a barren woman, she could become pregnant, without sexual intercourse, this is important for barren men and women who have no children, using a donor sperm. Critics argue that there is a moral, ethical, even religious question here.

b) Contraceptives and abortion: a woman may decide not to be pregnant by taking contraceptive pills or by terminating it through abortion. Abortion is a medical practice where death is induced in the fetus to save maternal life. It is a long tradition that includes embrayotomy for cephalopelvic disproportion to the removal of pregnancies implanted in sites other than the uterus, which is ectopic pregnancies (National Open University (NOUN, 2018). This seemingly humanistic and innocuous procedure was belaboured by women activists who demanded the right to have the number of children they want and at the time they want, thus distorting its traditional value. Human rights activists (antibortion groups, religious and civil society) say the unborn child has right to life and that it is tantamount to killing or murdering the child. They argue further that it is immoral and unethical. This is in spite of the uncertainties in terms of the woman's health, which might be incurred.

c) Genetic engineering: this generally refers to the future possibility of introducing new genetic information which is contained in molecules of DNA into human cells with the view to treating human genetic diseases. With genetic engineering, scientists can in principle decide the sex of a baby before being born; manipulate qualities such as intelligence, beauty, temperament, and even eliminate (potentially and in principle) totally some hereditary diseases and create other human qualities which are highly cherished (Eugenics), once the gene responsible is known. Are scientists trying to take the role of God? Critics query. Also using Genetic engineering, scientists can create a baby exactly its own copy! A technique known as cloning. Such experiments have been banned on humans. The technology is available and there are fears that some people might be doing secret experiements on it. In 1997 the sheep nicknamed *Dolly* was cloned from her mother, an actual replica of her was reproduced. Unfortunately, Dolly was put to death on 14th April, 2003, following protracted lung disease due to rapid early ageing; one of the fears expressed by the public, apart from other socio-cultural implications when practised on humans.This had raised many questions about human cloning. For example, marriage may not be necessary for both men and women in the future as one may as well ask for a *clone*! There is however, legislation on human cloning in many European countries. In fact a religious scientific organization in France, CLONEAID, had once claimed it cloned a baby successfully. Everyone waited for independent confirmation by scientists, but there was none.

d) Implants: the case of implants, example is kidney implants from animals, such as pigs, etc. for human bodies. Recently however, 3D printing when fully developed can produce human organs from replacement and is a revolutionary idea of the latest technology. All these medical manipulations and more, for which we cannot go into details, at the frontiers of medical science have stirred a lot of heated debates in the public about what and what should scientists not tamper with. Are scientists trying to play God? Are they trying to change the fundamental constitution of man thereby toy with his dignity?

These activities and more (such as the seemingly innocuous blood transfusion and its religious, social and safety issues and heart implant) stirred organized public outrage and debates from religious organizations, moralists, ethicists, etc., all of whom came out against scientists and their researches, calling for governments' intervention to legislate or ban scientists from carrying out certain experiments. Such experiments should be described as illegal, even punishable. Scientists would counter that science has to be freely practised without fetters, if there is to be any progress and genuine science. The politicians responded in different ways either by cutting budgets, or outright cessation of or imposition of a moratorium on some experiments. It should be noted that this agitation is more organized and strident in Europe and U.S. where scientific activities and awareness is greatest. For instance, anti-abortion groups forced the government to declare abortion as illegal in the U.S. Some have faulted contraceptives for the various side effects that may result. Scientists once again have found themselves in the whirlwind of a political storm in which they are required to compromise their freedom for scientific enquiry.Today politicians are the ones who set the tone and agenda for scientific research, rendering the scientists helpless, in addition to being funders of science.

5.3 Scientific Collaborations and Research

Another aspect of science and politics is evident in the following petition which was reported by Baum (2004) that 62 distinguished U.S. scientists, including Nobel Prize Winners, accused the administration of President George Bush of systematically misrepresenting and supressing scientific knowledge for political purposes. Notable points in the petition assert that when scientific knowledge had been found to be in conflict with its political goals, the administration had often manipulated the process through which science enters into its decisions. This is done by placing people who are professionally unqualified or had clear conflicts of interest in official posts and on scientific advisory committees by censoring and suppressing reports by the government's own scientists; and by sampling not seeking independent scientific advice. Furthermore, in advocating policies that are not scientifically sound, the administration had sometimes misrepresented scientific knowledge and misled the public about the implications of its policies.

Concomitant with this petition which is pregnant with political brouhaha, further report was released by the Union of Concerned Scientists (UCS) in which they made accusations to the effect that inconvenient scientific findings- and scientists themselves were being marginalized, suppressed or dismissed (Baum, 2004). Also for political and other reasons, collaborative research which has become necessary today due to the huge amount of money involved in some projects that have international relevance has resulted in problems of funding and disputes in the location of the laboratories. For example, Cartlidge (2004) reported of a disagreement that arose about the location of a collaborative science project on the International Thermonuclear Experimental Reactor (ITER) between Europeans and Japan which nearly jeopardized the $1bn U.S. Dollar project. The sites were in Japan and France; China and Russia backed the European bid, while U.S. and South Korea backed Japan. Even scientific publications were not exempted from politics as their circulation is being limited for political reasons. For example, the U.S. had embargoed publications of scientific material coming from countries it termed *rouges*, Iran, Cuba and Libya (Libya had been delisted due to its denuclearization) (Carroll, 2004). The U.S. has been used as a classical example of science and politics at its peak because a greater part of scientific and technological activities are localized there. However, it is also true about other European countries, though in various guises.

5.4 Science and the Practice of Agriculture

Another area that has been seething with political agitation for action against science is agriculture (more details in chap.10). The two most controversial areas are in crops, farming inputs and animals. Through genetic engineering scientists can modify the biological constitution (i.e.

genetic components) of a typical crop to improve its yield or quality. For example, the milk yield of cows can be increased quantitatively. Let us consider the capacity of the scientists in this regard. Scientists can:

a) produce *green* or *blue* tomatoes with ability to stay as long as three months without going bad (preservative).
b) produce crops that would normally yield in six months, to yield in one month or in all seasons or have ability to resist certain pests.
c) produce varieties of fertilizer to improve crop yields of different varieties.
d) produce pesticides and herbicides for proper and healthy growth of crops.
e) infect cows with some hormones so that they can improve and increase quality and quantity of milk respectively.

