NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF EDUCATION

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COURSE TITLE: FOUNDATIONS OF SCIENCE EDUCATION

SED 811: FOUNDATIONS OF SCIENCE EDUCATION

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COURSE GUIDE

Introduction

Foundations of Science Education is a two-credit course. It is a core course for all those offering Masters in Science Education (M.Ed). Perhaps other graduate students may like to offer it as an elective.

The course consists of *twenty-three* units approximately *five modules* i.e. *5 units* in a module. It involves aspects of history and philosophy of science. The course includes: nature of science, branches of philosophy of science, psychological, social, cultural and political issues in science education that have generated much concern in recent times such as equity in science, scientific literacy among others. It also addresses modern philosophers, their views and contributions toward the development of science teaching and learning.

On the historical phase, the course provides a comprehensive summary of the history of science before there were scientists i.e. 2,400,000— 599 BC to twentieth century science i.e. 1895-1945. It also treats examples of historical developments for different periods in history such as Greek Science, works and contributions of Copernicus, Galileo and Francis Bacon, and also paradigms that changed the course of scientific development such as: Darwin's theory of evolution, Newton's theory and Einstein's theory of relativity, to strike a balance — the periodic table as well as the computer were discussed.

Of course, the course would be incomplete without discussing history of science education in Nigeria. This covered two units. A unit on writing an academic paper is also provided. This is to ensure that students write scholarly papers as the requirement of this course is to write a term paper chosen from topics to be provided by your lecturer. A unit-to-unit breakdown of the course will be provided later in this course guide.

What you will learn in this Course

The overall aim of the course in *Foundations of Science Education is* to discover how science education contributes to science teaching by bringing history and philosophy of science and science teaching in closer contact. The course is developed on the premise that science teaching can be improved upon if it is infused with the historical and philosophical dimensions of science. It is based on the conviction that learning of science needs to be accompanied by learning about science.

This course will expose you to a better understanding of the nature of science and improve your competence as a teacher of science by enabling you to figure out answers to such questions as: 'Sir, why do we draw the picture of an atom when we have never seen one?'

It will help you to connect disciplines of science with each other and to connect the sciences with philosophy, culture, psychology, history, theology to mention but a few.

Some of the topics will inform you about modern developments in science and technology such as the computer. The study of the scientific paradigms that revolutionized science were treated from the historical and philosophical perspectives only. They are expected to increase your scientific imagination and critical thinking as well as value the ingenuity accomplished by such works.

Aims of the Course

The aim of the course can be summarized as follows: *this course aims at* providing a meaningful explanation of the nature of science, understanding of the basic tenets of the philosophy of science, familiarization with some issues that have generated concern in recent times as well as a wide knowledge of history of science from stone age to the twentieth century and the history of science education in Nigeria. This will be achieved by aiming to;

- introduce you to the products, processes of science and attitudes towards science.
- show how the basic tenets of philosophy are used to explain issues in science.
- expose you to issues that have generated a lot of concern in recent times.
- provide a comprehensive and meaningful description of the views of modern philosophers and their implications to science teaching.
- summarize the history of science from Greek time to twentieth century.
- present the history of science education in Nigeria.

Course Objectives

To achieve the aims set out above, the course sets overall objectives. In addition, each unit also has specific objectives. The unit objectives are always included at the beginning of a unit, you should read them before you start working through the unit. You may want to refer to them during your study of the unit to check on your progress. You should always look at the unit objectives after completing a unit. In this way, you can be sure that you have done what was required of you by the unit.

Set out below are the wider objectives of the course as a whole. By meeting these objectives, you should have achieved the aim of the course as a whole.

On successful completion of the course you should be able to;

- define science
- explain what scientific world view entails
- list and describe the products of science
- classify scientific knowledge into declarative, procedural and operational knowledge
- list some of the processes of scientific inquiry
- describe scientific attitudes
- explain the branches of philosophy of science
- identify who is a creative person
- state the causes of great inequality among Nigerians
- apply analogy and metaphor in explaining scientific issues
- create models for the explanation of abstract concepts in science
- apply the principles of constructivism in teaching science
- discover the importance of psychological theories in science learning
- state who is a scientifically literate person
- recognize that science and science education are two different issues
- describe how Popper's views revolutionized science
- explain normal and revolutionary science
- compare the views of modern philosophers
- recognize that science has a human face
- appraise the contributions of each specific era of history to the development of science
- mention the great Greek philosophers
- compare Christian's view of creation with Darwin's theory of evolution
- explain how Einstein's theory of relativity replaced Newton's theory
- outline the highlights of history of science in Nigeria
- write a scholarly term paper.

Working through this Course

To complete this course, you are required to read the study units, read set books and other materials by NOUN. Each unit contains activities to enable you follow the trend of what you are reading and be sure you understand it. There are *Tutor-Marked Assignments* which you are expected to complete and submit for assessment. There will be a final examination at the end of the course. Below you will find listed (all the) components of the course, what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time.

Course Materials

Major components of the courses are:

I Course Guide
2. Study Units
3. Textbooks
4. Assignment file
5. Presentation Schedule

Study Units

1. What is Science?
2. The Scientific World View
3. Products of Science and Classification of Scientific Knowledge
4. Scientific Inquiry and Scientific Attitude
5. Branches of Philosophy of Science
6. Ethics of Science
7. Science and Creativity
8. Equity and Science Learning
9. Analogy Metaphor and Scientific Learning
I 0. Constructivism
11. History of Science and Psychology of Learning
12. Science Education and Scientific Literacy
13. Karl Popper — Philosophical Views
14. The Philosophical Views of Thomas S. Kuhn
15. New Philosophers of Science : Lakatos, Bronowski, Toulmin and Feyerabend
16. Human Face of Science, Scientists, Society and Science and Politics
17. Science and History
18. Greek Science, Bacon, Copernicus and Galileo
19. Charles Darwin's Theory of Evolution, the Periodic Table and the Computer
20. Newton's Classical Theory and Einstein's Relativity
21. History of Science Education in Nigeria (1)
22. History of Science Education in Nigeria (II)
23. Writing an Academic Paper

The course is arranged in *modules* and *five units* make *a module.* Each study unit consists of *three to six weeks* work and includes specific objectives, directions for study and reading materials.

Each unit consists of a number of activities. In general, these activities question you on the material you have just covered or require you to apply it in some way and thereby help you to gauge your progress and to reinforce your understanding of the material. Together with Tutor-Marked Assignments, these exercises will assist you in achieving the stated learning objectives of the individual and of the course.

Set Textbooks

Computer Software). to follow
Assignment File

Presentation Schedule

The presentation schedule included in your course materials give you the important dates for this year and for the completion of the Tutor-Marked Assignment and *attending Tutorials.* Remember you are required to submit all your assignments by the due date. You should guard against falling behind in your work.

Assessment

There are two aspects to the assessment of the course. First are the Tutor-Marked Assignments, second is a Written Examination.

In teaching the assignments, you are expected to apply information, knowledge and technique gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadline stated in the *Presentation Schedule* and *Assessment File.* The work you submit to your tutor for assessment will count for *50%* of your total course mark.

At the end of the course, you will need to sit for *final written examination* of *three hours* duration. This examination will also count for *50%* of your total course mark.

Tutor Marked Assignments (TMA)

There are *twenty-three* marked assignments in this course. You only need to submit *fifteen assignments.* You are encouraged, however to submit all the twenty-three, in which case the *best ten* will be counted. Each assignment contributes *3.0%* towards your total course marks. Make sure that each assignment reaches your tutor on or before the deadline given in the Presentation Schedule and Assignment File. If for any reason you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Extension will not be granted after the due date unless there are exceptional circumstances.

Final Examination and Grading

The *final examination will be three hours* duration and have a value of 50% of the total course grade. The examination will consist of questions which reflect the types of self-testing practice exercises and tutor-marked problems you have previously encountered. *All areas of the course will be assessed.*

Use the time between finishing the last unit and sitting for the examination to revise the entire course. You might find it useful to review your activities, tutor- marked assignments and comments on them before the examination. *The final examination covers information from all parts of the course.*

Course Marking Scheme

The following table lays out how the actual course marking is broken down.

Assessment	*Marks*
Assignments 1-5	15 Assignments, best 10 @ 3% each = 30% of course mark
2 Essays at 10% each	20%
Final Examination	50%
Total	100%

Course Overview

This table brings together the units, the number of weeks you should take to complete them, and the assignments that follow them.

Unit	Title of Work Course Guide	Weeks activity 1	Assessment (end of unit)
2.			
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4.			
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22.			
23.			

How to **get the most from this Course**

In distance learning, the study unit replace the university lecturer. This is one of the great advantage of distance learning: you can read and work through specially designed study materials at your own pace, and at a time and place that suit you best. Think of it as reading the lecture instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do. Just as a lecturer might give you an in-class exercise, your study units provide exercises for you to do at appropriate points.

Each of the study units follows a common format. The first item is an introduction to the study matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit. You should use these objectives to guide your study. When you have finished the unit you must go back and check whether you have achieved the objectives. If you make a habit of doing this you will significantly improve your chances of passing the course.

The main body of the unit guides you through the required reading from other sources. This will usually be either from your set books or from a Readings section. You will be directed when you need to use a computer and guided through the tasks you must do. The purpose of the computing work is two fold. First, it will enhance your understanding of the materials in the unit. Second, it will give you practical experience of using programs which you could well encounter in your work outside your studies.

Activities are interspersed throughout the units, and answers are given at the ends of units. Working through these tests will help you to achieve the objectives of the unit and prepare you for the assignments and the examination. You should do each activity as you come to it in the study unit. There will also be numerous examples given in the study units; work through these when you come to them, too.

The following is a practical strategy for working through the course. If you run into any trouble, telephone your tutor or post the question on the WebCT OLE's discussion board. Remember that your tutor's job is to help you. When you need help, don't hesitate to call and ask your tutor to provide it.

I Read this Course Guide thoroughly.

2. Organize a study schedule. Refer to the 'Course Overview' for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information, e.g. details of your tutorials, and the date of the first day of the semester, is available from the WebCT OLE. You need to gather together all this information in one place, such as your diary or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working on each unit.
3. Once you have created your own study schedule, do everything you can to stick to it. The major reason for students failure is that they get behind with their course wolk. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.
4. Turn to Unit I and read the introduction and the objectives for the unit.
5. Assemble the study materials. Information about what you need for a unit is given in the 'Overview' at the beginning of each unit. You will almost always need both the study unit you are working on and one of your set books on your desk at the same time.
6. Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from your set books or other articles. Use the *unit* to guide your reading.
7. Keep an eye on the WebCT OLE. Up-to-date course information will be continuously posted here.
8. Well before the relevant due dates (about 4 weeks before due dates), access the Assignment File on the WebCT OLE and download your next required assignment. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore, will help you pass the exam. Submit all assignments not later than the due date.
9. Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.
10. When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.

11. When you have submitted an assignment to the tutor for marking, do not wait for its return before starting on the next unit. Keep to your schedule. *When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment firm and also written on the assignment.* Consult your tutor as soon as possible if you have any questions or problems.
12. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

Tutors and Tutorials

There are 20 hours of Tutorials (ten 2-hour sessions) provided in support of this course. You will be notified of the dates, times and location of these tutorials, together with the name and phone number of your tutor, as soon as you are allocated a tutorial group .

Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter and provide assistance to you during the course. *You must mail your tutor-marked assignments to your tutor well before the due date (at least two working days are required).* They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail, or discussion board if you need help. The following might be circumstances in which you would find help necessary .Contact your tutor if:

- you do not understand any part of the study units or the assigned readings
- you have difficulty with the self-tests or exercises
- you have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

Summary

SED 701 intends to introduce you to the history and philosophy of science. Upon completing this course you will be equipped with the knowledge of current issues in history and philosophy of science as well as other societal issues that influence science and science education. You will be able to answer these kinds of questions:

- What is science?
- What constitute African and Western views of science?
- How do we develop scientific attitudes in our pupils and students?
- What are the qualities of a creative person?
- Are we born creative?
- Do metaphor and analogy influence science teaching?
- Who is a scientifically literate person?
- What is the use of 'Greek Science' in the 21st century?
- Has history taught us anything in our effort to develop quality science education in Nigeria?
- How can we write a quality academic paper?

UNIT 1

What is Science?

1.0 Introduction

To study History and Philosophy of Science, you should be able to explain what science is. Because of the role of science and technology in improving our lives, they have become everyday terms or words. In this unit you are going to study the meaning and other attributes of science.

1.1 Objectives

At the end of this unit, you should be able to:

- Explain the meaning of science.
- State the basic assumption of science.
- Describe the two forms of science, realism and empiricism.

1.2 Definition of Science

Science has been described in so many ways by scientists and science educators that there is no clear-cut definition of science. The best way to define science is to consider its different aspects. The Oxford Advanced Learner's Dictionary defines science as the study of the structure and behaviour of the physical and natural world and society especially through observation and experiment. According to Ogunniyi (1986), definitions of science vary from one scientist to another. To some, science is an organized body of knowledge, to others science is a search for meanings or explanations of event in nature. Science can also be defined in terms of its methods and processes i.e. what scientists do, in terms of its products i.e. knowledge in the form of facts, concepts, laws and theories. Also science can be defined in terms of its ethics and motives.

Activity 1.1: *State two attributes of science by which it can be defined.*

Ogunniyi (1986) defines science as an attempt by human beings to organize their experiences about nature into meaningful systems of explanations. The term experience includes such things as the discovery of regularities or discrepancies and their effects in nature, knowledge of human actions on things, events or situations and the consequences of such actions and understanding derived from control of diverse phenomena in nature etc. Science is a dynamic human activity concerned with understanding the workings of our world. This understanding helps the scientist to probe further into the nature of things and events and to control and harness such things and events for the benefit of mankind.

Science has little to do with manufactured goods such as cars, lorries, aeroplanes etc. Science is concerned with finding out about nature. Science began with the early man, from his experiences with nature he discovered how plants grow, which plants flowers and seeds are edible, why we have night and day among others. From the earliest times, man has concerned himself with the study and interpretations of the universe and the events that occur within it.

Activity 1.2: What is your own definition of science?

1.3 Definitions of Science by Some Scientists and Science Educators

You have provided your own definitions of science, in this subsection, you are going to read about the definitions of science by some philosophers, scientists and science educators. Uduigwomen (1992) explains that science is based on what we can see, touch, taste, hear and smell. Personal opinions, prejudices or preferences, superstitions and speculative imaginations have no place in science. He states that science is characterized by systematicity and comprehensiveness — it has characteristics, methods, addresses, specific types of question, advance specific types of answers and carries with it a find of results (often changing) as well as characteristic set of propositions (also sometimes changing).

Conant (1951) defined science as an "interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation". Also Brandwein et al (1958) defined science as "use of intelligence in a very complex manner and at present little understood, celebration in an attempt to discover the regularities, if any, of nature". Otuka (1983) defined science as man's attempt to understand his environment.

Squire (1976) states that science is made up of our knowledge of the physical world and of the ways we have of exploring the boundary between our knowledge and the unknown. Knowledge makes up the content of the subject and the way of working constitute the process.

You discover that no definition has exactly the same words or terms with the other. Some say that there are as many definitions of science as there are scientists.

Activity 1.3: Compare your own definition of science with that of other scientists as in Section 1.3.

1.4 Basic Assumptions of Science

Cleminson (1990) and others have advanced 'new' basic tenets claiming that "the following assumptions could be used as a foundation in the study of science":

- Scientific knowledge is tentative and should never be equated with truth. It has only temporary status.
- Observation alone cannot give rise to scientific knowledge in a simple inductive manner.
- We view the world through theoretical lenses built from prior knowledge.
- There can be no sharp definition between observation and inference.
- New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry. As such, science is a personal and immensely human activity.
- Acquisition of new scientific knowledge is problematic and never easy. Abandoning cherished knowledge that has been falsified usually occurs with reluctance.
- Scientists study a world which they are a part not a world from which they are apart.

Activity1.4: State two basic assumptions of science.

1.5 Who Determines the Tenets of Science?

It is noteworthy that apart from the tenets of science stated by Cleminson and others, there had been earlier one by Lederman (1983) Giddings (1982).

According to Alters (1997) the different tenets from different individuals and groups raised the issue of who determines, for science education, organizations and researchers, the primarily, philosophically based question of what are the tenets of the nature of science?

He contended that because scientists do science, they are the most appropriate ones to make the decision. However, Shapiro (1994) state that most working scientists are not philosophically sophisticated while Pitt (1990) was critical of today's scientists, saying that they are not knowledgeable in the Nature of Science and suggested that the Philosophers of Science should not only examine the basic tenets of nature of science held by science education organizations and researchers but also to provide some insight into establishing more accurate criteria for the nature of science. He however added that this did not suggest that a consensus of philosophers of science be used to construct one set of basic tenets but that some scheme could be developed wherein multiple sets of views from the philosophers could be organised into useful accurate criteria.