Much as these have a real positive aspect economically, they as well have negative antecedents, health wise. The sharpest criticism so far is in the case of modified crops, so-called genetically modified foods (GMFs). Most of Europe has banned the importation, planting or consumption of GMFs for safety concerns. One cannot, conclusively argue that eating them would not result in some serious unknown consequences for the human body in the future, environmentalists argue; or that planting them would not cause a mutation in the natural species, the ecosystem. A long-term study has to be undertaken to ascertain their effects on humans before they can be confidently accepted. In America, consumers and the government made it mandatory for all companies producing such foods to put a label indicating that it is GMF to give people a choice. However, the companies resisted. Southern Africa, particularly, Zambia and Zimbabwe faced serious case of drought in 2004 which caused starvation. However, the leaders of these countries would not accept GMFs for their people, for the same reasons expressed earlier. This is in spite of calls by the international community for it to do so. In Latin America, Bolivia also banned the use of GMFs in 2006. As for the fertilizer, apart from depleting the soil of nutrients and making barren after many years of use, the fear of the chemicals used in pesticides is more acute as they may persist. Many pesticides or herbicides have been found to be harmful to humans. When one eats such crops they could result in many unknown aliments. Particularly fearful, is that they may be carcinogens (cancer-causing agents). Activities of scientists in this field have once again encroached on the society and the politicians have acted by banning it or limiting the use of some chemicals, like DDT (Dichloro-Diphenyl-Trichloroethane), which has been recently reintroduced by the UN after its ban in America and some countries for many years based on environmental concerns. There had been also talk in Nigeria on introducing GMFs, particularly by some state governments as a means of boosting food production. How this will play out in view of the above controversies and fears remain to be seen.

5.5 Science and Environmentalism

The political minefield and the most engaging area of dispute in the science and politics saga is environmentalism. Environmentalists' agenda have been viewed by some as more political than genuine preservation of environment. In any case, they have worn seats in parliament in most of Europe. Environmentalists' agenda affect both science and non-science issues. For instance, they are against felling of trees, building a dam, construction of some facility, if it will harm the ecosystem, etc. We shall not be concerned with these; instead, we concentrate on activities that have scientific disposition as environmentalists are basically concerned with the physical environment (earth and air). One of the most controversial areas is in the reprocessing of spent nuclear fuels, which are to be transferred from one country to another; or dumping them into the sea. In 2006 there was a case of dumping of nuclear wastes in Cote d'Ivore which resulted in ten deaths and in which more than sixty victims were hospitalized, even pigs that ate rubbish from the dump were killed. It was the French that accepted to evacuate the waste dump. The scandal led to the resignation of the then Prime Minister, Charles Banny. Once again, science has stirred controversy by raising the question about nuclear activities and safety. The main environmentalists group is Green peace. This group made efforts to stop dumping of spent nuclear fuels or building new nuclear reactors due to the very dangerous nature of its radiation which persists over long periods of time. Both governments and scientists face enormous pressure from the group and so a lot of legislation has been enforced to guarantee safety of persons and the environment. Another source of concern for environmentalists is the industrial effluents released into gutter ways and rivers and emissions that contain highly harmful chemicals. The effluents released by industry can lead to contamination of drinking water and biodiversity which can be harmful to man. The gases that are released destroy the ozone layer; they can cause skin cancer, breathing problems, etc. Coalhouses, chemical factories, refrigerators, automobile, among others, normally produce these gases. They release so-called *chloroflorocarbons,* some of which heat the atmosphere, leading to Global Warming. These have led to legislation on the use of lead in cars.Thus energy sources that are environmentally friendly have been encouraged as alternatives. Many industrialized countries, led by the U.S. are the main source of air pollution. The U.S. has pulled out of agreements limiting the rate of emission of these gases. Infact many governments have been lukewarm on this.

5.6 Climate Change Debate

An issue that is closely related to environmentalism is Global Warming, or in current terminology, Climate Change, due to its multidimensional nature. Because of the various emissions from automobiles and industries in particular, in the form of carbon dioxide, sulphur dioxide, among others, the worldis believed to have been warming over the last one hundred years or so. Strong debates about the scientific grounds of such results has been taking place, much of which is politically and economically motivated in the view of experts. Attempts to ratify agreements among nations which will cut down to some acceptable emission rates have met strong resistance from industrialized countries. President Donald Trump has refused to ratify the last agreement reached in France during the summit on environment during the Obama administration.The U.S. is more strident in its refusal to adopt the agreement and has contested the scientific bases of the evidence of warming. The most important causes identified as responsible for warming the earth and atmosphere are carbon dioxide, CO_2 (from fossil fuels), Nitrogen dioxide and CFCs (*ChloroFloroCarbons*). Based on different computer models of calculation of these effects, different rates of warming have been computed: Nilsson (1992) and Houghton *et al.* (1990) say the global mean air temperature had increased over the last 100 years by 0.3-0.6^{o}C, whereas Bernade (1992) gave a much shorter range of 0.5-0.6^{o}C. Everyone recognizes the need for an international agreement for limiting emissions, however, the most important issue in trying to negotiate global climate convention is how responsibility is to be shared between developing and developed countries, given that industrialized countries are responsible for most emissions, particularly, fossil emissions and that developing countries are responsible for deforestation which contributes to green house effect. One such series of conferences took place in Kenya in 2006. Developing countries argued that the developed ones are responsible for about 97% of emissions and therefore should take the financial burden of curbing this trend. The conference predicted dire consequences for Africa in terms of increased flooding and hunger in the near future in Africa if action is not taken. For instance, at (www.nationalcenter.org), Randall and Randall (2001) refuted virtually all accusations against the U.S. and the scientific basis of the Global Warming saga. The authors denied that President George Bush killed the 1997 Kyoto Protocol, an agreement on ways of controlling Global warming and argued that it will lead to serious economic consequences for the U.S. such as loss of millions of jobs; that the burden of the agreements is unfair compared to that of China, India and Brazil, for instance. They deny that there is evidence of man-induced Global Warming, faulting the computer models. We thus have a classical case on global warming where scientists are against scientists who have allied themselves with the politicians. Scientific results are jettisoned in favour of a more politically convenient or acceptable explanation. To effectively tackle global warming the present existing technology on almost everything has to be changed in favour of so-called green technology, which is environmentally friendlier. The cost of which is daunting, so argued President George Bush. It will be easier to work within the framework of existing technology and set some targets of cutting emissions that will be favourable to all parties. This shows that scientific knowledge and activity are deeply enmeshed in politics and attempt to argue otherwise would be untenable; science and politics are intricately related (Dubridge, 1973). Scientific knowledge has become more politicized, contestable and less autonomous. According to Dubridge (1973) we all believe in open science without without which we have no viable scientific enterprise at all. But this very openness carries with it the risk that the very knowledge which we had been produced and published may be used by others for purposes for which we disapprove.