Activity 1.5: Who should decide the tenets of science and why?

1.6 Realism and Empiricism

Science can be classified into two namely real and empirical science. Empiricism is the doctrine that knowledge is confined to the world of experience or phenomena and that the aim of science is to produce theories that predict phenomena and connect economically — usually mathematically, items of experience. According to Matthews (1994) there were debates on such experiential issues such as that between Newton and Cartesia over the reality of gravitational attraction and over the reality of atoms between Ernst Mach and others in the nineteenth century .

Realists, believe that the point of science is to postulate theoretical entities and to test the accuracy of these postulates. Realists do not believe that all what science postulates at any time is aUcurate but they do believe that science strives to uncover the hidden nature of reality.

There are many ways of posing the realist/empiricist distinction. The fundamental distinction is that empiricists wish to confine the claims of science to what we can experience saying that any claims that go beyond experience have to be treated only as aids, tools, models or heuristic devices for coordinating sensory or observable phenomena. For empiricists, the theoretical, as distinct from observational, terms of a theory do nott)tefer, and are not meant toaefer to existing entities.

Activity 1.6: The aspect of science that postulate theoretical entities and tests the accuracy of these postulates is known as ....

1.6.1 Newton's Realism and Berkeley's Empirism

Newton was a realist. He proposed that gravitational attraction gave rise to the celestial laws of planetary motion covered by Kepler and the terrestrial laws discovered by Galileo. He insisted on the reality of absolute space and time in contradiction to those who maintain that only relative space and time exist -i.e. the space and time of our experience.

Also Newton as a realist stated that when a body accelerates there was a real force acting upon it, something is making the body to accelerate. Force was responsible for the body moving.

Newton believed that a real unseen force is responsible for the acceleration. Force is a theoretical construct to explain observational occurrences.

Berkeley as an empiricist attached the reality of gravitational attraction and the reality of forces. He said, "Force, gravity, attraction, and similar terms are convenient for purposes of reasoning and for computations of motion and moving bodies, but not for the understanding of the nature of motion itself."

Activity 1.7 What is Newton's view of 'Force' as a realist?

1.7 Conclusion

In this unit, you have learned that: science can be defined in many ways -viz in terms of its products, process, also as an organized body of knowledge as well as in terms of its ethics and motives. You also learnt that many scientists provided definitions of science which varied from one scientist to another. The basic assumptions of science which form the foundation for the discussion of scientific ideas was also discussed. That science could be classified into two namely: realism and empiricism was also discussed. Newton was discussed as a realist and Berkeley as an empiricist.

1.8 Summary

Among the things you have learned in this unit are: Berkeley and the empiricist tradition wanted to keep science close to its experiential and specifically observational base and expressed scepticism about constructions passed beyond this firm base. Newton and realist tradition sought to understand an extrasensory reality and believed that science was revealing the features of that reality.

Having defined what science is, you will learn in the next unit about the scientific view and worldview of science.

1.9 TutorMarked Assignments

1. (i) Define science and state four basic assumptions of science.
   (ii) Who should determine the basic tenets of science and why?
2. With the help of any two named scientists or philosophers, explain the contributions of realists and empiricists to the definition of science.

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UNIT 2

The Scientific World-View

2.0 Introduction

In the last unit you learnt about the definition of science. This unit also continues the discussion on "what is science?" However this aspect will deal with the body of beliefs, assumptions and sentiments with which a people, tribe or larger group confront an organized life, for the universe has always presented humankind with a vast mystifying untidy environment. This unit will discuss: man and nature, the scientific world-view, the African world-view, comparison of African and Western world-views and their implications to science teaching.

21 Objectives

By the end of the unit, you should be able to:

- Explain what world-view means.
- Describe how humankind treats nature and natural events.
- State the scientific or western (modern) world-view.
- Discuss the African world-view.
- Compare the African world-view with the modern world-view.

2.2 Humankind and Nature

You are aware that human beings are born into a natural world which is not their own making. Each group of people have their own ways of managing, treating and adapting to the natural world around them. According to Abimbola (1977) humankind first regarded nature and natural objects and forces around them —mountains, thunder, winds as being or possessing what they possessed. These things were regarded as alive, seen to be active with varying capabilities and varying spheres of action where action was required. According to him it appeared the river, the clouds, the sun, moon, the trees swayed by the wind, all fall into the category of things that move. Some acted or performed some functions or appeared to perform some functions such as the cloud provided rain, the sun gave light during the day and the moon at night.

Humankind saw these functions as gifts where they were beneficial such as: the trees bore fruits, the sun and fire provided warmth and the rivers, water for all forms of domestic use.

However, some objects or powers of nature were hostile as they often caused injury, misery and at times death to human beings. Trees fell and killed people, people drowned in rivers and seas, thunders struck and killed people. Poisonous fruits were erroneously eaten and people died. According to MacCulloch (1974), All these gave a more or less clear idea of the aliveness of nature or of many of its parts not necessarily to all directly but to the more thoughtful of them and issued in a crude personalization. People could regard nature only as in relation to themselves and those parts of it in which they were more immediately interested or with which they were more directly in contact, would first be assumed to be alive.

According to Abimbola (1977), to keep their sanity, people needed some guiding principles for making sense out of the everyday occurrences and experiences. These principles and the attitudes and the sentiments that go with them constitute a people's world-view.

Activity 2.1: State two natural objects that are beneficial to life ofPeople and two that are hostile.

23 Definitions of Worldview

Many people have defined world-view. Some of the definitions are stated below:

Abimbola (1977) defines world-view as the body of beliefs, assumptions and sentiments with which a people confront an organized life for the universe has always presented man with a vast mystifying untidy mass.

While Maquet (1954) stated that "The world-view of a people refers to a kind of reality which is not directly observable. We can observe things and behaviour but not ideas or mental attitude" Cobern (1993) defines world-view as the culturally dependent, generally subconscious fundamental organization of the mind that manifests itself as a set of presuppositions that predispose one to feel, think and act in predictable patterns. According to Jegede (1998) his definition implies that world-view precedes and forms the cognitive background for both modern science and indigenous knowledge. It also implies that western and non-western conceptual systems are grounded in different world-views.

Aikenhead (1996) reminds us that science itself is a subculture of Western culture. School science and technology as currently taught in Africa are based on one type of world-view that claims to be superior to others. He states that "Western Science" identifies the science that dominates the world, the science that is taught throughout Africa and is often labelled as "modern".

Also Jegede (1998) states that according to Cobern (1993) the world-view on which science and technology is based has two main aspects namely: the conceptual aspect which concerns how individuals in a particular environment perceive knowledge and the social aspect which describes how individuals negotiate knowledge in their society, these aspects or "eologies" have been referred to as eco-cultures (Okebukola and Jegede 1990) or conceptual cultures (Jegede 1995).

It is necessary to inform you that since most non-Western societies are traditional, they are considered non-modern and dependent on Western Culture. The terms "modern" and "traditional" are frequently taken as opposites in Western cultures. However, Jegede argues that this is not necessarily the case. He maintains that the fact that a culture is traditional does not mean that it is not modern, that a culture is non-western does not make it dependent or inferior.

Activity 2.2 (i) Explain the term world-view

(it) What is the difference between modem and traditional culture?

2.4 The Scientific Worldview

As you read in Section 2.2 of this unit, the scientific world-view is also called "Western Science" or "modern science".

According to Abimbola (1977) what constitute the scientific world-view may be understood if science is thought as the following:

(a) Attitudes—these are certain beliefs, values, opinions characterized by curiosity, humility, scepticism, open mindedness, avoidance of dogmatism or gullibility and a positive approach to failure which have become rules of behaviour for scientists to follow in scientific investigations.

(b) Processes or methods — certain ways of investigating problems. These include observing, classifying, measuring, hypothesising or predicting, describing, or making conclusions from data, asking insightful questions about nature, formulating problems, designing investigations including experiments, constructing from data, principles, laws and theories.

(c) Products: the products of scientific inquiry are the accumulated and systemised tested body of knowledge including: concepts and principles. These form the foundation that the scientists make use of in their construction of broad conceptual schemes called theories or laws. These theories or laws -relate, explain and predict wide varieties of experimental and observational findings in the simplest and most efficient ways.

Activity 2.3 What are the major aspects of the scientific world-view?

2.5 An African World-view

The question has always been asked whether there is an African world-view. Non-Africans and some Africans wonder if Africans share a unified culture. Africa has 54 countries over 660 million inhabitants with over 500 languages and ethnic groups. How possible then is it to claim that Africans share a common world-view? (Jegede 1998).

Jegede tried to answer the question he raised thus: the original inhabitants of Africa where hunters and gatherers who moved from one part of the continent to another. Population growth resulted in kingdoms, chiefdoms and with the arrival of the Arabs emirates. They shared certain characteristics due to their common experiences of pre-colonial trade in goods, crops and slaves as well as common ancestry .What now constitutes the 54 countries are artificial boundaries dividing cultures and families. They were created by colonial powers in the 16th and 17th centuries and formally ratified by the infamous 1884 Berlin conference without the consent of the people.

Abimbola (1977) stated that in spite of minor differences in the ways African communities look at nature, there are similarities that can justify speaking of an African world- view. He asserted that most African communities have similar beliefs, customs and traditions relating to theories of knowledge, causality , religion, concepts of time, and space, kinship system, rituals, marriages celebrations, witchcraft, ancestral worship, reincarnation, story telling etc. According to him, these constitute an African world-view that is shared by most cultures of sub- Saharan Africa. However he added that differences in practice are of degree rather than kind for example most African countries believe that once an individual dies suddenly, she must have been killed by some mystical means. The possible mystical means varies from country to country.

Activity 2.4 Name 3 sources of the common characteristics of Africans.

2.5.1 Fundamental Features of African World-view

According to Jegede (1994), the diverse African world-view share four fundamental features thus

- a belief in the existence of the creator — that supreme God.
- a belief in the continuation of life after death — reincarnation.
- the human being as the centre of the universe.
- a theory of causality.

These constitute an anthropomorphic view of nature that governs how Africans think, the way they act, the way they relate to one another and these are the socio-cultural antecedents of how Africans learn science.

Activity 2.5 State two fundamental features of African world-view.

2.6 Implications for Schools Science Teaching

According to Glaser (1991) "the way students represent the information given in a science problem or in a text they read, depends upon the structure of their existing knowledge". The structures enable them to build a representation or mental model that guides problem solution and further learning. African learners use an African rather than a Western world-view to build enabling structures to understand nature and school science.

Using the logic -structural model of world-view categorization borrowed from anthropology by Cobern (1993), it is possible to differentiate between African and West World- views as set out in table 2.1 (Jegede 1998).

Table 2.1

Worldview categories	Sub-category	African worldview	Western worldview
Non-self	The supernatural	Common religious beliefs	Privatised religion
	The natural	Anthropomorphic; monistic/vitalistic	Mechanistic; empirical/theoretical
	The social	Sage practice; oral culture Communal learning	'questions authority', written culture; individual learning
Self	Group	Strong social cohesion	Weak social cohesion
	Individual	Communal good takes priority; individual is a contributor to communal goals	Realization of personal goals given priority
Classification	Knowledge acquisition	Determined more by age, and community structured	Realization of personal goals given priority
	Materials	Derived from nature for all circumstances	Different classificatory systems
Relationship		Communal; goal structure; deference to sacred sites	Individualist and competitive; nothing is sacred
Causality	Role and place of person	Victim regarded as constant; every event ascribed a cause; elements not relevant to each other	Victim and circumstances regarded as variables in a hypothetico-deductive fashion.
	Accidental occurrence	Can be observed	Conjunctions with no laws
Time	Solutions	Appeasement/purification of the system	Through education
	Life	Cyclical, continuous flow; present in everything; reincarnation ensures relationship	Linear , time is in separate units and looks towards the future
Space	Physical	Everything, including those invisible, is one reality	Must be visible to be real
	Spiritual	Intangible but very important; everything has a god	Not considered an objective assessment of reality

Activity 2.6 Compare the African and western World-views as they relate to () Relationship and (h) Time.

2.7 Conclusion

In this unit, you have learnt that each people have their own ways of managing, treating and adapting to the natural world around them. The definitions of world-view include that of Maquet (1954) which states that the world-view of a people refers to a kind of reality which is not directly observable. You also studied the attributes of the scientific world-view namely: attitudes and products. The four fundamental features of African world-views such as reincarnation and causality. You learnt that African learners use African world-view rather than the Western world- view to build enabling structures to understand nature and school science.

2.8 Summary

This unit suggest that the Africans have two possible ways of studying nature or science i.e. through an African world-view or the scientific world-view. None should be considered superior to the other but should be applied as the need arises. You will recall that we mentioned the attributes of the scientific world-view in the unit. In the next unit you will study these attributes in greater details.

2.9 Tutor Marked Assignments

1. Discuss the various ways humankind has adapted to the different objects and events in nature.
2. (i) State the fundamental features of African worldview.

   (ii) Compare the African and Western worldview in terms of: Nonself, Self, Relationships, Causality, Time and Space.

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UNIT 3

Products of Science and Classification of Scientific Knowledge

3.0 Introduction

Knowledge of science entails knowledge of scientific facts, laws, theories i.e. the products of science. It also entails knowledge of the processes of science. The technical and intellectual ways in which science develops and tests its knowledge claims. These constitute the major part of the scientific world view as discussed in unit 2.4. In your effort to understand what is science, you studied some definitions of science in unit I. In unit 2 you studied among other things the scientific worldview. You learnt that the scientific worldview would be better understood if the products of science were clearly stated. In this unit you will study the products of science -facts, concepts, generalization i.e. laws, theories and hypothesis. Also you will learn about the classification of scientific knowledge into Declarative knowledge (DK), Procedural Knowledge (PK) and Operational Knowledge (OK).

3.1 Objectives

By the end of this' unit, you should be able to:

- List what the products of science are.
- Describe each component of the product of science.
- Provide a hierarchy of the product of science.
- Identify scientific knowledge as Declarative Knowledge, Procedural Knowledge and Operational Knowledge.

3.2 Products of Science

The products of science deal with scientific facts, concepts, laws and theories. Each of these components will be discussed in detail below.

3.3 Scientific Facts

According to Ogunniyi (1986) scientific facts are specified or singular instances (observations) about nature e.g. the heated metal is hot, it is raining. Conant (1951) stated that a scientific fact is not considered valid unless it is observable and demonstrable. However scientific facts cannot be divorced from theoretical interpretations of what we have directly or indirectly experienced or perceived (Kemmy 1959). The confirmed consequences of a theory are facts. For example, singular observations are sharpened by one or more theories about behaviour of electrons, magnetic phenomena or genes respectively. This means that facts deal with particular instances of their occurrence. Ogunniyi stated that without facts philosophers, scientists and science educators will not be able to make scientific assumptions. Generally, scientific facts constitute building blocks for scientific concepts.

Activity 3.1 When is a scientific fact considered valid?

3.4 Scientific Concepts

According to Harre (1974) concepts can be classified into two broad groups, which he called material concepts and formal concepts. Also Ogunniyi (1986) classified concepts into two groups namely empirical and theoretical concepts. Material concepts or theoretical concepts are property, kind, quality and substance concepts which can be used in the description of things, materials and processes. Examples are mass, length, charge force, etc. But empirical or formal concepts also known as "structural" or organisational concepts include: "causation", "existence", "identity" and the spatial and temporal concepts. For example to identify the state of a thing or the presence of a thing at a certain time, as a cause, is not to attribute to it any new quality or power which had not previously been ascribed to it, but rather to come to see it as related in a certain way to other states of things which are its effects. Similarly, to say that something exists is not to attribute to it a special characteristic lacked by non existing things. Concepts such as 'existence' and 'identity' impose an intellectual organisation upon our observations. They are used to express our understanding of what is happening.

Activity 3.2: State the two classes of concepts and give an example of each

The concept of momentum is used for a characteristic of moving bodies that is not observable by senses, whether naked or extended, whereas redness is an observable characteristic of things. Redness is like smoothness, being an observable characteristic, but differs from it in being simply correlated with a quantitative concept, namely the wavelength of the light reflected from the thing to when we are seeing something red. On Ogunniyi, concepts could be regarded as a condensed meaning derived from a massive reduction and synthesis of sense-data about time, space, matter, their assumed relations and their concomitant events or consequences. To him success in communication depends on the way and manner these sense-data are selected and organised to manageable key concepts. Empirical concepts are associated with observable phenomena while theoretical concepts deal with the unobservables. One important function of scientific concepts is that they are used to formulate scientific laws and theories. Just as facts are related together to form concepts, so are concepts related together to form scientific generalisations.

Camap (1966) organised scientific concepts into three levels of complexity: classificatory, comparative and quantitative. Classificatory concepts merely place an object or phenomenon in a set or class on the basis of characteristics present or absent e.g. hard, soft, cold, conductor, solid etc. Comparative concepts relate one concept to another e.g. harder, longer, equal to, etc. Quantitative concepts attach numerical values to concepts e.g. period, volume, ph etc. He explained that each of these concepts are derived from primitive magnitudes i.e. length, mass and time.

Activity 3.3: Mention one important/function of concepts.

3.5 Scientific Generalisations

So far you have discussed facts and concepts as products of science. You have discovered that facts give rise to concepts and concepts to generalisations. According to Ogunniyi (1986) scientific generalisation, relate to scientific statements used to describe, explain and to predict events in nature. Scientific generalisations are made up of hypotheses, laws and theories.

3.5.1 Hypotheses

A hypothesis is 'a scientific guess' or prediction, while a law or theory is more than a guess. This stems from the fact that before a scientific statement is regarded as a law or theory, it must have passed through series of experimental testing and found to be valid. To settle the truth of a hypothesis, it is necessary to know whether the things it refers to exist, because only if they do, can they be studied to see if they have the qualities, natures and behaviour that the hypothesis alleges.

3.5.2 Scientific Laws

Laws are generalisations about observable regularities in nature. Statements that refer to relationships between 'real' things or observable consistencies in nature or man-made world are scientific laws. Scientific laws are used to describe and predict events in nature.

Activity 3.4: Name three scientific laws

3.5.3 Scientific Theory

A theory is defined as a generalisation requiring further experimental testing. Generally it is usual to regard scientific laws as generalization of observable phenomena, while scientific theories are defined as generalisations of unobservable phenomena. Although scientific theories deal specifically with unobservable phenomena, often they do contain empirical concepts (i.e. concepts derived from direct observation) in order to be understood. For example empirical laws such as the gas laws do formulate relations between immediate sensory data, but deal with unobservable entities such as atoms and molecules of gases which are believed to behave in a variety of ways depending on the conditions and several physical laws operating under such conditions.

According to Carin and Sand (1970) scientific laws are derived from and explained by scientific theories. A scientific law or theory survives to the extent that it serves as an adequate tool for the description, explanation and prediction of natural phenomena.

Activity 3.5: Define a theory and give two examples of a scientific theory

3.6 Flow Chart for Products of Science

From the discussion above, a possible flow chart for products of science is as shown in Table 3.1 below:

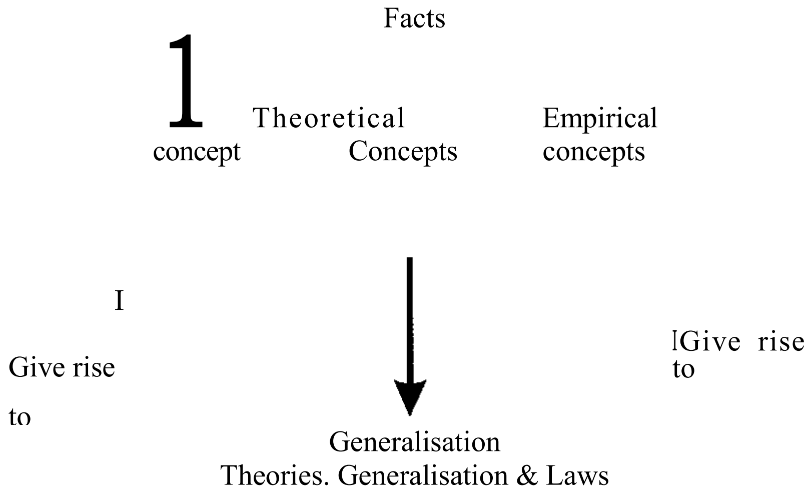

Table 3.1: Flow chart for products ofttience

The flow chart in table 3.1 shows that facts are the building blocks for concepts while concepts are the building blocks for generalisations. Theoretical concepts give rise to theories while empirical concepts give rise to laws.

3.7 Declarative, Procedural and Operational Knowledge

Earlier you have been told that facts are specified or singular instances about nature and a fact is not considered valid unless it is observable and demonstrable. Concepts on their part can be classified into empirical and theoretical concepts while generalisations are made up of theories laws and hypotheses. All these together constitute scientific knowledge. In this section you will read how Scientific Knowledge is classified into Declarative Knowledge (DK), Procedural Knowledge (PK) and Operational Knowledge (OK).

3.7.1 Declarative Knowledge (DK)

Declarative knowledge means that the learner can memorise e.g. the speed of light, parts of a plant, the halogens. Declarative knowledge requires only a certain capacity of short-term memory i.e. memorising constants, words and phrases, may be sufficient to pass a multiple choice test. But this ability is no proof that one has any idea of what the knowledge to be acquired is all about.

3.7.2 Procedural Knowledge (PK)

Gaining procedural knowledge means emphasizing technique-drills. Examples are calculations in physics, writing a program for the Personal Computer (PC) or calibrating a spectrometer. These are activities that could be learned in a cook book manner. Even solving so- called 'problems' as they appear at the end of chapters in textbooks can often be 'solved' by just following a recipe.

However for the application of procedural knowledge the possession of declarative knowledge is very often needed. One may need to know that E-means electric field strength and that the order of magnitude of Planck's constant is 10^{-34}.

However most of the declarative knowledge is required for the application of procedural knowledge. They are more reliable than human long-term memories.

The question is whether students learn science or not. They have their science classes and as long as memorising facts and formulae is considered to be the main goal of the science classes; as long as teachers are satisfied with a certain stockpile of declarative and procedural knowledge, they can claim that they teach and that the students learn. But it is not science, because it has not been taught as an important tool for:

(a) the intellectual and ethical development of the individual and

(b) the social and economic development of the society in this age of science and technology.

3.7.3 Operational Knowledge (OK)

So far we have discussed declarative and procedural knowledge, you will now study operational knowledge in this section.

Operational knowledge (OK) involves the ability to use, apply, transform and connect declarative knowledge and procedural knowledge. It is further characterized by the capacity to construct and reconstruct connections between different subdisciplines of science and to recognise the relevance of declarative and procedural knowledge. It includes the insight where this knowledge comes from and what underlies it.

It can be concluded that operational knowledge requires understanding of science.

Activity 3.6: Give an example each of Declarative Knowledge, Procedural Knowledge and Operational Knowledge.

3.8 Conclusion

In this unit you have learnt that scientific facts are valid only when they are observable and demonstrable. Facts constitute building blocks for concepts. There are two types of concepts; empirical and theoretical concepts. Scientific concepts are used to formulate scientific laws and theories. Generalisations are made up laws, theories and principles. Knowledge can be classified as declarative, procedural and operational knowledge. (Nachtigall 1992).

3.9 Summary

The products of science constitute the building block for scientific knowledge and meaningful learning occurs when we are at the operational level of knowledge. In the next unit you will study scientific inquiry and scientific attitudes which are still part of the nature of science.

3.10 Tutor Marked Assignments

I Briefly describe each of the following:
(a) Facts
(b) Concepts
(c) Generalisation

2. Show how the three types of knowledge interrelate.

3.11 References

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UNIT 4

Scientific Inquiry and Scientific Attitudes

4.0 Introduction

In the last unit, you learnt about the products of science. The products of science are: the building blocks for scientific knowledge. They are used to describe, explain and predict natural phenomena. In this unit you will study how scientific inquiry (investigation) sheds lights on: products of science particularly concept acquisition. All of modern science curriculum developments in recent times stress science as an inquiry. Also you will read and study components of scientific attitude which is an important goal of science education. If science is taught effectively, it will reinforce desirable human attitudes and values.

4.1 Objectives

At the end of the unit, you should be able to:

- Describe scientific inquiry.
- Relate discovery, learning and problem solving to inquiry learning.
- Mention those who advocated for inquiry learning.
- List some components of scientific attitude.
- Discuss the importance of the development of positive scientific attitude by students.

4.2 Scientific Inquiry

During the United States and British Science Curriculum reforms of the 60's, the reformers tried to develop scientific methods (inquiry) and attitudes among students. Reformers wanted students to become scientist not just learn science. According to Matthews (1994), all of modern science curriculum developments stress teaching science by inquiry. The inquiry or discovery approach to teaching and learning was separately advocated by two scholars: Joseph Schwab and Jerome S. Brunner. Brunner (1956) introduced the cognitive human centred ideas of Jean Piaget to psychologists. He also stressed the importance of "structure" for learning. This was connected with his idea of "generativeness" of knowledge:

> "Learning" is most often, figuring out how to use what you already know in order to go beyond what you currently think. There are many ways of doing that. Some are more intuitive, others are formerly derivative. But they all depend on knowing something 'structural' about what you are contemplating - how it is put together. Knowing how something is put together is worth a thousand facts about it. It permits you to go beyond it

Activity 4.1: Who were the scholars who advocated for inquiring learning?

According to Matthew (1994), the structure of discipline which Brunner and Schwab elevate to the forefront of science learning, are structures in the theoretical object of knowledge such as: the structure of interrelating definitions and concepts contained in Newton's Principal and the structure of evolutionary theory in Darwin's origin.

In Brunner's discovery, learning was a way for students to grasp the nature of scientific inquiry. He said that inquiry methods were preferable, because they promoted an increase in intellectual potency, they involved a shift from extrinsic to intrinsic rewards, they taught the heuristics of discovery, and they were an aid to memory processing (Brunner 1961).

Activity 4.2: State two reasons why the inquiry methods were preferable to others.

4.3 Science as Inquiry: Structure of Science and Scientific Skills

Inquiry lies in the heart of science. Scientific process skills are the trolls of inquiry; the conceptual frameworks and information its products. Disciplines such as physics, agriculture, technology, environmental studies or whatever woulg not exist if women and men lacked inquiring minds. Debates such as whether science precedes technology or technology precedes science, assume less importance when one recognizes the paramouncy of inquiry. So too, do discussions on integrated or environmental education, design education or education that stresses societal aspects of science. Surely school science, or whatever they are called, that do not give learners an authentic experience of inquiry should not be called science.

Throughout the world, much of the science curriculum reform of the 1960s was inquiry based, emphasizing the structure of science. Projects of that era have been criticized as elitist, concerned with producing future scientists. In a sense they were especially secondary school projects such as the Physical Sciences Study Committee (PSSC), the Biological Sciences Curriculum Study (BSCS) etc. It was the school system, not the course designers that arranged for only 20% of the school population in the United States of America (U.S.A) to offer physics. Primary science projects developed within the same period were not described as elitist. Perhaps that is because children were encouraged to inquire into a wider range of phenomena in primary than in secondary schools. Children's interests and questions took them into technology, societal issues and so on. But the basis remained inquiry the range of phenomena explored was wide, and there was little criticism from scientists that these projects did not reflect science.

From an early age children everywhere and more so in Africa, learn by observing, their immediate environment. They learn more specialized skills later under an older, experienced mentor.

There is much current debate on the relevance of constructivism and alternative world views on classroom practice (Jegede 1995). In an inquiry learning environment, children bring their mental and cultural constructs to their inquiries to be challenged and reconstructed with help from materials, peers and teachers. Such reconstruction and organic growth of understanding is holistic and leaves learners more empowered to continue their learning. They will more easily accommodate the countless challenges they will meet throughout life by learning the schizophrenic behaviour taught in most African classroom.

The most powerful reason to promote inquiry science in Africa is that science starts Itbm inquiry into phenomena and Africa is rich in phenomena. The elegance of those such as Newton, Hooke, Faraday etc. lies not so much in their discoveries, that have been modified by others standing on their shoulders, as in the way they persuaded the phenomena of nature to reveal their secrets (Naidoo 8c Savage, 1998).

4.3.1 The Scientific Method

According to Rutherford and Ahlgren (1990) the various scientific disciplines are alive in their reliance on evidence, the use of hypothesis and theories and the kinds of logics used. However scientists differ greatly from one another in what phenomena they investigate and how they go about their work and the reliance they place on experimental finding and on qualitative or quantitative methods and in how much they draw their findings of other sciences. Still, the exchange of techniques, information and concepts goes on all the time among scientists and there are common understandings among them about what constitutes an investigation that is scientifically valid.

Scientific inquiry is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientists always follow (i.e. there is no specific scientific method). There are, however certain features of science that give it a distributive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, everyone can exercise them in dealing scientifically with many matters of interest in everyday life.

Activity 4.3: Give two reasons on why scientists differ in their work.

Although all sorts of imagination and thought may be used in coming up with hypothesis and theories, sooner or later scientific arguments must conform to the principles of logical reasoning -that is testing the validity of arguments by applying certain criteria of influence, demonstration and common sense. Scientists may often disagree about the value of a particular piece of evidence or about the appropriateness of particular assumptions that are made and therefore disagree about what conclusions are justified. But they tend to agree about the principles of logical reasoning that connect evidence and assumptions with conclusion. It is necessary to mention that formulating and testing hypothesis is one of the core activities of scientists to be useful, a hypothesis should suggest what evidence would support it and what evidence would refute it. A hypothesis that cannot in principle be put to test of evidence may be interesting but it is not scientifically useful. The essence of science is validation by observation but the credibility of scientific theories often comes from their ability to show relationships among phenomena that previously seemed unrelated. Theories should also fit additional observations that were not used in formulating the theories in the first place i.e. theories should have predictive power.

When faced with a claim that something is true, scientists respond by asking what evidence supports it. But scientific evidence can be biased in how data are interpreted, in the recording or reporting of the data or even in choice of what data to consider in the first place. In science, no scientist no matter how famous or highly placed, is empowered to decide for other scientists what is true, for none are believed by other scientists to have special access to the truth. There are no pre-established conclusions that scientists must reach on the basis of their investigations: Infact new ideas that do not mesh well with mainstream ideas may encounter vigorous criticism and scientists investigating such ideas may have difficulty obtaining support for their research (e.g. Dr. Abalaka and his HIV vaccine). Even most prestigious scientists have occasionally refused to accept new theories despite there being enough accumulated evidence to convince others. In the long run theories are judged by their results: when someone comes up with a new or improved version that explains more phenomena or answer more important questions than the previous version, the new version eventually takes its place.

Activity 4.4: Mention two important activities of scientists.

4.4 Processes of Science

You have gone through the inquiry approach to science teaching and in the course of the discussion, you read about formulating and testing hypothesis and observation as important activities of scientists. These are part of processes of science. The process of science related to those activities carried out by scientists during a scientific inquiring. Such activities are:

Hypothesizing
Observation
Measurement
Raising questions
Manipulation
Prediction

Collection of data
Analysis of data
Synthesis of data
Drawing conclusion
Classification
Communication etc.

Scientific processes involve activities in order to obtain valid generalizations and to raise the right kind of question about objects and events in our efforts to study our environment. Scientific processes provide a way of gaining insight into the problems confronting us.

Activity 4.5: Name four process skills.

4.5 Scientific Attitudes

Part of developing scientifically is acquiring positive attitude. Experimentation and other skills are not fully developed if they are developed in a negative framework or only finished 'to get it over with .Science is different from most of the other disciplines where the task is simple and there is only one correct answer. Science includes developing attitudes and questioning those attitudes. The development of these attitudes is part of the responsibility of the teacher.

It is important for people to be aware that science is based upon everyday values even as it questions our understanding of the world and ourselves. Surely science is in many respects the systematic application of some highly regarded human values and attitudes - integrity, diligence, fairness, curiosity, openness to new ideas, scepticism and imagination. So if science is taught effectively, the result will be to reinforce such generally desirable human attitudes and values. It is within teachers power to foster positive attitudes among their students, if they choose significant accessible and exciting topics in science, if they feature team work as well as competition among students, if .therfpcus on exploring and understanding more than the rote memorization of terms and if they make sure all their students know they are expected to explore and learn and have their achievements acknowledged then nearly all of those students will indeed learn. Other components of scientific attitudes are: curiosity; scepticism, willingness to change opinion, humility, desire for experimental verifications objectivity, precision, tilling for scientific explanation, suspended judgement, awareness of assumptions, acceptance of probabilities, a liking for new things and faith in the possibility of solving problems. How does one acquire attitude?

Psychologists and educators agree that there is no simple answer to this question. All that can be said is that scientific attitudes evolve as one carries out scientific activities using the process skills. Scientific attitudes emerge the way other professing attributes emerge i.e. by practice and rational decision. According to Ogunniyi (1986), an artist on discovering an atmosphere of apathy and boredom in his audience performs an act or series of acts that would animate that audience. In the same way a chemist expecting bubbles from a chemical reaction and finding none at once considers either increasing the temperature or reducing the air pressure. This therefore means that scientific attitudes are necessary products of knowledge of the arts of science.