Finally, consider the following controversial issues for more insight and conclusive inference:

a) since the mid 80's the U.S. banned the sale of weapons or their technology to Iran, classifying her as *rouge* country with subsequent embargo on various U.S. companies and Europeans on trade relations with Iran due to her nuclear programme since 2006, which the US alleged that it is towards developing nuclear weapons whereas Iran claimed on the contrary that it is for power generation and the subsequent standoff. The U.S. and its allies in the Security Council are suspicious that Iran may ultimately be building nuclear weapons instead. Economic and banking sanctions were slapped on Iran, in conjunction with the encouragement of U. S. allies to do the same.This seemed to be biting, even as Iran remained adamant.That was after Iran refused the incentives proposed as pay back for cessation of nuclear activity and the stoppage of Uranium enrichment. This was further compounded by its test-launching of three missiles which it claimed could travel 2000 km. Russia and China, permanent members of the Security Council are against sanctions and argued for dialoque. Eventually, an agreement was reached (2015) in the P-5 plus one group (Britain, China, France, Russia, US and Germany) talks which addressed most of the concerns and fears of the US and its allies but included a strict monitoring regime; this is in return for the defreezing of billions of US Dollars of the Iranian government in the US. However, President Trump has questioned this agreement which was concluded by the Obama administration and promised to revisit it.

b) in late 90's the U.S. through the U.N. imposed an embargo on North Korea to freeze its nuclear programme following allegations that they were producing Nuclear Weapons. In 2006 it test-launched its Intercontinental Ballistic Missiles which it claimed could reach the U.S., an action that prompted a lot of condemnation from the U.S., South Korea and Japan. However, the 2006 testing of a so-called nuclear device by the DPRK (Democratic People Republic of Korea) attracted the same condemnation but with strident calls for action, among other *provocative tests*, in the words of the U.S. and its allies. These tests angered even the DPRK traditional allies, Russia and China. The UN Security Council was unanimous in imposing limited sanctions without delay. The so-called six-party talks have now resumed. It was earlier suspended following North Korea's withdrawal from the negotiations aimed at resolving the crises and its subsequent breakdown due to several test-launching of Intercontinental Ballistic missiles which culminating in the Intercontinental Ballistic (ICBM) missile which has the capacity to reach the United States of America; the subsequent threat to attack Quam and the acclaimed Hydrogen bomb test, which is the sixth nuclear test in ten years. Eventually, president Trump and the North Korean president Kim met at a summit in Singapore in which the issue of nuclear threat was diffused.

c) similarly, in 1998, the U.S., sanctioned Pakistan and India for testing nuclear weapons, even though embargo was lifted after September 11 attack.

d) Iraq has been in great turmoil following U.S.'s and allies' 2003 invasion on grounds that it possessed nuclear weapons and other Weapons of Mass Destruction (WMD). Even, though America and its allies emerged victorious, militarily, the alleged WMDs were never found, even though Saddam Hussein was toppled, captured and hanged.

All these portray the entanglement of politics and science in the society and are just a tip of the iceberg. The question is why are all these various actions taken, both covert and overt, to the extent of war being prosecuted in order to discourage the proliferation of scientific knowledge? Lots of political manoeuvres and strategic considerations are involved. Analysts have however, tried to portray some of the reasons:

a) some countries do not want others to have specific scientific and technological knowledge or know-how which are perceived to be of strategic importance, e.g., nuclear power and other unconventional warfare apparatus.
b) some are afraid of others having such weapons or the technological know-how; they want to remain the only ones that have them, or at least limit them to their allies; they feel insecure.
c) Others want to ensure their military, political and economic stability, superiority and viability.
d) the need to maintain balance of power, militarily in specific subregions and other considerations.

Aside from these, there are other restrictions in the form of treaties and international laws that limit countries that do not have some weapons technology to remain at status-quo, while those who have are not allowed to proliferate them, for example, the U.N. Nuclear-Non Proliferation Treaties–NPT, classified technologies, etc.; and the ban on some experiments. These arguments are by no means exhaustive, because the reasons why some countries or groups of countries do not want others to have scientific or technological know-hows are not often stated in unequivocal terms.The formal position is that it is for international peace and security, hence there is the nagging suspicion that it is political. For the international community, the reasons are much clearer, security of the world, protection of human dignity, values and the environment, that is, through bodies like the UN and other international protocols.

Chapter Summary

Politics has been defined within the context of this discussion as it is related to science. The activities of scientists can no longer be left to them due to the various uses to which the results of science can be put to. The activities of scientists in the areas of military, environmental degradation, agriculture, genetic engineering, amongst others, have brought the scientists under sharp focus and resulted in strong criticisms of their work, and even resentments in some quarters. International treaties such as NPT, under the auspices of the U.N. and other multilateral bodies have all been evoked in order to control and monitor scientific activities to ensure that the type of science being carried out is within acceptable and agreed standards and principles. Particularly, the issues of nuclear weapons and genetic engineering generated so much heat that in the case of the former, war was prosecuted with Iraq as the classical case in the science-politics saga. Neither the objectivity of science nor its freedom is tenable and can for certain not be said to be apolitical.

Review Questions

1. Discuss briefly the evolution of science and technology in warfare.
2. Enumerate and discuss any two important issues in the field of medical science that have caused controversy due to their social implications.
3. Discuss any two key areas of controversy in the field of agriculture due to the science involved.
4. Analyse the relationship between environmentalism, science and politics.
5. Identify and discuss any three reasons why politics should be good for science.

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As to the supposed 'conflict'...between science and religion, no such conflict should exist because each subject has a legitimate magisterium, or domain of teaching authority—and these magisteria do not overla-**Stephen Jay Gould**

Chapter 6

THE EDUCATION SYSTEM AND SCIENCE

At the end of this chapter you should be able to:

1. narrate briefly the important milestones in the history of education in Nigeria.
2. discuss the pattern of spending on education in Nigeria.
3. identify and discuss three problems of education in Nigeria.
4. enumerate the national objectives of education in Nigeria and how they are linked with science education.

6.0 Introduction

In order to properly contextualize the Nigerian policy on science and technology, it is a necessary prelude to appreciate some pertinent indices that define education within which framework the science objective was established. The happenings in science cannot be divorced from the overall malaise that has bedeviled the education system. Fundamental problems, such as relevance and functionality of the educational system as a whole must be seen to affect implementation of the science policy effectively. The issue of compatibility or balance between what is taught in our universities or schools and the requirements of the labour market and strength of economy must be taken into consideration. The debate should not be about whether or not our curriculum is appropriate, rather, whether there is the will to realize the set objectives. Also, the basic question is about Nigeria's long term objectives, what it aims at achieving in practical terms in the next 20–30 years, an issue that has always been vague and illusive. Education has been described as a means of training the entire person to enable him not only to be able to read, write and calculate or to be proficient in a given job, but also to enable him fit himself effectively in a society (Ogbulafor, 1992). Most graduates in Nigeria have a problem fitting into the economy and apparently everybody relies on government jobs and government-dominated economy for which their training fails to reconcile with the labour market. Avowedly, the intention of government is to achieve its overall national philosophy and objectives through its educational policy. Whether this policy is formulated such that it is reliable, practicable and sustainable is an academic matter. Public schools exist to fulfill national priorities, so we could not have been wrong. The national goals of Nigeria (NPE, 2013) include:

a) free and democratic society
b) united, strong and self-reliant nation.
c) just and equalitarian society.
d) a great and dynamic and
e) a land of bright opportunities for all citizens.

These lofty declarations are laudable. However, whether we have achieved them and to what extent is another matter. Our present democratic system should have paved the way for more reform towards setting educational objectives in consonance with realizable and sustainable objectives with the appropriate will expended. Democracy is intrinsically related to education and benefits immensely from it, at least from the American experience. Science itself is democratic since every issue has to be openly discussed and debated before it is accepted. John Dewey, a modern philosopher has identified this symbiotic relationship between education and democracy when he observed that through education, society could formulate its own progress, organize its own means and resources and thus shape itself with definiteness and economy in the direction it wishes to move (Yusuf, 1996).

6.1 Funding of Education

The education sector at all levels has for a long time been singing the same tune of poor funding. As a fundamental problem, this has had repercussions manifested in various forms, including poor remuneration of teachers; lack of teaching and instructional facilities; politically-motivated expansion and establishment of schools; crowded and dilapidated classrooms with roofs blown of, among other inadequacies (Olarewaju and Shuiab, 2001). These will be discussed in-depth at the various educational hierarchies later. The overall budgetary allocation to the education sector has in general been increasing, but the practical results have not been commensurate. Moreover, Nigeria's spending compares favourably with those of other developing countries but the results are poorer which points to some enigmatic phenomenon. It has been reported that 3.47% of the total Federal budget in 1993 was allocated to education. In 1994, it increased to 9.3% (Olarewaju and Shuiab, 2001). Expenditure on education in recent times indicate an increasing trend close to 200 billion in 2006 to about 300 billion by 2010 (http://nigeria.usembassy.gov/nigeriafactsheet.html). The issue of funding of universities and the education sector in general has generated a lot of heat within the academic circles and often degenerated into prolonged strike action by members of Academic Staff Union of Universities (ASUU). ASUU argued that since 1999 not more that 15% of total budget was allocated to education and that for the year 2003 it was only 1.8% (Oyekanmi, 2003). That is, between 1993 and 2003 funding increased from 3.4-15%, an increase of more than 300% over a decade. With other sectors competing for attention within limited funds and various political permutations and pressure at work, it is not easy to maintain a steady rise in budgetary allocation considering the fact that government is the principal funder of education though this is inexcusable when compared to other African countries spending. The need to increase spending commensurably with improved revenues in other sectors cannot be overemphasized. Education is a cost intensive venture in any country. Regional comparison of government expenditure on education show Nigeria had a GDP share of 2.9% in comparison to East Asia's 4.8% and Sub-SaharanAfrica's 3.1% (Shuaib and Olarewaju, 2001). This should be contexualised with Nigeria's 49% illiteracy (recent figures show over 65% of the population are illiterates) and East Asia's 24% during the period. Nigeria's expenditure based on GDP is as good as those of the whole Sub-Saharan Africa, Middle East and Latin America; far better than that of South Africa and short of East Asia's in the period under review. However, comparison within the African subregion in the period 2012-2016 shows that Nigeria's budgetary allocation is far behind those of Benin Republic, Bostwana, Kenya, South Africa and Tanzania. That is, far below the UNESCO benchmark of 26% budgetary allocation to education. During this period Nigeria's average budgetary allocation to the sector averaged 9.3% when compared with the range 22-27, 27-28 (except 2013-11%), 21-26, 18-19 and 16-17%, respectively, for these countries (Nwachukwu, 2016). Even in the earlier period of 2008-2011 it was in the range 6-13% of GDP much below the UNESCO threshold which generally exceeded by Bostwana and Bebin Republic and to some extent Kenya. The regional performance is certainly not impressive and no explanations will surfice. In spite of these it is evident that the practical benefits derived by these countries (Africa and Asia), assuming the same spending level, are more glaring. Shuaib and Olarewaju (2001) provided illiteracy figures which showed that the performance is encouraging, almost at par with the best. Figures released by the literacy commission of Nigeria indicate that there were 50 million illiterates (Mohammed, 2003) by 2003. Similarly, Shuaib and Olarewaju (2001) showed that Nigeria had the lowest enrolment figures at the secondary and tertiary levels (20 and 4%, respectively), figures that must be reckoned within the context of Nigeria's population. Nigeria has the highest pupil to teacher ratio among these countries. All these factors have overall influence on the quality of education obtained. Considering Nigeria's superior economic resource which should balance the population disadvantage, it has been argued that we ought to spend more or do better than what is presently the case. A brief survey of the historical development of our education system will answer some of the current issues and hint to what should be expected and the action to be taken in the future with respect to science education.

6.2 The Traditional Education System

Traditional education has been criticized on various fronts based on narrow curriculum, meagre resources, shallow learning experiences and the total set-up, among others. Nevertheless, it was able to cater for the immediate employment of the individual as the child is prepared into jobs such as fishing, pottery, trading, hunting, etc. Traditional education deals with immediate society in an integral motley of father, mother and teacher, amongst others. The aim of education is to fit the individual perfectly into the society which can be said to have been achieved. The economy, the needs and aspirations of the society are in total harmony and the issue of relevance and functionality are easily attained with the issue of unemployment or underemployment was non existent.

6.3 The Early Western Education

Western education was introduced in Nigeria in the Badagry, Lagos and subsequently expanded to all parts of the federation. It is like the traditional type but has been criticized on various fronts and from different quarters, not least of which is its Christian content. It emphasized reading and writing to produce teachers of the Bible, amongst other ecclesiastical activities. Even so, their products were generally assimilated into the local economy.Until the felt need for clerical assistants arose, for example, the colonial masters were satisfied with the status quo. It was the criticisms of colonial education that led to introduction of reforms albeit reluctantly and to the introduction of vocational subjects, such as carpentry, building, agriculture, etc. With all its inconsistencies, there was a good degree of accommodation in the economy and the social conditions required people of such training. The education fulfilled the criteria of relevance and functionality to social reality as it existed then. There were more demands than were actually met. Looking back in retrospect from purely utilitarian point of view, it was relevant and functional education.