4.6 Conclusion

In this unit you have learnt that all of modern science curriculum developments stress teaching science by inquiry, the advocates of the inquiry approach are Joseph Schwab and Jerome S. Brunner. Brunner's discovery learning was a way for students to grasp the nature of scientific inquiry. Also there is nothing like specific scientific method which all scientists conform to while doing their work. Formulation testing hypothesis is one of the core activities of scientists. Scientists insist on evidence to verify any classics by their colleagues. The processes of science relate to those activities carried out by scientists during a scientific inquiry such as observation, hypothesizing, predication etc. Scientific development involves acquiring positive attitude such as curiosity, scepticism, openness to new ideas among others.

4.7 Summary

All you have studied so far are to help you understand the nature of science. You will in the next unit study the general theory of some intellectual activity known as philosophy.

4.8 Tutor Marked Assignments

(I) Discuss the importance of scientific inquiry in science teaching.
(2) Explain the following using relevant classroom examples.
   (a) Processes of science
   (b) Scientific attitude

4.9 References

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Further Reading

Find explanation to the components of scientific attitude listed in section 4.5. Any good methodology text will provide that.

UNIT 5

Branches of Philosophy of Science

5.0 Introduction

From the ancient Greeks to the present time, science has been interwoven with philosophy. Most of the great scientists were at the same time philosophers such as Galileo, Copernicus. Newton, Faraday, Max to mention but a few. The work of the scientists are often shaped by philosophy. All philosophy of science begins with analytical logical matters. In this unit you will study: the meaning of philosophy, the main branches of philosophy and their relevance to science teaching.

5.1 Objectives

At the end of this unit, you should be able to:

- Explain the philosophy of science.
- State the different conceptions of the philosophy of science.
- Name the different branches of the philosophy of science.
- Describe the different branches of the philosophy of science and the relations between them.
- State and evaluate some of the philosophical thesis advocated in science for all Americans.

5.2 Meaning of Philosophy of Science

According to Forshaw (1980) philosophy is the general theory of some intellectual activity. It can also be a justification for a course of action. Uduigwomen (1996) stated that philosophy of science originated from the great debate between proponents of two epistemological systems in Europe namely rationalism and empiricism. You will recall that you have already studied these two schools of thought in unit I of this course under "what is science?"

Philosophy of science is concerned with uncovering the presupposition and predisposition of the scientist. The conception that the philosophy of science does not presuppose or predispose any knowledge claim, but instead strives to unveil them. Science for instance presupposes that there are regularities or uniformities in nature which can be discovered by the investigator. Scientists are predisposed to accept determenstic laws or explanations rather than teleological explanations. The task of the philosopher of science is to uncover such presuppositions and predispositions.

Also the philosopher of science clarifies and analysizes scientific theories and concepts with the aim of making their usage understood. This suggests that philosophy of science can be described as a discipline whose subject matter is the analysis of not only the concepts and theories of science but also the procedures and logic of scientific explanation. Arising from the manner of scientific inquiry of two positions, empiricists and the realists while the empiricists argue that scientific inquiry be carried out inductively through observation and experimentation, the realists state that scientists cannot do everything through observation and experimentation. In trying to acquire knowledge the knower brings in his/her organising capacity' and this varies from scientist to scientist by reason of circumstances, age, training and prejudices. However, the empiricist approach has been more dominant.

Activity 5.1: What is the main concern of the philosophy of science?

5.3 The Branches of the Philosophy of Science

Philosophy has four branches namely: logic, epistemology, metaphysics and ethics. A brief description of each branch is provided below:

5.3.1 Logic

This is the theory of reasoning. It is the attempt to specify the rules of correct reasoning where reasoning is typically a passage of thought from some given or assumed statements to others. The complexity of science is evidenced by the number and diversity of ideal forms of reasoning that have been advocated. Some examples of the reasoning from the history of science are:

(a) Menders Laws: According to Mendel, the general statement of the ratios of dominant to recessive characters is inferred from the set of ratio found in a number of experiments, by rounding off to the nearest whole number. There is some reason to think however that the process of reasoning on Menders part was more elaborate involving a stage such as that described followed by an application of the hypothetical law to the experimental results to eliminate aberrant cases.

(b) Keepler's Orbit of Mars: Keepler after repeated failures, to infer a good looking law from the observed positions, supposed that the orbit was elliptical and used the observation to test the law. Case (a) has been called an example of the inductive method.

(c) Of the Hypothetical: Deductive method. It should be noted that the kind of induction advocated by Francis Bacon does not conform with (a)

Also the principles of correct reasoning may be valid only for one area of knowledge and simple ideas on validity cannot be extended to cover scientific reasoning.

Activity 5.2: List the/our branches of philosophy

5.3.2 Epistemology

This is the theory of knowledge. In the epistemological knowledge, we reflect on the standards to which genuine knowledge should conform. The kind of knowledge which a given method of study might yield about a certain subject matter is characterized and how far the kind of knowledge conforms to what are taken to be standards of genuine or true knowledge. From these considerations it will be possible to form some idea of what sorts facts could not be known or identified. It is the job of the epistemologist to show how knowledge can be distinguished from true belief and probability. Philosophers of science are interested in determining how far confidence in particular methods of discovery should extend. They are also concerned with more general epistemological questions such as whether knowledge of the existence of things and materials is more certain than knowledge of the effects that things and materials have upon our senses. Philosophers and scientists would like to know whether there is any part of scientific knowledge that is certain and not liable to revision under any conceivable circumstances. There are other epistemological questions such as:

How do new discoveries affect the status of what we already think we know? Is the information acquired by learning a theory different in kind from that acquired by making an observation ? Can observation be made without a scientist having some theories in mind? Is all knowledge in the last analysis a theoretical knowledge?

Activity 5.3: State two questions that can be discussed under epistemology.

5.3.3 Metaphysics

Forshaw (1980) defines metaphysics as the study of the concepts used in science and in ordinary life, through the study of the internal structure of the language used in different areas. Harre (1974) defines metaphysics as the theory of concepts and their relations. In modern metaphysics the most general concepts used in science and in ordinary life are investigated. For example a modern metaphysicist might study the space — concepts and time concepts used in ordinary life and compare them with those used in special relativity. He could examine various concepts of cause or the concepts of possibility and necessity.

Modem metaphysics is aimed at achieving clarity of thought by a careful study of concepts. This is done by a study of various aspects of language use. In metaphysics, efforts are made to discover how various concepts are related e.g. how our thing concept is related to our space concepts. Also it covers such studies as to whether our concept of temporal direction is contingently or necessarily connected with our concept of causality. In recent years these studies have moved into the field of science. Conceptual problems about space and time have been studied under theory of relativity, problems as to what are the limits of the concept of an individual have been studied in Biology particularly in discussions of the attempts to specify the unit of evolution i.e. what evolves? From the discussion so far, it is clear that such questions *as:* are these concepts fundamental? Is the world atomic? Cannot be carried out experimentally, but only by philosophical debate.

Activity 5.4: What is philosophy?

5.4 Ethics

Ethics is the theory of evaluation particularly moral evaluation. God l (2000) talked about ethical issues in the twenty first century. He argued that because of recent advances in biotechnology and biomedical science. The social and the ethical issues in science and technology will become prominent in this century, as they have never been before. Therefore the social and ethical issues in science and technology education must find prominence in our teaching in the twenty first century.

Also there are ethical and social issues emerging out of environmental sustainability. Today's citizens will have to be trained to consider the relationship of durability to cost in their consumption decisions; to be made aware of the short, medium, the long-term consequences of their decisions: and to realise that their decisions will have an impact on future generations. It is therefore suggested that each country will have to establish suitable measures to address the ethics of the practice of science and of the use of the knowledge of science and technology.

5.5 Philosophical Theses and the Curriculum

According to Mathews (1994) all science curricula contain views about the nature of science, images of science that influence what is included in the curriculum, how a material is taught and how the curriculum is assessed. The image of science held by curriculum framers sets the tone of the curriculum, and the image of science held by teachers influences how the curriculum is taught and assessed. When spelled out the images of science become statements about the nature of science or about the epistemology of science for example — an inductive — empiricist view of science dominated the curricula reforms of the 1960s.

Some of the philosophical theses advocated in science for All Americans (project 2061) are presented below; They are worthy of mention for the teacher who might be coming across them from time to time:

(I) **Fallibilism:** This means that humans can have knowledge of the world even though such knowledge is imperfect, and reliable comparisons can be made between competing theories or opinions. Fallibilism is an epistemological position that is opposed, on one hand to relativism, which holds that no reliable comparison can be made between competing views, and, on the other hand, to absolutism, which holds that current theory constitutes absolute, unimprovable knowledge. The report says that "scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works.

(ii) Durability: Science characteristically does not just abandon its central ideas. The simple falsification picture of scientists examining and rejecting ideas as some sort of quality control process does not hold up. The report says. The modification of ideas, rather than their outright rejection, is the norm in science, as powerful constructs tend to survive and grow more precise. The philosopher Otto Neurath first gave picturesque expression to this view when he spoke of the correction of scientific theory as the fixing of a leaking boat at sea. The entire hull is not taken out; rather planks are examined and replaced one at a time. Willard van Orman Quine gave wide currency to the image (Quine, 1960). Imre Lakatos formalised this conception with his idea of science as a series of research programmes with hard-core commitments that were very resistant to change, and protective belt commitments that changed to accommodate discordant or falsifying data (Lakatos, 1970). The philosophical views of Imre Lakjos will be fully discussed later in this course.

(iii) Antimethodism: Although rationalist in its justification of scientific theory, the report rejects the idea that there is a single method of scientific discovery, saying that "there simply is not fixed set of steps that scientist always follow no one part that leads them unerringly to scientific knowledge". The report — stresses the creative dimension of science saying, "Scientific concepts do not emerge automatically from data or from any amount of analysis alone. This aspect is often overlooked in schools. Inventing hypotheses or theories about how the world works and then figuring out how they can be put to test of reality is as creative as writing poetry, composing music or designing skyscrapers.

(iv) Objectivity: It is recognised that science is a far more human activity than it was once conceived to be. We know that Francis Bacon's idols of the mind have persisted long after he urged their eradication in 1920. But the reports, while recognising this human face of science nevertheless maintains that science at its best tries to correct for, and rise above, subjective interests in the determination of truth. It says, "Scientific evidence can be biased in how the data are interpreted, in the recording or reporting of the data, or even in the choice of what data to consider in the first place. Scientist, nationality, sex, ethnic origin, age, political convictions and so may incline them to look for or emphasize one or another kind of evidence or interpretation but scientists want to know the possible sources of bias and how bias is likely to influence evidence. The possibility of objectivity in science has been challenged by some feminists, some constructivists, and by most philosophical postmordenist. The issue is discussed later in the course.

(v) Moderate Externalism: The attempt to eliminate subjectivity and interest from the realm of the determination of truth claims is not the same as saying that various interests should not influence what spheres of knowledge science should investigate. Whether research is conducted on space travel, or cheapened public transport, on nuclear energy or solar energy, on chemical insecticide development or biological controls, will be a function of personal and social interest. Science does not proceed in a political vacuum; most countries draw up lists of national priority areas and will only release public funds for scientific research in these areas. Being on or off the list is a political matter.

The report recognises that "As a social activity, science inevitably reflects social values and viewpoints... The direction of scientific research is affected by informal influences within the culture of science itself, such as prevailing opinion on what questions are most interesting or what methods of investigation are most likely to be fruitful. Funding agencies influence the direction of science by virtue of the decisions they make on which research to support. When decisions about truth or otherwise are made in order to serve the interests of funding or political bodies, then science had moved from moderate to complete externalism. While some sociologists of science argue the latter view (Matthew, 1994), these theses express the views of those who framed the curriculum proposals for project 2061. As a recent development, teachers should be able to evaluate them and use them in appropriate philosophical contexts.

Activity 5.5: Name the philosophical thesis that talks of the modification of ideas rather than their outright rejection.

5.6 Conclusion

In this unit you have learnt that philosophy is the general theory of some intellectual activity. It can also be a justification for a course of action. The philosophy of science does not presuppose or predispose any knowledge claim but instead tries to unveil them. There are four branches of philosophy namely: Logic, epistemology, metaphysics and ethics that logic is the theory of reasoning, epistemology; the theory of knowledge, metaphysics; the theory of concepts and their relations and ethics; the theory of evaluation particularly moral evaluation. The branches are related to each other. You also learned about some philosophical theses in project 2061.

5.7 Summary

In this unit you have learnt the meaning and different branches of philosophy. In the next unit you will study, ethics of science.

5.8 Tutor Marked Assignments

(i) Explain the term philosophy.
State the importance of the branches of philosophy in science instruction.

5.9 References

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UNIT 6

Ethics of Science

6.0 Introduction

In Unit 5 you studied the branches of philosophy and you were told that philosophy comprises -Logic epistemology, metaphysics and Ethics. In this unit you are going to study more about ethics.

Ethics is the study of what is proper and improper behaviour, of moral duty and obligation. Moral principles can be grounded in philosophy, theology or both. For scientists, ethics involves the responsibilities they owe to society. Because of recent advances in biotechnology and biomedical sciences, the social and ethical issues in science and technology will become more prominent than they have ever been before. Therefore the social and ethical issues in science and technology education must find prominence in our teaching in this 21st century. Speaking of ethics, one is reminded of the social and ethical issues emerging out of environmental sustainability. Today's citizen will have to be trained to consider the relationship of durability to cost in their consumption decisions, to be made aware of the short, medium and long term consequences of their decisions will have an impact on future generations. Each country will have to establish suitable measures to address the ethics of the practice of science and of the use of the knowledge of science and technology. If people have right to private life, a right to self-determination and one person should not do anything to intentionally harm another person. Then those who handle issues that could affect the lives of others very adversely should be upright considerate and above all obey the ethics of their profession.

The purpose of this unit is to discuss the basic intellectual ethical issues the scientist should conform with.

6.1 Objectives

At the end of this unit, you should be able to:

- Explain what ethics means.
- Discover how the scientist applies some ethics in his/her work.
- Apply some ethics to you daily activities.

6.2 The Scientist

Earlier you have discussed the products of science which you were told were made up of facts, concepts, theories, laws hypotheses and generalization. You were also told that the scientists use some methods (processes) to arrive at these products. These processes include observation, classification, measurement prediction, problem identification, collection of data, analyses of data, interpretation of data drawing valid conclusions aniong others. It is noteworthy that the list above has not been organised in any particular order. From the above, it means that scientific processes involved several efforts to obtain valid generalisations and to raise the right kinds of questions about objects and events around us.

A scientist observes and records his observations carefully, also with the help of measuring instruments he is able to determine the numerical values of what he observes. He makes rational predictions on the basis of the data collected. He formulates hypotheses and tests them. He draws valid conclusions on the basis of experimental findings and so on.

Activity 6.1: Name two processes a scientist uses in doing his work

When a scientist encounters genuine problems, he does not rush to collect data but defines his problem as clearly as possible. He consults the established "library of knowledge". He discusses with his colleagues and after much insight he formulates an hypothesis. As stated earlier, it is the hypothesis that guides him in his/her experimentation and the selection of methods of data. With further consultation of literature careful experimentation and much thinking he finally arrives to further experimentation before a more refined conclusion is arrived at. Numerous and varied confirming results by other scientists gradually {though never completely} verify the conclusion or reached. A valid scientific conclusion or generalization is normally called a scientific law or theory as mentioned earlier depending on the major concepts from which it is derived.

63 Scientific Investigation

According to Ogunniyi (1986) there is no approach to a scientific investigation. In fact, there are almost as many approaches as there are scientists. This may sound contradictory to the earlier statement about the scientific method which tends to lean towards a hypothetico-deductive logic of science. What is carried out in a scientific investigation is quite flexible and personal without our overall model. Incentive, intuition, creativity, alertness of the mind, trial and error etc. all play an important role in the scientific investigation. By the picture of scientific inquiry often encountered in books, to say the least, gives distorted view of the actual processes of science. A common structure of scientific inquiring in scientific papers and textbooks is represented below.

Problem —>Experimentation---> Result

The model above presents science as a straightforward inductive process. Earlier it was noted that this view of science is incomplete and misleading. A true scientific inquiry as mentioned earlier starts with some expectations of some kind which propels and controls that inquiry. It is in the context of an expectation or a hypothesis that some expectations are held relevant or irrelevant, that some methods or attitudes are adopted. Others discountenanced that some experiments are chosen in preference to others.

Activity 6.2: List the necessary steps of the scientific method.

64 Ethics and Science Education

According to Matthews (1994) ethical questions increasingly arise in the science classroom. The green-house effect, pollution, extinction of species, genetic, engineering, military technology and the employment of scientists in the defences industries, the cost and direction of scientific research, nuclear energy and nuclear war and so on are all matters that are raised by students, and appear in new science curricula. Most major universities have ethics committee that regulate research in science and social science. The once straight forward and unreflective use of animals for scientific experiments and laboratory dissections is now questioned and in many places strictly controlled – an aim of the New Zealand science syllabus is "the care of animals" and recognition of their rights. At the same time, in philosophy these questions are being dealt with in applied ethics and environmental ethics courses.