6.4 The Post-Independence Era

One of the Landmark achievements by the nationalists and the few educated elites of colonial era immediately after independence was curriculum conference of 1969. All the relevant stakeholders in the education enterprise, both within and outside the country participated in the fashioning out of a curriculum which reflected our national aspirations; a thing the colonial masters would not undertake. This document would later lead to the formulation of the philosophy of education in Nigeria and the means of achieving the national goals of education at all levels. Experts have wondered whether the enabling environment and a clear objective in terms of vision for the nation were subsequently pursed in its implementation, an action that eventually led to the publication of the National Policy on Education (NPE, 1981) which had been revised severally to the current version NPE (2013). The interest now is in the clause in the educational goals which emphasized the acquisition of appropriate skills and development of mental, physical and social abilities and competencies as equipment for the individual to live in and contribute to the development of his society; the document further noted the acquisition of competencies necessary for self-reliance. These two clauses were definitely the ideas that reflect the use of science and technology for national development but it is debatable the degree to which these have been pursued to a successful level. It is only science and technology that can bring about the realization of these objectives. With hindsight, one can say that those who prepared the document had laid the basis for our future development in the exploration of our scientific manpower or their development. The question of unemployment and underemployment in the country is now pervasive and has reached an alarming proportion. A research conducted by the National Manpower Board sometimes in the '90s found that fresh graduates were less favoured by the labour markets compared to professionals. The labour market favours those who already have jobs. Experts have argued that majority of students who completed school end up with little relevant knowledge to enable them fit into the traditional society or the modern sector. This further raises the issue of relevance and functionality of education. Irrespective of whether a student studied science or arts, what job is a secondary school graduate in a position to undertake? Does the education system have any skill to prepare the student for survival at the appropriate level of education? Must every child that goes to school have to complete education up to the university level before he or she can be in a position to eke out a living? Later, it would be shown that even university graduates cannot rely on themselves. What does a primary school graduate who cannot proceed with education have to offer? These are the kinds of questions the government should start asking so that we do not just displace children from their parents only to turn them into unproductive individuals in an attempt to provide basic education to all, which nevertheless is necessary. The curriculum does not prepare the students for the local living nor does the opportunity to fit them in the modern sector abound for the multitudes. A detailed picture of recent trends in primary education funding and management have been analysed by Ahmadu (2000). Industrial and economic activities do not correspond to products of education. One of the philosophies of Nigerian education is the realization of the value of science and technology for self-reliance and national development. Thus government biased admissions into tertiary levels in favour of science, without a proper study of the long time implications as currently obvious. The dynamics of the pursuit of these objectives, pari passu with proportionate economic expansion and requisite manpower requirements were overlooked. This resulted in a situation where most science and engineering graduates are in teaching and other areas where their qualifications are not needed and relevant to economic or industrial processes. Moreover, some science jobs have be taken over by non scientists due to *who you know* syndrome. Mass production of science graduates would not produce the required development without appropriate fine-tuning to sensitive economic and infrastructural indices. Nigeria has engineers teaching in primary and secondary schools instead of being in industries, companies or research institutions, that is, where they are lucky to get the jobs. Ordinarily, there would not have been problem but for the fact that we have not yet attained the required number of scientists and engineers appropriate for a developing country. This is no doubt a wastage and gross underutilization of our scientific manpower. The very nature of our educational training, ensures it is not one of independence or self-reliance but for dependency, as every one looks forward to getting government jobs. Educationists have argued that we are pursuing an educational system which makes us more dependent and on being employed as workers or job seekers.

We need creativity to become less and less dependent on government jobs. This delicate issue has always been neglected and the various policies implemented in this direction have so far been inimical to a healthy and harmonious relationship that will elicit the necessary results. Poor instructional modes and lack of harmony of the educational system with social reality have been a source of grave concern to parents. Parents realize the importance of education in principle but at the same time know its problems in terms of fitting the individual into the society. Thus in spite of all these failings, parents and students alike are still opting in their multitudes for higher education because of the opportunity and prestige it confers on the individual. For proper planning, the regulatory body for students' admission into universities (Joint Admissions and Matriculations Board (JAMB)), now transformed into Unified Tertiary Matriculation Examination (UTME), is entrusted with the job. The body revealed that less than 25% of students that seek admissions into higher institutions are offered a place. In 2006, the former JAMB Registrar, Professor Salim, revealed that out of about one million who wrote qualifying examinations only 150,000 got admission. The ability of government to expand educational facilities at all levels is related to its economic buoyancy and is a worrisome issue, with chain effects through all the levels of education. Thus, even the 25% is too much trouble to cope with. Moreover, government has to balance this with its resolve to provide equal educational opportunities to all its citizens in the face of competing political interests from educationally advantaged states who oppose streamlining the number of varsities for effective running of the institutions. Parents have thus resorted to seeking admissions for their children into foreign universities as an alternative, an issue costing the nation billions of Naira and US dollars.

According to Dr. Babalakin, chairman of the committee of pro-chancellors, Nigeria was spending about N160 billion annually in Ghana to educate about 75, 000 Nigerians schooling there; whereas the budget for 2011 was less than N160 billion, that is, Nigerians spend more on Ghanian universities than the Federal Government spent on education in 2011(http://www.punchng.com/opinion/nigeria-which-way-forward-in-science-and-technology-1). Similarly, former CBN (Central Bank of Nigeria) governor, Prof. Charles Soludo revealed that there were 71, 000 Nigerian students in Ghana paying about US$1 billion annually as tuition fees (http://www.punchng.com/feature/2012-in-view/education-will-fare-worse). Of course, this is not taking into account those in Asia, Europe and America, amongst others. Recent trends showed admission placement increased from almost 100,000 in 2006 to 250,000 by 2010; whereas applications denied admissions increased from about 1,300,000 to 1,500,000 in the same period (http://nigeria.usembassy.gov/nigeriafactsheet.html). Recent establishment of additional eleven universities, apart from many private ones between

2011 and 2012 may lead to an increase in these problems though ease the admission saga. Nigeria is the most populous black nation with almost 168 million people, 30 million of whom are students. The literacy rate is estimated at 61% (http://nigeria.usembassy.gov/nigeriafactsheet.html). There are 36 Federal universities, 37 state universities and 45 private universities accredited by the NUC (National Universities Commission). The figures have since increased as will be seen later. Average enrolment into Nigerian universities was 37.6% for women compared to 62.4% for men in the years 2008-2010. Over 60% of academic staff in Nigerian univesities are in the category of lecturer I and below due to intra- and inter-brain drain. In 2012, 8.42% of the budget was allocated to education and was the largest second priority in the budget (http://nigeria.usembassy.gov/nigeriafactsheet.html). Proliferation of private universities and to a lesser extent Colleges of Education and polytechnics have therefore been pursued with vigour. The expansion of the economy is out of step with educational relevance and output. This had been noted as far as the '70s when the National Development Plan (1975–80) observed that there was a mis-match between the output of the higher education system and the needs of the labour market.There is urgent need for re-orientation in order for schools to know what knowledge and skills to impart that will satisfy the demands for a rapidly changing economic and industrial market place like that of Nigeria.

Since the mid-1980s, economic recession began to set in, in terms of low industrial output, goods and services and in real income due to fluctuating fuel prices in world market and the dependence on mono-economy. The price of crude oil has now reached its lowest point in recent history though has picked up again. Recent downturn of the economy and its subsequent recovery as revealed by the National Bureau of Statics (NBS, 2017) reveals in its December, 2017 report about the state of the economy has been reviewed briefly below.

Nigeria's economic growth began to decline since Q2 (second quarter, etc.) 2014 and eventually culminated in an economic recession in Q2 2016. It became technically over by Q2 2017. The total number of people in full-time employment (at least 40 hours/week) declined from 52.7 million in Q2 2017 to 51.1 million in Q3 2017.

Unemployment rate increased from 14.2% in Q4 2016 to 16.2% in Q2 2017 and 18.8% in Q3 2017. The number of unemployed within the labour force or underemployed increased from 13.6 million and 17.7 million, respectively, in Q2 2017 to 15.9 million and 18.0 million in Q3 2017, respectively. The total unemployment and underemployment figures combined within the period increased from 37.2% in the previous quarter to 40.0% in Q3 2017.

In Q3 2017, 21.2% of women within the labour force (that is, 16-64 years of age) who are willing, able and actively seeking work were unemployed compared with 16.5% of men within the same period. In the same quarter, 16.4% of rural and 23.4% of urban dwellers within the labour force was unemployed. Unemployment increased at a slightly faster rate for urban dwellers than for its rural counterparts. Also, underemployment was predominant in the rural areas (26.9% of rural residents within the labour force in Q3 2017) are underemployed (that is those engaged in work for less than 20 hours a week) compared to 9% urban residents within the same period. The unemployment rate for young people stood at 33.1% for ages 15-24 and 20.2 % for those aged 25-34 during the period.

Many industries inherited during the pre-independence and post-independence periods have now collapsed; refineries are not working at their full capacities or have been shut down due partly to vandalisation caused by the Niger Delta crisis, lack of maintenance, among other reasons. These are billed to be sold or privatized under the Bureau for Public Enterprises (BPE). The railways have collapsed, although there is renewed activity due to the face lift it recently received. PHCN (Power Holding Company of Nigeria) has been commercialized and privatised to independent power generators, distributors and Transmission companies. Ajaokuta Steel Company, despite gulping billions of dollars and the concession given to Global Infrastructure Nigeria Limited (GINL), among others, is still not working. Most of these problems were cummulative and illustrate the lack of endogenous scientific and technical manpower. Majority of the products of our educational system after graduation depend on government for jobs, except some categories of the medical profession. Most doctors have to run their private clinics side by side with their government jobs with all the conflict of interest being borne by patients. Recent pronouncement by the Federal government against private practice by doctors is yet to be enforced. These problems can be traced in the case of science and engineering students, to the virtually theoretical manner in which these courses are taught as a result of lack of equipment and other relevant teaching facilities. Even when available, they may never be sufficient to induce the type of self-reliance that is needed as most of the practical experiments carried out are more academic than having any physical and practical correlation with what students meet in their immediate environment and industry. Programmes such as the UPE (Universal Primary Education) and the UBE (Universal Basic Education) have no doubt helped a great multitude of children who would otherwise never have had the opportunity to go to school to enroll. Arguing based on expansion of educational opportunities it is certainly a good thing, though quality is lost in the process. This avalanche of pupil enrolment led to the dislocation of children from their traditional home settings as the present system seem to convert them into semi-skilled who can neither fit into their traditional set up nor the modern sector afterwards.

The certificate syndrome dethroned meritocracy and helped in building an army of jobless school leavers because competence, skill, hard work and ability which are acquired outside the theoretical classrooms are looked down upon. Some have even argued that the training received by the ordinary roadside mechanic, electronic repairer, amongst others, are more relevant and beneficial to the society based on a utilitarian perspective, than the theoretical expositions of the academic graduate. Science and technology graduates are always at disadvantage at the jobs they get, as one with lesser qualifications working in some *juicy* government department may be doing much better. Similarly, most published advertisement for jobs in national dailies do not provide for science and engineering graduates. They are mostly in humanities, finance and to some extent, health industries. Even mobile phone industries, like MTN, GLO, and their promotional activities exclude science graduates and students. These and many more have demoralized prospective science graduates from choosing the subject, and those already in it have no appetite for any serious research.

Government has begun to appreciate the problem and several remedial measures have been taken but they are not adequate and far-reaching. There is need to redirect the educational objectives toward more relevant and functional curriculum which should involve a diagnosis of all the requisite parameters affecting the realization of the objectives. Although many of the remedial programmes taken so far are commendable, they are often short-term measures taken to solve long-term issues. Many novel programmes were evolved by the Federal Government such as the National Poverty Eradication Programme (NAPEP), extending the powers of erstwhile NACB (Nigerian Agricultural and Co-operative Bank) to become Nigerian Agricultural Rural and Co-operative Development Bank (NACRDB-which has subsequently metamorphorsed into the Bank of Agriculture (BOI)), amongst others, all in an effort to eliminate poverty and foster self-reliance. These efforts eventually culminated in the N-Power project currently in voque in the effort aimed at boosting youth unemployment.

The Millennium Development Goals (MDGs) project which was in collaboration with the UN was a laudable effort in this regard. Many have benefited, especially primary school teachers, among others. State governments also evolved their apprenticeship programmes for school leavers in which they are supplied with relevant tools after training, but these come and go too due to various lapses. For example, the Federal Government once gave a directive to banks to give loans to graduates who are willing to go into self-employment (Ajayi, 1992) but the programme had to be termminated because as it was characterised by half-hazard arrangements that led to funds being embezzled or the beneficiaries not paying back their loans. Establishing these programmes instead of integrating them into the school system which are better prepared to undertake such functions could be wasteful and unnecessary. Polytechnics, universities of technology and technical schools that are meant and prepared (statutorily) for such functions are starved of funds, equipment and facilities to run the programmes successfully. The lack of co-operation between education and industry is also worrisome.

Industry to a large extent determines the type of labour needed so that graduates at whatever level could be trained in great proportions to meet the requisite manpower needs of such industries, whereas some should be trained to fit into traditional needs bringing with them new ideas to contribute to the development of the society. Agriculture is the ideal, but the problem of farming inputs and finance has crippled this sector (see chap. 10). Under the current Buhari administration, is at the frontiers of sectoral targets and has been designated as one of the strategies for diversifying the economy. Its contribution to GDP has risen phenomenally despite because of its remodeling as a business. It has thus lead to massive job creation and saved the country foreign exchange. There has enormous boost particularly in rice production, amongst others. The relationship between our labour market and economy is a delicate one and as such African governments must balance them by taking statistics of the various types of industries available, small, large scale, SMEs (Small and Medium Enterprises), the type of manpower needed and creation of job opportunities to enable graduates at all levels fit.

Happily reforms in the education sector are now taking these into cognizance and discussions to that effect, such as enterprenureship studies in almost all subjects from secondary schools to universities have begun, but the ugly trend is that it is heavily biased towards theory and has not been domesticated or contextualized to suit our local situations. Concerted efforts should be made to square the educational output, expansion and establishment of relevant industries to reflect the manpower output. Any prospective industry should, in collaboration with our universities, produce graduates proportionately. More than a hundred-thousand NYSC (National Youth Service Corps) members graduate each year. When these are added to graduates from Polytechnics, Colleges of Education and primary and secondary schools students and pupils, most of whom will not proceed with their education, and compared with the rate of expansion of industries, it would be realized that there is mismatch and a serious crises is looming, the symptoms of which has already emerged. The education system is at an explosive state.