Hitherto, partly under the influence of belief in value free science, these questions have largely been ignored in science education – rats and mice have been routinely killed in front of classes, the chemistry of fusion and fission discussed without the attention of bomb or the ethics of nuclear energy use, the science of extractive industries discussed without attention to the bomb or the ethics of nuclear energy use, the science of extractive industries discussed without the attention to the socio-political environmental issues involved.

Activity 6.3: State two ethical issues that students raise in the classroom

John Ziman and numerous others have pointed out that orthodox science education has long promulgated naive materialism, primitive positivism and complacent technocracy (Ziman 1980). These positions are now in intellectual retreat. The PLON project in the Netherlands, the SISCON project in the UK; various Canadian projects (A ikenhead 1980). STS courses and project 2061 proposals in the United States of America are educational responses to the recognition that science and values are more interwoven than previously acknowledged.

The interconnection of science and ethics is particularly clear in contemporary human genetics programs. The Human Genome Project has three percent (ninety million dollars) of its three billion dollar budget allocated to ethical and legal ramifications. In the United States of America, there are at least three state and national genetic education programs that explicitly address the ethical and religious dimensions of the Genome project. The Biological Sciences Curriculum Study (BSCS) program is outlined in a ninety-four page document sent to US biology teachers. In addition to the science of the Genome project, it has student engaging in analysis and debate over the ethical and policy issues generated by genetic screening and other techniques occasioned by the Genome project. Should employers be allowed to screen prospective employees for the Huntington's chorea gene? Should those identified as genetically disposed to alcoholism be forbidden to drink? It says of this situation that "Individuals, institutions (schools and other organizations) and society will have to deal with situations in which some interests are advanced and others are impaired. When the interests of everyone cannot be advanced and when some interests are advanced at the expense of others, whose interests ought to receive priority? Questions about 'oughts' properly are addressed by ethics and public policy (BSCS, 1992).

Our hopes that teachers will strive to make the ethical discussion as sophisticated as the scientific discussion. This requires that teachers be familiar with the history of ethical debate and its major arguments. Something, but not much is served by simply rehashing or asserting popular nostrums. Teachers can benefit and their classes be enriched, by serious grappling with these ethical and social questions (Matthews, 1994).

Activity 6.4: Mention one program where the interconnection of science and ethics is clear

6.5 Ethics of Science

This aspect of the nature of science according to Ogunniyi {1986) deals with the code of conduct of scientists i.e. his attitude and behaviours thus: intense curiosity, scepticism, objectivity, open mindedness, humility, honesty, determination etc. Ethics of science also includes strict regulative principles viz care observation, recording and reporting of data, using available skills and models, consultations and discussions at various levels etc.

Human kind is imbued with an intense curiosity and a consuming passion to seek for rational solutions to many problems that confront them as they interact with nature. It is this same consuming passion (though at a higher level) that drives the scientist to carry out—scientific investigations. Without the relevance of this attitude, it will be hard to justify the persistence, the painstaking rigours and dedication put into scientific investigation.

A scientist does not hold tenaciously to his own ideas. He has to be open-minded. In fact, a statement is not scientific because of the one who says it but what is said. Therefore scientific statements are not stated as immutable truth but as tentative generalizations susceptible to correction, revision or total abandonment.

Activity 6.5 State two ethics of science.

As mentioned earlier a scientist tries as much as possible to be honest, careful and objective in what he says or does. This is done not only because he will be criticized by others but to permit others to ascertain the validity of his findings. Science does not respect authority but testable facts. A scientific knowledge or skill that is not subject to critical examination is not respected. Science by nature is a public property and it stands or falls on the basis of consensus within scientific community. Scientists are patient and persistent to their work. They do not abandon a project simply because of repeated failures. They have deep faith that somehow, solutions will be found to a given scientific problem.

All along you have been reading about the ethics of science in its various forms. In this section you are going to read about ethics and research.

6.5.1 Ethics and Research

It is expected that a scientist should make careful observations, recording and reporting of data. It is also expected that he consults relevant literature and that he is quite knowledgeable of the available skills and models.

There are two ethical contexts affecting science. One is the external context where ethics can determine the questions to research or to avoid, the other is the internal context where ethical considerations affect the conduct of research itself. According to Matthew (1994) medical research is a prime example where ethics directly affects what is and is not researched -heart transplant research is conducted, but euthanasia research generally is not. More generally, certain areas are researched because society and scientists think it is morally good to do so, where these are human needs that the research can fulfil. But ethics also affects the actual conduct of research some things are not done because they infringe general ethical norms.

Most scientists conduct themselves according to ethical norms of science (these are) the strongly held traditions of accurate record keeping, openness and replication... etc. Another domain of scientific ethics relates to possible harm that could result from scientific experiments.., due regard must be given to the health, comfort and well being of animal subjects a scientist chooses to work on research of great potential risk to humanity, such as nuclear weapons or germ warfare, is considered by many scientists to be a matter of personal ethics, not one of professional ethics.

6.6 Conclusion

In this unit you have learnt that the products of science and the process constitute the nature of science. That for the scientist to generate laws, hypotheses and theories the process of science in trying to carry out experiments, this calls for some code of behaviour for the scientist and that is what we refer to as code of behaviour for the scientist and that is what we refer to as code of conduct or ethics. Also according to Matthew, ethical issues arise in the classroom almost on daily basis such issues as pollution, green house effect, etc.

6.7 Summary

Ethics of science call for some code of conduct for the practitioners. In today's world we are aware that science and technology rules the world, With war arsenals such as the nuclear bomb, it becomes necessary for the scientist to ask himself/herself searching questions on whether he/she should continue to produce weapons of mass destruction.

6.8 Tutor Marked Assignment

- Expal in why ethical issues increasingly arise in the classroom these days.

6.9 References

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UNIT 7

Science and Creativity

7.0 Introduction

Although creativity has been an area of legitimate concern and interest to educators since the time of the Greek philosophers, little has been done directly to encourage creativity in the science classroom. Research into creative process and product has been reported since 1950 but has had only a meagre effect on the literature of education and almost no impact on curriculum development in science. Although creativity may be readily identified as a by- product of many recent curriculum developments, widely published activities indicating creativity as a primary goal are difficult to find.

One possible reason that creativity has not been included directly in the science curriculum is disagreement about what creativity is, its relationship to science, and the nature of its products and processes. Much early thought correlated creativity with intelligence. As might be expected with two mental functions, there is a degree of correlation between IQ and scores on creativity measures. Various researchers have shown, however, that the correlation decreases with increasing IQ and becomes almost negligible above an IQ of about 115, thus, there appears to be an IQ threshold for creativity. Beyond this threshold, the old assumption that giftedness in intelligence is synonymous with giftedness in creativity has been effectively refuted by a number of studies.

Even though a number of talented investigators have researched questions of creativity, it is still an area in need of additional research. Researchers in the field of creativity have difficulty defining creativity and are in only reasonably close agreement when considering the process of creativity. Some scholars, such as Rhodes (1961), define creativity a creative product. Others speak of novel relationships or the capacity to find new connections. Others have mentioned insights or insist that the product is creative only if it did not exist previously in the same form. Stewart (1950) feels that the criterion should be newness to the individual even though the idea may have been produced many times before. Thurstone (1952) shares this idea by maintaining that a creative act has occurred when the individual reaches a solution that is new to the individual.

Creativity is a thinking process. Creative thinking is concerned with new ideas. Creativity is the act of drawing on all past experiences and the act of selection from these to yield a construct of new patterns, new ideas or new products. The keyword appears to be new: usually the concern is how the newness is related to society. In this unit you will learn about: characteristic traits of creative persons, personality traits of highly creative persons, elements of creativity, and how to encourage creativity.

7.1 Objectives

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

- Define creativity. State five characteristics of a creative person.
- List three personality traits of highly creative persons.

- Identify elements of creativity.
- Discover how to encourage creativity.

7.2 Creativity Explained

As you were told in the introduction, creativity is a thinking process. Creative thinking differs from critical thinking because it is concerned with new ideas as opposed to previous ideas or reflections on someone else's ideas. Creativity could be defined as: the act of drawing on all past experiences and the act of selection from these to yield a construct of new patterns, new ideas or new products. Just as we at times define science as what scientists do, creativity could be equally described as what creative people do. (Anderson et al 1970).

Activity 7.1: What is Creativity?

7.3 Characteristic Traits of Creative Persons

Creative individuals vary in motivational intellectual and personality traits. Individuals with creative potential can, most easily be recognised by the following characteristics:

(i) Curiosity: This probably is one of the easier signs by which a science teacher can discover creative individuals.
(ii) Resourcefulness.
(iii) Desire to discover.
(iv) Preference for difficult tasks.
(v) Enjoyment in solving problems.
(vi) Drive dedication to work.
(vii) Flexible thinking.
(viii) Rapid response to questions and habit of giving more answers to questions than do most students.
(ix) Ability to synthesize and see new implications.
(x) Pronounced spirit of inquiry.
(xi) Breath of reading background (Sund and Trowbridge).

Creative people have a marked ability to form abstractions and to analyse and synthesize information in science, they demonstrate persistent and sustained concentration on trying to get a piece of apparatus to work or to solve some particular scientific problem. They are usually sensitive and individualistic. Given freedom as well as direction, creative students often surprise the instructor with their capabilities and interest.

Activity 7.2: State four characteristic traits of creative persons.

7.4 Possession of Creative Ability

Creativity is something everyone possesses in varying degrees; everyone is born with some creative potential. Creativity occurs at almost all ages and in all fields of human endeavour. A creative artist or musician produces new, original unique paintings or music; a creative engineer produces new, original unique, ideas or constructs. According to Sund and Trowbridge (1967) creative engineer produces new, original unique ideas or constructs. So teachers dubbed creative produce new, original, unique learning situations wherein students can create, new, original, unique solutions to problems and discover new patterns, new ideas or new products. Creativity can be developed, and its development depends upon the environment into which it is introduced and circumstances that condition it.

Activity 7.3: At what age does creativity manifest in children?

7.4.1 Desirability of Creative Ability

It is generally accepted that creativity is a highly desirable and precious commodity, prized by teachers, scientists, engineers, industrialists, politicians, advertisers and others.

So far research has not unravelled those experiences and conditions that foster creativity .However it is generally believed that creativity can be developed in students if in the learning process the teacher initiate creative situations to which students can react accordingly.

This suggests that science teachers are capable of creative thought and action provided they are aware of the elements of creativity. However, creative teaching demands creative teachers because the production of creative teachers is tantamount to the production of creative students.

7.4.2 Creativity Helps Teachers as well as Students

Enhancing creativity yields many long range benefits to both the individual and the society for creative activity is involved in the development of new knowledge; the production of music, art, and literature; and in the pleasures and benefits of generally imaginative thinking and living. More immediately, creativity can be useful in the classroom.

Maw and Maw (1965) found that highly creative children, when compared to less creative children, had a greater level of self-sufficiency, felt more secure, were more flexible and dependable, and exhibited a healthier participation in group activities. Highly creative boys, specifically, were found to exhibit a higher level of maturity and social skill, and to feel that discipline was more fair. In addition, these more creative boys exercised better overall judgement than their less creative peers .

Studies have also demonstrated that creative people are more observant, seeing and valuing things as others do not. Creative people are viewed as healthier and more energetic. And, as Getzels and Jackson have pointed out on several occasions (1958, 1962), creative thinking abilities contribute significantly to the acquisition of new information. Creative people have a well-developed ability to sense problems. They possess originality and flexibility which is spontaneous and adaptive. Their fluency of associations, expressions, and ideas allows them to relate and perceive ideas in unusual ways. This leads to a redefining and juggling of ideas, further visualizing, arid still more elaborating. The tendency to think at right angles to the mainstream and develop an ability to focus attention in many ways while working and thinking on problems is very common. Creative people also show an ability to evaluate their own creativity, an ability perhaps related to their generally strong drive, inner- directedness, self confidence, intellectual thoroughness, and aspiration to making theoretical and original contributions.

7.5 Elements of Creativity

Creativity is both process and product. The recognition of a problem is the beginning of the encounter with it. The rate of problem recognition is closely allied to the number of and the utilization of all the life experiences upon which a child draws for any creative act. However the individual insight to problem recognition will vary.

Delineation -the step of assessment and clarification occurs when the individual or group analyses the problem and searches for a strategy for solution. This can be very frustrating and uneasy period. The frustration may be a temporary stalement. A manipulation of ideas must accompany the waiting period. During a creative training exercise you can assist the students in reducing this time factor by providing connectors (or clues) that aid this manipulation and linkage of ideas. The process in the creative act which involves the jelling of ideas is called revelation.

Activity 7.4: *What are the two elements of creativity?*

7.6 Divergent and Convergent Thinking

The delineation and the revelation are two distinct methods of thinking i.e. convergent and divergent. Instructors of science have generally accepted creativity as a valuable adjunct of the teaching of science in the elementary school.

In convergent thinking, emphasis is given to activities that are directed toward a correct answer and students assembled facts that enabled them to arrive at that, or the most nearly correct answer. See Fig 7.1.

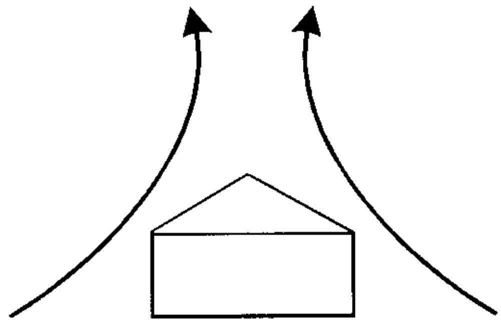

Figure 7.1: A convergent model

Divergent Thinking

Divergent thinking is an approach to a diversity of ideas or considerations. Fig 7.2 represents a divergent model of thinking.

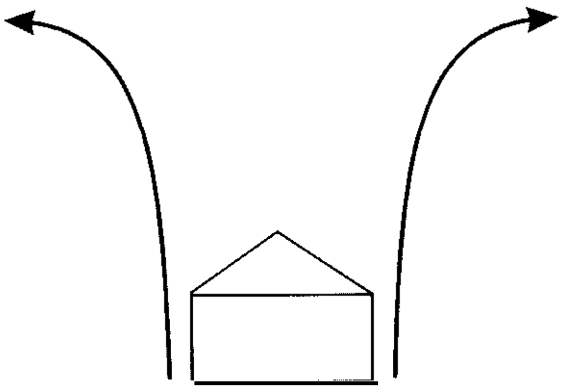

Figure 7.2 A divergent nodel

A divergent model continuously open new avenues for thought. It is dynamic rather than static. Students using a divergent approach to the solution of problems begin to look at problems in a varied manner. Thinking of all possible solutions to the problem.

However neither convergent or divergent thinking exists in isolation. The two complement each other.

Activity 7.5: Give an example each of convergent and divergent thinking.

7.7 Research in Creativity: Implications for the School

According to Trowbridge and Sund (1967) an accumulation of Psychological research in the field of creativity has attracted the attention of educators to the problem of improving the possibilities for manifestation of creative ability in the secondary schools. The findings of this solution are:

- All people of all ages and races are creative to some extent.
- Individuals differ considerably in the degree of their creative ability and expression Freedom to be creative has an effect on mental health.
- Students can learn more effectively in a creative solution.

7.8 Processes to Stimulate Manifestation of Creative Enterprise

In order to stimulate the manifestation of creative enterprise, the teacher should require students to:

- Originate problems
- Formulate hypotheses
- Design experiments
- Infer
- Evaluate an experiment or research and tell how to do it better .
- Invent new uses for objects
- Develop new approaches
- Produce original art
- Communicate uniquely e.g. in reporting or summarizing data
- Summarizing Data

7.9 Conclusion

In this unit, you have learnt that creativity is the act of drawing on all past experiences and the act of selection from these to yield a construct of new patterns, new ideas, or new products. That creative persons have specific characteristic traits. That every person possesses the creative ability to some degree. Creativity is a highly desired and precious commodity. That creativity is both process and product. That there are two models of thinking: convergent and divergent. There are specific processes to stimulate manifestation of creative enterprise.

7.10 Summary

Creativity is a highly desired and precious commodity which has specific purposes to stimulate manifestation of creative enterprise. It is therefore advisable that teachers should adopt the divergent model of thinking to enable the student develop creative capabilities. In the next unit you are going to study equity in the study of science. You will discover whether everyone is in the study of science. You will discover whether everyone has accessed to science which promotes creativity.

7.11 Tutor Marked Assignments

- State the four characteristics of a creative person.
- Describe the processes you would adopt to improve or develop creativity traits in your students.