6.5 Education and the Labour Market

The importance in the aims and attainable goals of education, not least of which are Dewey's and Cookey's definitions emphasized earlier, are the fact that education must be able to adapt and contribute to development of the economy. An educated person is expected by his training to be equipped with skills, aptitudes and knowledge to prepare him for a living. The educational philosophy emphasized the need for self-reliance of graduates. However, there are scores of graduates at all levels of our educational system who cannot find a place to fit in the labour market and their numbers have increased over the years, a situation which has now reached a crisis point with youth unemployment. There is problem with the nature of education being given to children which as a matter of urgency must be addressed. Experience has shown that nations structure their educational system to conform to their economic dynamics and socio-cultural reality. This minimizes the consequences of the imbalance between the two which ultimately leads to grave socio-political upheavels and consequences for society. Our educational goals through instructional objectives in the classroom reflect the needs and aspirations of the society and are sensitive to economic dynamics, encapsulating future developments. If there is mismatch between educational output, economy, instructional objectives and social aspiration and opportunity, unemployment and underemployment become the order of the day. Public schools exist to fulfill national priorities. The education system is made up of hierarchies at all levels with their objectives in consonance with one or more national objectives. In Nigeria the problem of relevance and functionality in the present manner of dispensing education has elicited the need for reorientation and restructuring of the whole education superstructure. The question of dropouts and unemployment, particularly those of university graduates disillusions those willing to undertake educational careers and parents. Educationists have blamed curriculum, politics, and commitment of government, among others. However, government has also taken steps to cushion these aberrations which are not good enough and time is running out.

Chapter Summary

A review of the history of education in Nigeria was presented and its inherent problems and challenges portrayed in terms of employability of its products and functionality of the system, squared with the overall aspirations of the people and economic advancement of the nation. Also, the inherent aberrations in our educational system and the labour market have been enumerated and how they have led to mass of unemployed youths. Nigeria spends comparable amount of funds with other African and Asian countries but has less to show for it. Our national objectives seem to be incapable of being realized through the current educational system because it is characterized by problems ranging from lack of funds, poor motivation for teachers, lack of instructional materials and demoralization, amongst others. These discrepancies have to be harmonized and smoothened out if the national objectives and goals are to be realized. The problems besetting the educational sector have immense implications on the overall implementation of science and technology policy, the practice of science and the training of graduates with relevant skills to fit and be relevant to the labour market. The implementation of science policy is within and not outside the national goals of education in general and therefore understanding the educational structure and appreciating its problems is a necessary prelude to an appreciation of the type of science expected in our classrooms.

Review Questions

1. Discuss any two reason why spending on education has not been commensurate with results obtained in Nigeria.
2. Identify any four major problems in the products of our educational system and the labour market and how to reconcile them.
3. Identify and discuss briefly any two significant factors in the evolution of Nigerian educational system and its socio-economic implications.
4. Discuss briefly any two measures taken by the Federal government to address the problems of unemployment of school leavers in Nigeria.
5. Discuss the overall impact of the evolution of the education system in Nigeria to its practice of science in schools.

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Being perpetually charmed by his...his geometry, he neglected to eat and drink and took no care of his person...he was often carried by force to the baths, and when there he would trace geometrical figures in the ashes of the fire...being in a state of great ecstasy and divinely possessed by his science-**Plutarch**

Chapter 7

NATIONAL SCIENCE POLICIES AND SCIENTIFIC DEVELOPMENT

At the end of the chapter you should be able to:

1. identify and discuss any two significant issues in the national science policies of developed countries.
2. compare, contrast and discuss developing countries' science polices with those of the developed ones with respect to funding and infrastructure in particular.
3. identify and discuss any three failings of the Nigerian science policy and how abberations in its implementation affect science education at a particular level of education.
4. enumerate and discuss any three characteristic features of women in science and technology.

7.0 Introduction

The best way to underline the importance or indispensability of science in our modern lives is to ask the rhetorical question: what would a world without science look like? Science has become the magic code for transforming our environment and for economic growth and recovery. In order to reap the benefits of science, its practice must be coordinated through a chain of well-articulated and formulated policies, together with relevant materials, human resources and institutions. The scientific enterprise flourishes best where institutions with trained and motivated personnel are devoted to it. Any such policy deliberately formulated not only to promote science and technology but articulated with the overall national goals and objectives form a National Science Policy. There is no consensus on the definitions of each of the words Science, Technology, and in recent times, Innovation (STI). These have been pointed out in the discussion earlier on technology. Science policy may also be taken as a set of actions taken by governments to mitigate multiple problems that criss-cross the science, technology and innovation interface in order to achieve a well-defined national objective when private incentives provided by the free markets have failed (Weimer and Vining, 1989).

Science and technology policies are classified into *vertical* (sectoral), *horizontal* and *mixed* policies. Sectoral policies refer to government's identified national priorities. But this has been criticized for its distortions because governments have to make choices on which sectors are the most desirous of consideration relatively. It introduces some elements of subjectivity and favouratism (so-called *winners and losers*), particularly in multicultural Africa. But it may also drive the global leadership positions in some sectors of science and technology and result in the creation of new technology transfers or endogenous science and technology efforts that would propel the nation forward (Weimer and Vining, 1989), among others. *Horizontal policies* are cross-sectoral and can lead to attenuation of the short-comings of *horizontal policies* since they follow market approach and provide general principles and guidelines that make it less susceptible to being accused of selecting *winners and lossers*. One disadvantage is that they seldom provide impetus for creating new sectors. *Mixed policies*, on the other hand, combine the attributes of the two. Their targets are theme-specific, such as energy, communications and environment, amongst others. Other methods of classifying STI policies are by *jurisdiction or inclusivity* (Weimer and Vining, 1989). This is generally common in advanced countries with large bodies of research–based companies. Experience shows that many governments adopt the *vertical policies*, including Nigeria, generally for economic and political reasons. In chapter 5, the inseparable nature of science from politics due to its economic dividends and political undertones were discussed. Because Nigeria's polity is democratic, everything has to be done in the democratic way and it is thus the role of politicians and a gamut of experts from all relevant fields to harmonize the overall national vision to the science policy. The science policy will now be highlighted in terms of relevant parameters such as funding, Research and Development (R&D), scientific manpower, among others. A brief review of international science policies will be presented in order to assess how Nigeria, as a case study, fits into the scheme of things within the developed and developing world.

Jones (1971) defined science policy as the sum of the legislative and executive measures taken to increase, organize and use scientific and technological potentials with the aim of achieving the country's overall development goals and enhancing its position in the world. Science policy, in its truest and holistic sense, goes far beyond the allocation of governments' funds to various fields of research (Ziman, 1980) and the creation of an environment in which science can flourish (King, 1974), rather, it has economic dimensions as well which overlaps into fields such as agricultural extension services, industrial incentives and the analysis of market requirements. Also, the policy encompasses, in addition to training and supply of research scientists, training and distribution of scientists and engineers in production, marketing and public administration, and most importantly, the development of technically-mindeed managers and entrepreneurs (Jones, 1971). Science policy is a document published by relevant governments in which the various relevant and thematic areas of research and development are clearly demarcated: the source of funding (short-and long-term); strategies for implementation; institutions to be created; manpower development and retention; facilities required; cost implications; time-able for achievement of set targets; bodies or partners in collaboration (e.g., industries), amongst others, are typical items in the policy document. The document is reviewed from time to time depending on social, economic, political or scientific trends and other exigencies. All necessary political will and commitment are injected into it and pursed. A method of measuring scientific output is in place, that is, evaluation procedure. The effectiveness of the scientific policy may be measured in terms of, for example, scientific activities such as research and publications in journals, citation index, development of research results into material devices and economic dividends, amongst other indices.

7.1 National Science Policies in Developed Countries

It has been said that nobody would fund something they do not understand (Alan, 2015). This emphasizes the relationship between science policies and funding from the outset. Surprisingly, despite the leading edge of America when it comes to science and technology, its scientific literacy rate is still very poor. Science is perceived to lie beyond the intellectual grasp of most men because its operative conceptions are alien to the mass of educated persons (Ahmadu, 2001). Nevertheless, the popularity of science draw crowds of up to 150 million per year to science museums and related facilities (Ahmadu, 2001).The statement underlies the necessity for scientists to engage with politicians in a well-articulated manner in order to illicit the necessary support and funding for science, because improper management of the synergy has led to several resignations of top scientists from science advisory posts in developed nations, amongst other misunderstandings. Thus James Wilson of the Science Policy and Research Unit at the University of Susex suggested that scientists and politicians have a kind of pact they should honour: politicians should respect the positions put before them, while scientists should steer clear of policy prescriptions (Edwin, 2014). He further advised potential science advisers on several other issues. One person who had done so much to develop a theory of science policy in the US is John H. Marburger (died 2011). He had a special perspective on science policy having spent seven years as science adviser for former US president George W Bush. He realized that good science policies go beyond making decisions about who gets much money but also depended upon the bases on which the decisions were made (Robert, 2015). He therefore called for a *science of science policy,* in order to help policy makers with new tools, metrics and models. It is definitely hard to study and improve science policy because it involves developing, sustaining and enhancing research chains (Robert, 2015). American presidential advisers usually operate in the bureaucratic shadows and serve as the bridges between the administration and the scientific community. They develop options for practical issues that involve science and technology (Peter, 2004).

In the UK, the former Chief Scientific Adviser, Sir John Beddington called on scientists to be involved in properly informing the government about science (Len and John, 2015). Jean Claude Juncker, president of the European Commission (EC) said that the European Union needs to make sure that the Commissions' proposals and activities are based on sound scientific advice (Len and John, 2015). The Organisation of Economic

Cooperation and Development (OECD) in one of its reports acknowledged that science is truly at the centre of many important policy issues and that scientists are increasingly visible and vulnerable too in the policy making process (Len and John, 2015). The issue is that of scientists improving their understanding of the imperfect nature of politics rather than the politicians enhancing their understanding of the imperfect nature of science (Len and John, 2015). The authors identified some twelve key points and the necessary conditions for each to be noted by scientists who wish to advise politicians based on examples of real successes and failures. This demonstrates briefly the dominance of scientific thinking in policy decision-making at all levels in developed countries as compared to almost zero interaction in the developing world. Yet it is believed that scientists are not celebrated and honoured in a befitting way compared to movie stars, footballers and other entertainers due generally to lack of public appreciation and understanding of scientific contributions (Brian, 2015; Brian, 2014). As a background to the discussion of African National Policies on Science and Technology and that of Nigeria's, it is good idea to review briefly some characteristics of the developed countries' policies in order to form a basis for comparison and evaluation.

Research and Development consist of two aspects: basic and applied research. Whereas basic research deals with investigations for the purposes of understanding phenomena and material things or problems, in addition to the huge amount of money being spent over many years without the guarantee of yielding dividends, applied research, on the other hand, is mission-oriented. Its purpose is to solve a particular problem which already exists. It could be in the agricultural, medical, industrial, military or social spheres, as the case may be. Governments and private bodies favour the latter. The pharmaceutical industries for instance, spend billions of dollars on developing new drugs for particular illness over many years. In America and most European countries, governments fund some researches in its research institutes or give them out to private organizations' research institutes. The organized private sector plays a leading role in conducting its own research in these countries, such as multinationals. Though, budgets have been tightened in recent times for researchers generally, they still enjoy a respectable patronage from their governments or private agencies. Governments in these countries sponsor a lot of individuals through scholarships, grants, amongst others, to pursue any subject deemed to have potentials for overall national development. Research facilities are state-of-the-art; both governments and private agencies provide what can be described as a researcher's paradise, in terms of the total environment necessary for the researchers to do their jobs. Government holds scientists in great esteem and this is evident from the various tasks given to them. For instance, in America during the Second World War, the then President Roosevelt charged the scientist Robert Oppenheimer and his team with the creation of the atomic bomb. Ashton Carter, a theoretical physicist, was appointed US secretary of defense, a key cabinet position (Peter, 2015). According to one survey, Harvard University in the US was the best university in the world. Also eight of the world's top universities are in the US. This is based on data collected on 2000 universities and ranked according to five parameters (Belle, 2004).

A 2011 UK labour survey showed 45% of all people with core STEM (Science, Technology, Engineering and Mathematics) degrees worked in sectors requiring scientific and technical knowledge, while about 12% of students in 2012/2013 session of those entering the work force with degrees in engineering, physical, biological, mathematical or computer sciences found jobs which reflect professional, scientific and technological activities within six months of graduating. Fewer than 19% went into manufacturing. Also, the number of students studying for STEM degrees in the UK rose by 18% since 2002 (Magaret, 2014) and is a demonstration of both the diffusion and importance attached to science in the society.

North America, Europe and Japan (Triad countries) make up about 15% of the world population but earn approximately two-thirds of the world's income today. In 2006, the Triad countries accounted for 77.1% (Europe 42.2%, North America 32.0% and Japan 8.9%) of the world's scientific publications which is a significant drop from its 2001 share of 83.1%.The US alone had a share of 43% in 2006 compared to 32.0% in 2001. During the year 2006 as whole, developed countries generally experienced decline in their share of scientific publications, the US share decreased by 7%, EU and Japan decreased by 7% and 15%, respectively, while Russia suffered the worst decrease of 29% (Gailard, 2010).

The US budget for the year 2015 was \$135.4 billion for Federal R&D activity, an increase of ~1.2% over the FY (Fiscal Year) 2014 (MRS, 2014). In Australia advances in the physical and mathematical sciences over the last two decades contributed 151 billion Pounds to the economy each year (Jude, 2015). In Russia, a top scientist was appointed as vice-premier for science education (Letvin, 1996). Russia even created a science city-*Acade migorodok* in Siberia with 40,000 inhabitants (Ukoli, 1985). In some, like France and Germany, they have ministers of science. In Britain, a select committee of the House of Lords influences the course of science. It is estimated that half the bills before congress in the U.S.