7.12 References

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UNIT 8

Equity and Science Learning

8.0 Introduction

The poor distribution of wealth of the nations in most African countries creates a lot of inequality within the continent. Majority of the population are very poor, children are denied quality education, good accommodation, have no access to comfortable transport, and hardly get a square meal in a day. Consequently most of the children within Sub-Saharan Africa are deprived of a conducive environment for learning. Equity as used in this unit refers to feminism or gender. This decision is informed by the many variables that could be addressed under equity.

81 Objectives

At the end of this unit, you should be able to:

- Discover that some feminists see girls reluctance to pursue science as a result of science being a discipline promoting objective, national and analytic behaviour.
- Provide information on performance in science in schools.
- State some reasons for the disparities.
- Recommend strategies for equity.
- Describe the state of education in Africa.

82 Feminism and Science Education

In the last four decades there has been concern about the low participation rate of women in science. Women and science research has focused on practical and pedagogical barriers to girls performing well in science. Issues raised had included: teachers paying more attention to boys than girls, lack of female role models and pursuits in textbooks and so on. In addition to this practical and empirical matters, there have been also developed feminist arguments about bias in the very nature of science and its practise. This bias is held by some feminists to be responsible for girls shunning science or underachieving in it. (Bleier 1984, Keller 1985, Longino 1989) to mention but a few. Some feminists see girls' reluctance to pursue science as the result of science "being commonly portrayed as a discipline promoting objective, rational and analytic behaviour". This argument does not provide any reason why objectivity, rationality and analytic thinking are bad. However many women reject the claim that objectivity, rationality and analytic thinking are alien to them.

Activity 8.1: Give two reasons why girls do not do well in science.

8.3 Gender Equity in Science Education in Africa

Before discussing the state of gender equity in science education in Africa, there is need to examine the relative access to education of boys and girls. While most countries start teaching science as a subject even at primary school, the serious study of science starts at the upper primary or secondary school level. Therefore a lack of gender equity at the basic level will be the beginning of inequality at the higher levels not only in education in general but more specifically in science, mathematics and technology.

8.3.1 Gender Equity in Africa

In general, there is gender inequality in education in most countries of the world, with females being disadvantaged. The unacceptably state of affairs has long been recognised. In Africa the gender gap in education and hence in most areas of human endeavour is wide.

In recognition of this problem the Forum for African Women Educationists (FAWE) was founded in 1992. The goal of FAWE is to close the gender gap in education in Africa where women continue to lag behind men both in access to and continued participation in education .

8.3.2 Participation in Science Education in Schools

All pupils in primary school study science, where it is called names such as general science and integrated science. The participation in science at the secondary school level is a function of the secondary and the proportion of those who study science at the secondary school level. There is low participation in physical sciences at high school as well as a gender and race/gap in enrolment patterns in biology, physics and chemistry with the greatest difference in physical sciences. **In** most countries students at the upper secondary school are supposed to offer one compulsory science subject. Most students offer Biology with a few taking chemistry, physics or physical science (Lewin 1990). For example in Nigeria in the Senior Secondary School (SSS) about 93% studied Biology, about 30% chemistry and 16% physics (Okebukola 1995).

Activity 8.2: Which science subject is offered most in Nigeria?

8.3.3 Performance in Science in Schools

Performance in science subjects is generally poor. There are fewer 'A' grades in science, than in English or Mathematics, there are also gender disparities in Mathematics and Science.

8.3.4 Some Reason for Disparities

A reason for low (GERS) in schooling, low participation in science and poor performance in science education is an interaction between supply, demand and the learning process. Supply refers to the availability and quality of science facilities, materials and teachers. Decisions made by parents based on opportunity costs of schooling, and religion cultures, create the demand. The learning process involves the experiences that children have in school that are linked to the curriculum (Lockheed & Verspor 1891). Disparities between groups arise for different reasons; one reason for the lower participation of girls is a lack of demand because of family and societal view about schooling for girls. Furthermore curriculum inadequacies and different treatment in the classroom of female students by both male and female teachers affect performance.

Schools are far apart in rural areas with a low population density. Inhabitants are generally poor and cannot absorb the extra cost of schooling. For children living far from school there are transport cost and time spent, walking to and fro school reduces time for household maintenance and production chores, especially for girls. In poor families, particularly in rural areas, such child labour is often critical to family survival. Gender differences are more acute when desegregated by urban-rural residence.

Many rural schools only offer three to four grades and lack resources such as teachers, materials, facilities and equipments. They often have more than one grade level per class. Teachers either treat the whole class as a single grade level, or, if there are two grades per class, each grade level gets half the attention. Also the language of instruction may not be that of the local population and often the curricula arc taught in a national urban language that is not understood in the rural areas. (Reddy 1998).

Activity 8.3: State three reasons for th' disparities between urban and rural pupils.

8.4 Equity in Science c.k

So far you have looked at feminism and science education. Gender equity and science education in Africa, and some reasons for disparities. Now you are going to study the reasons for equity in science. Achieving equity in science is important because of its relationship to economic development: many countries with successful recent histories in economic development have invested in human resources development at primary and later at secondary levels achieving approximately universal level of enrolment. These countries have also stressed the study of science during the period when economic growth was most rapid. To ensure economic growth, one of the necessary but not sufficient conditions is that all the population be educated (Lewin 1992). In a democratic country, all groups should receive a quality education.

Harding (1992) and Erinosho (1994) list reasons why science education should involve girls and women. The reasons would apply to all disadvantaged groups and are compelling:

- Equity of opportunity is necessary so both sexes can be part of mainstream development.
- Equity is important for technological and socio-economic development.
- There is a need for more female scientists in decision making position to enable them control the direction of technological research and promote policies that favour females .
- Science is exciting and its study promotes intellectual understanding, exploration and mastery of the environment.
- If women suffer discrimination in science a lack of appropriate qualifications will limit their financial rewards and bar them from prestigious positions.
- Being excluded from science would lead to a sense of alienation among women.

8.4.1 Causes of Girls' Poor Participation in Science Education

The issue of gender equity in education needs urgent attention, not only because females have a right to education, but more importantly because education of all human resource is a key factor to development. Furthermore, given their roles in a home the education of females in SMT has proved to be a powerful factor in eliminating major problems that cripple the continent, such as preventable diseases and household poverty. Therefore, Africa has a pressing need to ensure gender equity in science education. However, countries of sub-Saharan Africa, like any part of the world that endeavours to close the gender gap must first identify and understand the causes of this gap to ensure that the strategies developed to redress the situation are appropriate and hence likely to succeed.

Reasons for the Gender Gap in Education in Africa

In Africa, the factors that militate against girl's access and participation in education have long been known. Most current Africa regional studies such as the UNESCO special project on STYE and FEMSA reiterate them. The major overriding factors for girls' poor access and continued participation in education are the negative attitudes of society towards the education of girls and poverty at the household level.

The Negative Attitude of Society Towards Girls' Education

Most African societies still believe that girls and women do not need much education to perform their roles which are unfortunately still believed to be limited to the home. Therefore, preference is almost always given to educating the boy who is still perceived as the 'bread winner and head of any family' The FEMSA 1997 studies revealed that specific key stakeholders in girls' education such as parents, teachers, peers, policy-makers and even the girls themselves, still nurse the view, and hence only pay lip service to the issues of girls education. Consequently, little or no effort is put into strategies to increase girls' access and continued participation in education.

Poverty at the Household Level

Africa is the most poverty-stricken region of the world where most people live below the poverty line. Many people cannot afford to send their children to formal school. Girls are often kept out of school to help with the harvest or petty trading to improve the house income. When the poor financial situation forces them to choose whom to educate, parents will almost invariably educate the boy in preference to the girl. This is because, apart from the lack of appreciation of the importance of girls' education, the chances for successful completion of any course are higher for boys than girls. The result is that many girls do not only miss a chance for education, but some are even withdrawn from school so that the money could be spent on the education of their brothers. Worse, some girls may be married early so that their parents can get the dowry to help alleviate family financial problems. Other factors that affect girls' access and participation include pregnancies, poor academic performance due to a host of reasons beyond the girls' control, and even lack of physical facilities that provide a conducive environment for girls' education, such as appropriate sanitary and sitting facilities at school.

Negative Attitudes

There is a strong, deep-seated, traditional and conservative belief among parents, teachers and students including the girls themselves, that the study of SMT subject is only for boys and men. They continue to consciously or unconsciously, believe that girls lack the ability and determination to study and succeed in these 'very difficult' SMT subjects. Therefore, despite lip service to the equality of girls and boys, many people including teachers, advise and actively discourage girls from studying SMT subjects. Moreover, the girls believe that even if they succeed in SMT, there are few opportunities for them and they are not likely to attain their full potential in what they perceive to be male-dominated professions.

Lack of Awareness of Gender Issues in Education

Many teachers are not aware of gender issues in education and of the special difficulties that girls face in learning SMT. They are insensitive to the different out-of-school experiences that girls bring to the study of SMT and the fact that the current SMT content in most countries in Africa builds more on male than female experiences. They do not take account of the anxiety many girls experience when topics such as hygiene and reproduction are discussed in the classroom or when girls are asked to use unfamiliar equipment and apparatus or live specimens. Teachers fail to understand when girls, especially from traditional and conservative backgrounds, seem unwilling to enter discussions or ask questions, especially in mixed classrooms. The girls therefore appear less bright and capable than boys. and end tip performing badly and dropping out of SMT. e4-0.2

Activity 8.4: State two reasons why there should be gender balance in science.

8.5 Planning for Equity

Policy is a blunt instrument to produce intended educational change Reasons why changes have not yet been effected include:

- Shortage of well-trained and motivated teachers
- Failure to implement curricula because of lack of resources.
- Failure to consider prevailing national conditions
- Not involving teachers in policy formulation.

A lack of planning and coordination between those institutions concerned with provision of science education. (Lewis 1995). It is important to point out that having equity will require more than language of the educational policy. Planning, programming, management, implementation, monitoring and evaluation must ail have an equity perspective.

8.6 Conclusion

In this unit you have discussed the reasons for gender disparity, the need for equity in science and ways through which equity could be attained.

8.7 Summary

No doubt there is need for equity in science instruction. However this require short term and long term plans.

8.8 Tutor Marked Assignment

Justify the huge amount the government is spending to ensure gender equity in science education.

8.9 References

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UNIT 9

Analogy, Metaphor and Scientific Thinking

9.0 Introduction

Analogy and metaphor are used constantly in science textbooks and by teachers to explain science in terms that students can comprehend: the apt use of metaphor is often the key to pedagogical success. A good deal of science method courses are devoted to practice in the use of metaphor and models. In this unit you will study; metaphor, analogy, models and scientific thinking.

9.1 Objectives

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

- Speak very figuratively
- Write scientific essays using metaphors
- Interpret sentences containing analogy(ies) very correctly
- Explain abstract issues, using models.

9.2 Metaphors and Analogies

The use of metaphor and analogy in science teaching is increasingly researched (Du it 1991). What is often overlooked in this research is the degree to which metaphor is present in the content of scientific theory. It is not the case that there is non-metaphorical science content that then has to be made intelligible metaphor: analogy and metaphor are present within science. The use of metaphor in both science and education gives rise to interesting epistemological questions that can be encouraged in Teacher Training. This is another way in which philosophy can contribute to reflective and informed science teacher education. Some examples will indicate the issues.

9.2.1 Newton's Principia

Exemplifies the problem of metaphor in science. He goes to great length in the introductory definitions to point out that his treatment of motion will be a mathematical treatment:

> "the words attraction" and "impulse" or any "propensity" to a centre, however, I employ indifferently and interchangeably, considering these force not physically but merely mathematically. The reader should hence beware lest he thinks that by words of this sort 1 anywhere define a species or mode of action or physical cause and reason.

After Newton had derived the mathematical relation between bodies, he gave it a commonplace name 'attraction' — because that was the only way to make the relation intelligible, but stressed that this was to be understood metaphorically. It is well known how his followers and the originators of the corpuscularian world view, lost sight of the metaphorical quality of Newton's description. Newton correspondence with Richard Bently, the first Boyle lecturer is in part concerned with pulling Bendy back from his literalist non-mathematical interpretations of the principia's definition.

Newton urges caution:

> "You sometimes speak of gravity as essential and inherent to matter. Pray do not ascribe that notion to me, for the cause of gravity is what I do not pretend to know and therefore would take more time to consider it" (Thayer 1953,53).

Activity 9.1: *Explain how Newton's princtpia serves as an example of metaphor in science.*

9.2.2 John Locke's Explanation

John Locke was the philosopher -champion of Newton and self-styled underlabour in Newton's garden he struggled over the same matters as Bently in the three editions of his famous essay "Concerning Human Understanding (1690, 1694, 1695). Locke enunciated the basic tenets of the mechanical worldview, saying that "bodies operate one upon the another ... by impulse and nothing else". Increasingly he came to appreciate the contradiction between these tenets and the foundation of the principia, which had been published in 1687. In a letter to a fellow philosopher he admits that:

It is true I say, "that bodies operate by impulse and nothing else". And so I thought when I write it, and can yet conceive no other way of their operation. But I am since conceived by the judicious Mr. Newton's incomparable book, that it is too bold a presumption to limit God's power, in this point by my narrow conceptions. The gravitation of matter towards matter, by ways inconceivable to me, is not only a demonstration that God can ... and therefore in the next edition I shall take care to have that passage rectified (Stein 1990,32).

Activity 9.2: *What were the basic tenets of Locke :v mechanical work/view?*

Matthews (1994) reports that book 2 of the fourth edition of the essay (1700) contained these changes, which were the first changes within philosophical atomism, or the mechanistic worldview, prompted by modern science. He points out that this is an example of the interaction of physics and metaphysics.

The problem with which Newton was grappling in the seventeenth century was felt more accurately after the scientific advances of the nineteenth century and early twentieth centuries. Eddington (1928) describes the situation as follows: "it is difficult to school ourselves to treat the physical world as purely symbolic. We are always relapsing and mixing with the symbolic in congruous conceptions taken from the world of consciousness ... Indeed, unless we confine ourselves altogether to mathematical symbolism, it is hard to avoid dressing our symbols in deceitful clothing. When I think of an electron there rises to my mind a hard, red tiny ball." (Eddington I 928/1978).

This comment was made in the context of Eddington's idealist worldview, but the problem of speaking metaphorically — is just as pressing for realists. Matthews (1994) suggests that one aid to untangling the conceptual issues is to distinguish the realms of the natural world and the theorized world with which science deals.

Activity 9.3: *The problems Newton grappled with in the 17111 century became easier in the 19th century yes/no (tick)*

9.3 Darwinian Theory and Analogy

You have so far followed the development of science in which mathematical expressions were expressed in phrases and sentences to suggest some meanings to them using examples from Newton and Locke. These phrases and sentences were metaphorical in nature. In 9.3 you are going to read about Darwinian theory and analogy.

Darwinian theory with its 'struggle for existence' "war of nature" trace of life and "survival of the fittest" is full of metaphorical expression that can aid and also deflect understanding. Darwin's reconciliation of his gradualist assumptions with the abrupt breaks found in the fossil record, by use of the analogy of damaged book with chapters, pages, paragraphs, sentence and words missing, is an outstanding instance of analogy in science.

Many other philosophers discussed metaphor and analogy. For example Black (1962) asserts that performing every science must start with metaphor and end with algebra; and perhaps without the metaphor there would never have been any algebra.

The write up in this unit so far shows that science makes powerful use of metaphor and analogy, both of which draw upon everyday or prescientific conceptions. A constant problem for teachers and students is to keep apart the technical or scientific meanings of concepts and commonplace images so often used to make the technical images comprehensible. A foundation course in science for teacher training calls for consideration of the number of rich epistemogical, ontogical and psychological issues occasioned by the constant metaphorical and analogical conversation of classrooms and textbooks. Analogies played a key role in the historical development of scientific knowledge, (Hesse 1966). Analogies appear to be powerful tools for students learning in schools. Several approaches exist for using analogies in teaching for example Glynn's (1991) six stage teaching with analogies. Glynn (1989) investigated the value of analogies used by textbook authors and they assert that their teaching with analogies model of using analogies can stimulate students to generalize what they have learned and apply their learning to other concepts.

9.4 Models in Science

An important part of the process of scientific investigation is the development of models. Models of all sorts are being constructed and matters formerly identified with common words like hypothesis, theory and empirical equation are now often called models. The term model is now used in most ambiguous and elusive way i.e. as a noun (representation) or an adjective (description of perfection) or verb (demonstration).

A model is simplified representation of reality. Models are constructed to test explanations and provide feedback to those trying to understand scientific phenomena. Many students see models of scientific phenomena as sample copies, of observable events rather than as explanations or conjectures about relationship.

In science reference is made to basically three different models: the iconic, the analogue and the symbolic. In general, however iconic and analogues models are used as a preliminary to the development of symbolic models which are the most useful type.

Activity 9.4: What is a model?

9.4.1 Iconic Models

An iconic model looks like what it represents model house, skeleton, car etc. Iconic models are concrete objects. However scientists find them difficult to manipulate for purposes of determining the effect of change on real things. For example if you model a plastic heart, changes in human temperature would not register at all.

9.4.2 Analogue Models

In this model on characteristic or property is used to represent another e.g. colour or shading in a diagram to represent a specific property such as elevation. In the analogue model the easier to manipulate characteristics are usually substituted for the real and difficult ones thus you are taken further away from the real thing. A graph is a good example of the analogue model. Fig. 9.1 shows the population growth of bacteria. By the use of simple lines we can show the following: the time of minimum growth, the time of maximum growth and the growth curve.

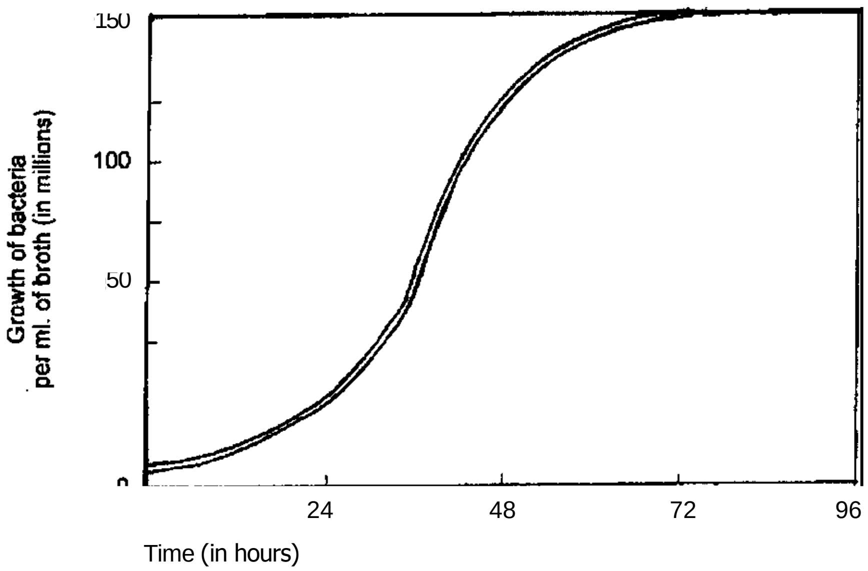

Fig. 9.1: *Population Growth of Bacteria*

9.4.2.1 Population Growth of Bacteria

Thus from a simple arrangement of lines you can derive much information.

9.4.3 Symbolic Models

These are the most abstract models to be considered in this discussion. Analogue models facilitate the use of iconic models in that difficult properties are substituted or altered to permit ease of manipulation. In symbolic models all properties are represented by conventional notation e.g. $K.E = 1/4MV^2$ .This means that you have taken away in the corner of your mind, an idea or model that holds true calculating the kinetic energy of moving objectives. Symbolic models are less complicated than reality and hence easier to use for research purposes and easier to manipulate and carry about than the real thing.

Models of such things as atoms, genes, DNA, protein and the universe, consist of inferences to describe and explain structure and reactions of matter in cases we can observe indirectly. However this construct is an analogy and no one expects an analogy to be completely accurate. Thus we can say that models represent relationships that are helpful in understanding data. There must be some kind of relationship or "fit" between the data and the model.

Activity 9.5: Name the three types of models

9.5 Conclusion

In this unit you have learnt that the use of metaphor and analogy in both science and education gave rise to interesting epistemological questions such as those of Newton's principia, John Lock and Darwin. Science makes powerful use of metaphor and analogy both which draw upon everyday or prescientific conceptions. Models represent relationships that are helpful in understanding data. There are three types of models namely iconic, analogue and symbolic.

9.6 Summary

In this unit you found out that early development of theories, concepts and scientific knowledge were based on mathematical constructs, which were later translated to metaphors, and analogies for better understanding also that models help in understanding of abstract ideas such as DNA.

9.7 Tutor Marked Assignments

I Discuss how philosophy can contribute to reflective and informed science teacher education.

2. How are models used to improve the understanding of scientific knowledge?

98 References

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UNIT 10

Constructivism

10.0 Introduction

Constructivism in science education has its roots in a reaction against two features dominating science curriculum reforms in the 1960s and 1970s -an epistemology based on naive empiricism (Harris and Taylor, 1983) and a development stage model of cognitive growth which was interpreted as implying deterministic limitations to children's capabilities. Driver and Basely (1978) initiated the reaction of these schools of thought when they argued that "achievement in science depends to a greater extent upon specific abilities and prior experience than general levels of cognitive functioning". From here, research based on this premise developed rapidly, as did attempts to evolve a theoretical base for the empirical findings to the point where the growth of publications in this field has become almost exponential (Duit 1993). Such is the dominance of this school of thought that it has been contended that it offers a new paradigm for science education (Tobin et al 1994) and it has acquired implicitly the status of a meta or "grand theory".

10.1 Objectives

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

- Explain constructiv ism.
- Show that constructivism has many forms.
- State the constructivism view of learning.
- Describe the implications of constructivism to science teaching.
- Describe radical constructivism theory.

10.2 What is Constructivism?

There are two basic traditions of constructivism. The first is psychological constructivism originating from Jean Piaget's account of children's learning as a process of personal individual, intellectual construction arising from their activity in the world. The second is epistemological which emphasizes that knowledge cannot be separated from knowing. These two principles which make up von Glasserfield (1990) radical constructivism, often serve as a reference position for discussions of constructivism in education.

The first principle states that knowledge is not received passively but is built up by the cognising subject. In other words, it is not possible to transfer ideas into student's heads intact, rather students construct their own meanings from the words or visual images they hear or see. Consequently, when engaging in a this construction of meaning, what the learner already knows is of central importance.

The second principle states that the function of cognition is adaptive and enables the learner to construct viable explanation of experiences. Consequently, knowledge about the "world outside" is viewed as a human construction. A 'reality' outside is not denied, but it is possible to know about that reality only in a personal and subjective way (von Glasserfield 1990). This second principle is controversial for some educators as at first sight, it appears that it might never be possible to understand what anyone else is saying or meaning, and it might not be possible to understand the meaning that is given to what we all accept as known, particularly in science. Rather than being concerned with knowledge as the representation of the truth, constructivism focuses on the way in which learners construct viable and useful knowledge. According to this position, the only constructions that survive are those that prove to be successful in dealing with multiple contexts in which the learner is engaged.

A third aspect highlights the fact that although individual have to construct their own meanings of a new phenomenon or idea, the process of constructing always is embedded within the social setting of which the individual is a part.

Activity 10.1: (i) State the first principle of constructivism
(ii) Which are the only constructions that survive ?

10.3 Epistemological and Ontological Commitments

10.3.1Epistemological Commitments

According to Matthew (1994) constructivism emphasizes that science is a creative human endeavour which is historically and culturally conditioned and that its knowledge claims are not absolute. As its core constructivism has a subjectivist, empiricist and personalist understanding of human knowledge and consequently of scientific knowledge, hence Glasserfield (1990) states: "Knowledge is the result of an individual subjects constructive activity not a commodity that somehow resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication.

However epistemology even when supposedly abandoned is vital to constructivism, it drives constructivist education theory and practice. Constructivists adopt most of the epistemological theses of postpositive philosophy of science. These theses have been well summarized in Garrison (1986). Some of them are:

(i) Observational statements are always dependent upon particular theoretical systems for their expression. There is a difference between 'seeing' and "seeing as".
(ii) The distinction between observational and theoretical terms in a theory can only be made on pragmatic grounds not on epistemic grounds.
(Hi) Observations themselves are theoretically dependent or determined, what people look for and notice is influenced by what they want to see or what they regard as relevant to an investigation.
(iv) Theories are always underdetermined by empirical evidence, no matter how much such evidence is accumulated. For any set of data, any number of theories can be constructed to have that data as an implication; for any data points on a graph, any number of curves can be drawn through them.
(v) Theories are immune form empirical disproof or falsification because adjustments can always be made to their auxiliary assumptions to accommodate the discordant evidence, there can be no crucial experiments in science.

However, Lerman (1989) suggests that the core epistemological theses of psychological constructivism are:

(i) Knowledge is actively constructed by the cognising subject, not passively received from the environment.
(ii) Coming to know is an adaptive process that organizes one's experiential world, it does not discover an independent, pre-existing world outside the mind of the knower.

Activity 10.2: State one of the theses of post positivist philosophy of science.

10.3.2 Ontological Commitments

Constructivists often embrace an idealist ontology, or idealist theory about the existential status of scientific and everyday objects. Idealist ontology maintain that the world is created by and dependent upon human thought. Von Glasserfield radical constructivism is the best known idealist variant in educational circles. He states:

> The realist believes his constructs to be a replica or reflection of independently existing structure, while the constructivist remain aware of the experience's role as originator of all structure for the constructivist there is no structure other than those which the knower constitutes by his own very activity of co-ordination of experiential particles. (Glasserfield, 1987).

Also this idealism has been carried through by the Edinburgh school. Latour & Woolgar (1986) say that reality is the consequence rather than the cause of scientific construction. All realists acknowledge that reality does not just imprint itself on the mind of scientific or observers. Science does not deal with real objects per se but with real objects as they are depicted by the theoretical apparatus of sciences i.e. falling coloured balls becomes point masses with specified accelerations, fields of peas phenotype of particular descriptions, bubbling solutions becomes chemical equations etc. The fact that the theoretical apparatus is humanly constructed, and that natural objects are only considered in theoretical-dress, does not imply that the real objects are human creations, or that the real objects have no part in the appraisal of the scientific worth of the conceptual structures brought to bear upon them.

The common constructivist move is from uncontroversial, almost self-evident premises, stating that knowledge is a human creation that it is historically and culturally bound, and that it is not absolute, to the conclusion that knowledge is claims are either unfounded or relativist. (Mathews 1994).

Activity 10.3 • State the idealist theory

- *Reality is not the consequences rather than the cause of scientific construction Yes/No.*

10.4 Constructivist Teaching Practice

In section 10.3 and 10.3.2 you read about epistemological commitment or how do we know commitment? And ontological or what do we know commitment respectively as philosophical thoughts under constructivism. In section 10.4 you are going to learn about the constructivist teaching practice.

There are many constructivist inspired teaching methods. Some of the prominent ones are Driver and Oldham (1986), Schecker and Niedderer (1982) just to mention a few. Constructivist methods emphasizes the engagement of the students in the learning process and the importance of prior knowledge or conceptualisation for new learning. Constructivist view of learning have been summarized by Driver and Bell as follows:

- Learning outcomes depend not only on the learning environment but also on the knowledge of the learner
- Learning involves the construction of meanings. Meaning constructed by Students from what they see or hear may not be those intented Construction of a meaning is influenced to a large extent by our existing knowledge.
- The construction of meaning is a continuous and active process.
- Meaning once constructed, are evaluated and can be accepted or rejected.
- Learners have the final responsibility for their learning.
- There are patterns in the type of meaning Students construct due to shared experiences with the physical world and through natural language.

It is necessary to point out that most of the constructivist teaching techniques and understanding of learning are not unique to constructivism, much of the best constructivist technique-with its emphasis on activity engaging the learner in their own learning and paying attention to their own learning and paying attention to their prior beliefs and conceptualisation of students have been in existence for a very long time.

Activity 10.4: One constructivist view of learning is .... please complete the sentence.

10.5 Radical Constructivist Theory

Ernst Von Glasserfield has had greater influence on the development of constructivist theory in mathematics and science education in the past decades. According to Matthews (1994) he has published over one hundred papers, book chapters and books. Von Glasersfeld is an advocate of "Radical constructivism" a position based on the "the practice of psycholinguistics, cognitive psychology and-the works of Jean Piaget".

He gives perhaps the most systematic account of the epistemological and ontological underpinnings of psychological constructivism that can be found in the educational literature. He has come up with what is referred to as von Glasserfeld's principles or perhaps von Glasserfeld's philosophy (VGP) and it subsumes a number of epistemological and ontological theses, among which are the following:

(i) Knowledge is not an observer independent world.
(ii) Knowledge does not represent such a world; correspondence theories of knowledge are mistaken.
(iii) Knowledge is created by individuals in a historical and cultural context.
(iv) Knowledge refers to individual experience rather than to the world.
(v) Knowledge is constituted by individual conceptual structures.
(vi) Conceptual structures constitute knowledge when individuals regard them as viable in relationship to their experience, constructivism is a form of pragmatism.
(vii) There are no preferred epistemic conceptual structure, constructivism is a relative doctrine.
(viii) Knowledge is the appropriate ordering of an experiental reality.
(ix) There is no rationally accessible extra experiential reality.

Some problems with VGP as delineated will not be considered under the present programme.

Activity 10.5: Give two reasons why Ernst Von Glasserfield is called the Father of Radical Constructivism.

10.6 Implication for Teaching Science

You have learnt in this unit that learner's respond to their sensory experiences by building or constructing in their minds, schemes or cognitive structures which constitute the meaning and understanding of their world. Individuals attempt to make sense of whatever situation or phenomenon they encounter, and a consequence of this sense making process (a process which takes place within the minds of these individuals) is the establishment of structures in the mind.

These structures or schemes as they are often called can be thought of as one' s beliefs, understandings and explanations in short one's necessarily subjective knowledge of the world. Because it is created in the mind of the learner, it cannot simply be told to the student by the teacher.

It is important to note that these mental constructions are often not in accord with those of the community of scientists or those given in textbooks and as such described variously as: misconceptions, alternative conceptions and intuitive concepts (Saunders, 1992).

The constructivist perspective holds that meaningful learning or understanding is constructed in the internal word of the learner as a result of his or her sensory experiences with the world (hence it cannot be told to the student by the teacher). The teacher in the classroom serves as a guide or facilitator. While these understandings or schemes tend to resist change, they can change as a result of disequilibration. The implications for classroom instruction include the ample use of hands' on investigative laboratory activities, a classroom environment which provides the learners with a high degree of active cognitive involvement, use of cooperative learning strategies and the inclusion of test items which activate higher level cognitive processes.

Activity 10.6: What is a scientijic misconception?

10.7 Conclusion

In this unit you have learnt that there are two types of constructivism: psychological and epistemological. That knowledge about the world outside is viewed as human construction. The constructivist epistemological and ontological commitment, the constructivist teaching practice which calls for special teaching models like that of Driver and Oldham (1986). The learner is responsible for his/her own learning as the teacher is just a facilitator. Von Glasserfield is the advocate of Radical Constructivism. Misconceptions and how to remediate them were also discussed.

10.8 Summary

Constructivism has become a dominant paradigm in the field of education including science education. Also the growing body of literature in this area is beginning to provide unprecedented insight into the nature of the learning process especially those cognitive processes thought to underlie meaningful learning. You will therefore enjoy the next unit which is dealing with history of science and the psychology of learning.

10.9 Tutor Marked Assignments

- Describe the two basic traditions of Constructivism.
  What is the relevance of studying the epistemological and ontological commitments of constructivism?
- State five statements of the consstructivist view of learning as summarised by Driver and Bell.
- How should misconceptions be handled in the classroom to ensure meaningful learning.

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UNIT 11

History of Science and the Psychology of Learning

11.0 Introduction

The study of the History and Philosophy of Science (UPS) in teacher education has been in terms of its contribution to the teaching of specific subject matter, its integrative function in bringing science and other disciplines together and its importance for teachers to understand their occupation. But in recent times UPS is seen to be relevant to problems in the learning of the sciences. A significant part of the recent UPS and science teaching literature has been concerned with the conjunction of H PS and the psychology of learning. In this unit you will learn about Jean Piaget, David P. Ausubel, Jerome S. Brunner and Robert Gagne. These are cognitive psychologists whose work have had tremendous impact on primary and secondary school science teaching and teaming. Also you will learn about the work of Peter W. Henson and others on teaching for conceptual change.

11.1 Objectives

At the end of this unit, you should be able to:

- Discuss history of science and the psychology of learning.
- Describe the work of Henson and others on conceptual change.
- Explain the contributions of cognitive psychologists like Piaget, Ausabel, Brunner and Gagne to primary and secondary school science teaching and learning.

11.2 History of Science and Psychology of Learning

Over the years the methods and concepts of cognitive psychology have been used to study science and its processes (Jung, 1993). The view was given its most influential exposition in the writings of Jean Piaget; indeed it underlies his account of cognitive development. Kitcher (1988) suggests that historians and philosophers of science can learn from the experimental results and analyses of child psychologists. From the historical perspective, Steinberg and others (1990) showed how the study of Newtons conceptual development of impetus theory towards inertial mechanics in his 1687 principia can illuminate the conceptual journey that modem students have to make from their naive non inertial misconceptions to an understanding of the mechanics of Mature Newton. Also Gruber (1974) has provided a Piagetian study of Darwin's conceptual development.

Activity 11.1: *What is Kitcher 's advice to historians and philosophers about learning science?*

11.3 Hewson and Others and Teaching for Conceptual Change

A model of conceptual change was developed by Posner. Strike. Hewson and Gertyog (1982) at Cornell University and was expounded by Hewson (198 I. 1982). It describes learning as a process in which a person changes his or her conceptions by capturing new conceptions, restructuring existing conceptions or exchanging existing conceptions for new conceptions (i.e. a process of conceptual change). Matthews (1994) states that important studies of individual conceptual change in science that is science learning, have made use of historical and philosophical theses. Hewsons (1981) initial formulation of the conceptual change model of science learning quotes Kuhn and Lakatos on the conditions for theory change and following the latter reports that some of the most important conceptions influencing conceptual change in an individual were found to be ... the metaphysical and epistemological commitments which he or she held." This conceptual change model which Hewson contributed drew upon the accounts of scientific theory change given by Kuhn, Toulmin and Lakatos. They propose that for individual conceptual change or learning to take place, four conditions must be met:

- There must be dissatisfaction with current conceptions.
- The proposed replacement conception must be intelligible.
- The new conception must be initially plausible.
- The new conception must offer solutions to old problems and to novel ones, it must suggest the possibility of a fruitful research program.

Also Strike and Posner in retrospect. describe their original conceptual change theory as largely an epistemological theory and not a psychological theory. Carey (1985) a psychologist has suggested that success in comprehending the complexity of conceptual change in science students will require the collaboration of cognitive scientists and science educators who together must be aware of the understanding of science provided by both historians and philosophers of science.

Activity 11.2: *State Iwo conditions that must be met before individual conceptual change take place.*

11.4 Contributions of Piaget, Gagne, Ausubel and Brunner to Science Teaching and Learning

Conceptual change is one of the strategies for correcting children's misconceptions in science. Compared with the work of the cognitive psychologists like Ausubel, it is quite a recent development. But in this part of the unit 11.4 you will study the contributions of those whose work led to the development of the conceptual change. Prominent among them are Piaget and Ausubel.

11.4.1 Jean Piaget

Piaget's developmental psychology has become an important guide •in science materials development particularly at the primary school level. His major work was the characterization of specific intellectual development stages of children. Piaget believes that individuals pass through four stages of mental development namely:

Sensorimotor stage 0-2 years
Preoperational stage 2-7 years
Concrete operational 7-11 years
Formal operational 11-14 years.

Table 11.1 Intellectual Development Stages

CODE	DEVELOPMENTAL STAGE	GENERAL AGE RANGE	CHARACTERISTICS OF STAGE PERTAINING TO PROBLEM-SOLVING ACTIVITIES; COMMENTS AND EXAMPLES .
I A	Sensorimotor	Birth to approximately I 8 months	Stage is preverbal. An object "exists" only when in the perceptual field of the child. Hidden objects are located through random physical searching. Practical basis knowledge is developed which forms the substructure of later representational knowledge.
I B	Preoperational or "representational"	IS months to 7- 8 years	Stage marks the beginning of organized language and symbolic function, and, as a result, thought and representation develop. The child is simple-goal directed; activity includes crude trial-and-error corrections. The child lacks the ability to coordinate variables, has difficulty in realizing that an object has several properties, and is commonly satisfied with multiple and contradictory formulations. Since the concepts of conversation are not yet developed, the child lacks operational reversibility in thought and action.
II A	Concrete operations	7 -8 years to 11-12 years	Thinking is concrete rather than abstract, but the child can now perform elementary logical operations and make elementary, groupings of classes and relations (e,g, serial ordering). The concepts of conservation develop (first of number, then of substance, length, of area, of weight, and finally of volume in the next developmental stage). The concept of reversibility develops.
II B			The child is unable to isolate variables, and proceeds from step to step in thinking without relating each link to all others.
A	prepositional or "formal operations"	II -12 years to 14 -1 5 years	This stage of formal (abstract) thought is marked by the appearance of hypothetical-deductive reasoning based upon the logic of all possible combinations; the development of a combinatorial system and unification of operations into a structured whole. The development of the ability to perform controlled experimentation, setting all factors "equal" but one variable (in substage rnA the child's formal logic is superior to his experimental capacity). Individuals discover that a particular factor can be eliminated to analyse its role, or the roles of associated factors. The reversal of direction between reality and possibility (variables are hypothesized before experimentation).
B		14- 15 years	Individuals discover that factors can be separated by neutralization as well as by exclusion, The individual can use interpropositional operations, combining propositions by conjunction, disjunction, negation, onward and implication (all rise in the course of experimental manipulation).

Gbamanja (1991) is of the view that Piaget believes that the learners rational understanding of the environment depends to a large extent upon the quality of his mental operations. Surely experiences should nurture the development of the child. Teachers should therefore be designing experiences to insure that students have opportunities to perform desirable mental operations.

According to Piaget, the child's mental process is limited to thinking about things when the age is 6-12 years. The child's concepts of quantity, time, space, conservation and reversibility develop during this period. The learner can classify things at this stage and he acquires logical processes of observing, describing, classifying and measuring real objects. Learning should go from simple to complex and importantly the learner should deal with concrete materials first before going to complex and he can learn abstract concepts and generalizations.

Piaget's cognitive theory: Piaget's work has relevance to science teaching: Piaget's learners must occupy themselves with exploration particularly at the primary stages. Problem solving rather than role memorization should be the focus of science.

Exploration and interaction with environment using locally available materials should be promoted by the teacher.

Activity 11.4: *State two implication of Pictgets stage theo v to science teaching.*

11.4.2 Jerome Brunner

Brunner's theory centres on learning through discovery as mentioned earlier. He maintains that the learner should obtain knowledge by himself/herself through the use of materials and the learner's mental processes. Brunner (1960) postulates two forms of discovery processes thus:

(i) the learner spontaneously recognizes a new situation that is familiar to the one of the elements in his existing structure of knowledge which she easily assimilates or

(ii) the learner sees a new situation not familiar to his/her existing structure of knowledge.

In this case (ii) the learner first restructures his cognitive framework so that the new information material can be accommodated. To Brunner, assimilation and accommodation are two forms of discovery learning. It is noteworthy that Brunner's discovery learning is consistent with the "paradigm shift" concept of the nature of science. Brunner urges teachers to expose the learner to problems that form contradictions in their source of information given in instruction. Under this condition, the learner gets 'intellectual discomfort' as a result of such incongruities or contradictions and she will undergo 'cognitive restructuring' leading to individual discovery(ies). A discovery activity involves mental processes like observing, measuring, inferring, classifying, hypothesizing etc. which are also the expected roles of the learners in science learning. Brunner states that knowledge acquired through discovery learning and problem solving has the highest retention .

Activity 11.5: *What are the Iwo 'bons of discovery learning?*

11.4.3 Robert Gagne

Gagne's theory of learning Hierarchy states that the learning of a new concept or skill depends upon the mastery of prerequisite concepts or skills. This means that any knowledge can be acquired by learners who already have certain prerequisite. Gagne believes that prior knowledge may determine what further learning may occur. He emphasizes the importance of task analysis of instructional objectives. He believes in task analysis of the concepts, skills and knowledge to be taught. Gagne believes that learning structure which results from task analysis is a system of learning hierarchy of intellectual operations.

Gagne states that materials to be learnt must be sequentially structured by the teacher from simple to complex until the desired objective is achieved. Problem solving is the highest level of learning in Gagne's hierarchy of learning. Lower levels involve facts; concepts, and generalizations. Learning should proceed from simple to complex. Gagne suggests that in a teaching situation the teacher should begin with a question like "What is it that I want the learner to be able to do? This objective must be stated in behavioural form. According to Gagne, learning occurs when the learner is capable to do something which she/he was originally unable to do. According to Gagne, science teachers need to state specifically the objectives for learning any material and learning tasks have to be sequentially organized so that learning can take place.

Activity 11.5. *The highest level of learning hierarchy is: (choose the correct answer).*

- *task analysis*
- *accommodation*
- *problem solving*
- *prerequisites*

11.4.4David P. Ausubel

Ausubel like Gagne believes in meaningful learning i.e. careful sequencing of experiences so that any unit taught is related to previous experiences. According to Ogunniyi (1986), it is the continuity and relatibility between the learners' existing cognitive structure and the material to be learned that makes the new material meaningful. To Ausubel learning by discovery is time wasting and inefficient. According to Ausubel — those parts of the learner's cognitive structure (i.e. organized knowledge) which provide the necessary interaction necessary for meaningful learning are called subsumers. Ausubel defines a subsumer as a generalized body of knowledge possessed by the learner for anchoring new knowledge. With the assistance of the subsumer the learner is able to relate the new material with what is already known. In the absence of subsumers Ausubel suggests 'advanced organizer'. Ausubel begins the instructional sequence with a set of broad but comprehensive statements at higher level of abstraction to what is to be learned. He calls such statement 'advanced organizers'. These organizing statements are used to link the new material with what the learner already knows (his/her cognitive structure). This can be represented thus:

Learner's Cognitive structure	4-4	Advance Organizer	New Material to be learned

Advanced organizers are useful alternatives to organizers.
Ausubel is an advocate of verbal learning.

Activity 11.6: *In the absence of subs timers, Ausubel suggest the use of* ________________________

11.5 Conclusion

In this unit you have learned that historians and philosophers of science can learn from the work of child psychologists, Hewson and others proposed the conceptual model for correcting misconceptions. For conceptual change, there are four conditions that must be met. That the cognitive psychologists played major roles in the development of learning theories.

11.6 Summary

The study of history of science and psychology of learning is rather abstract and you may have to read it severally to understand it. The conceptual pathway is a strategy for correcting misconceptions and Piaget, Gagne, Brunner and Ausubel are cognitive psychologist who have played major roles in trying to ensure that students understand their science lessons in the next unit you will study.

11.7 Tutor-Marked Assignments

A. What do you understand by conceptual change? Explain the conditions necessary for conceptual change to occur.

B. Describe AusubeEs subsumption theory with the help of specific examples.

11.8 References

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UNIT 12

Science Education and Scientific Literacy

12.0 Introduction

Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education, meaning education in science, mathematics and technology, should help students to develop the understandings and habits of mind they need to become compassionate human beings, able to think for themselves and to face life head on (Rytherfurd Ahlgren 1990). In this unit, you are going to learn about: What science education is, the objectives of science education, the meaning of scientific literacy, who is a scientifically literate person and how scientific literacy could be implemented in the society.

12.1 Objectives

At the end of this unit, you should be able to:

- Explain what science education means
- State the objectives of science education
- Write the definition of science literacy
- Discover who is a scientifically literate person
- Propose ways of implementing scientific literacy in the Nigerian society.

12.2 Meaning of Science Education

Knowledge of science entails knowledge of scientific facts, laws, theories -the products of science, it also entails knowledge of the processes of science as discussed in units three and four of this course. You may wish to review these units before you continue with this unit. But what is science education? According to Ogunniyi (1986) people confuse science and science education, while science like other subjects has well defined disciplines such as: Biology, Chemistry, Physics and Geology, science education cuts across many fields of human endeavour such as: the natural sciences mentioned above, sociology, philosophy, psychology, history, art, language among others.

Science education is not science per se but education in science. While science has very rich content, science education as a reflective subject, is relatively sparse in content. Science education has no real language of its own -that is language with vocabulary rules, sentence structure rules, rules for deriving meanings from sentences, operational definitions or theory of knowledge upon which the discipline is built.

12.2.1 Goals of Science Education

Science education is a field of study concerned with producing a scientifically literate society. Also it lays the foundation for future work in science and science related fields by acquainting the students with certain basic knowledge, skills and attitudes.

Science education is the bedrock upon which scientific and technological development depend. It is believed by most educators that the giant strides made by the developed countries such as Japan, United States of America (U.S.A.) and Britain is not unconnected to the type of science education available in those countries. For example, Ogunniyi (1986) refers to the general view that Japan rose to prominence as a result of the vast investment made by the U.S.A. after the second world war (a form of compensation for the large destruction carried out by the latter) as only a half truth. In reality, the emergence of Japan was based on a sound foundation of mass literacy programme that dates back to the 17th century and even beyond. In other words, Japan's entry into the scientific and technological age is not an accident but as a result of a well planned and implemented science education programme -a programme inspired and sustained by an intellectual tradition and an enlightened political leadership. Even now, the policies that shaped the Japanese science and technology curriculum points to a well thought out science education programme. These according to Goto (2000) are: to foster a rich and vibrant student spirit:

- Provide a firm foundation for life and learning.
- Promote quality education that spurs individuality
- Foster student ability to continuously pursue self-education .
- Inculcate respect for culture and tradition
- Promote international understanding.

Activity 12.1: *State one major difference between science and science education.*
What are the two major goals of science education?
What helped the Japanese to emerge as a developed nation?

12.3 Scientific Literacy

12.3.1 UNESCO and Science for All

In July, 1993 over 400 participants met at UNESCO headquarters in Paris to discuss how, in future, science and technological literacy can be achieved for all and launch project 2000+ — an internationally conceived drive to improve science and technological literacy worldwide. The important facts that emerged from this meeting were:

- Science for scientists is often irrelevant for life within society and suggested a more social and technological approach to science also.
- The heavy overcrowding of science curricular can only be overcome by a radical rethink of the objectives of science education and the emphasis placed on them.

Also the World Conference on Education for all 1990 declared that every person - shall be able to benefit from educational opportunities designed to meet basic learning needs required by human beings to be able to participate fully to improve the quality of their lives, to make informed decisions and to continue learning.

The Jometian conference of 1990 and Project 2000+ conference of (1993) are catalyst, that have awakened the entire countries of the world to search for w:vs of ensuring that their citizens benefit from educational opportunities designed to meet basic learning nc.,:ds.

12.3.2 Definition of Scientific Literacy

According to Penick (1993), there are many ways to define science literacy: from a narrow definition where literacy is the ability to recognise formulae and give correct definition to a more expansive or liberal definition which includes understanding of concepts and some degree of understanding about the nature of science and its historical and social dimensions. According to him, there is no one correct definition of science literacy; it is a matter of different conceptions proving their worth for the promotion of particulars ends.

Some other definitions of scientific literacy Layton (1993) states that scientific literacy has three levels of understanding:

- An understanding of a core knowledge -concepts, facts skills-which might be relatively culture dependent i.e. determined by the specific situation of those involved.

- An understanding of the methodology by which scientists works-how scientists make and validate work knowledge which might be much less culture dependent and
- An understanding of cultures of science, especially their organizations, forms of ownership of control. Rollnick (1998) defines scientific literacy as comprising the knowledge and skills needed to empower students to control their lives at an individual and a societal level, she states that a common misconception of science for all is that it is inferno and therefore not suitable for able students. However she emphasized that, able students and especially those who will become scientists and technologists need to understand societal issues. Designers of course materials for 'science for all' must consider whose science and what science, since society must respect local scientists and technologists, such as traditional healer. Rutherford and Ahlgren (1990) defined scientific literacy as encompassing mathematics and technology as well as the natural and social sciences-has many facts. These include being familiar with the natural world and respecting its unity, being aware of some of the important ways in which mathematics, technology and the sciences depend upon one another, understanding some of the key concerts and principles of science, having a capacity for scientific ways of thinking, knowing that science, mathematics and technology are human enterprises and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for thinking as social purposes.

Activity 12.2: • Name the conferences that prepared the background for the take -off of scientific literacy worldwide.

- *What is Penich's view about definition of scientific literacy?*
- *Scientific literacy encompasses (I)* __________________

  (2) __________________

  (3) __________________

Fill in the gaps I, 2 and 3.

12.4 A Scientifically Literate Person

Rutherford and Ahlgren (1990) defined a scientifically literate person as one who is aware that science, mathematics and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science, is familiar with the natural world and recognises both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes.

The National Science Teachers Association (NSTA) (1991) put forward seventeen points of defining a scientifically, technologically literate person. Also Ogunniyi (1986) listed twelve characteristics a scientifically literate person should demonstrate. Between those two, and taking into consideration some social and cultural factors, Otuka (2001) came up with sixteen characteristics of a scientifically literate Nigerian as follows:

- Uses concepts of science as well as an informed reflection of ethical values, in solving everyday problems and making responsible decisions in everyday life including work and leisure.
- Engages in responsible personal and civic actions after weighing the possible consequences of alternative options.
- Defends decisions and actions using rational argument based on evidence.
- Engages in science for the excitement and the explanations it provides.
- Displays curiosity about the appreciation of the natural and human made world.
- Reads and understands scientific literature of a general nature.
- Recognises that science is a human enterprise primarily concerned with the study of nature.
- Distinguishes between scientific and technological evidence and personal opinion and between reliable and unreliable information.
- Distinguishes between facts and superstitions.
- Appreciates the role of science in the society.

- Searches for objective facts rather than rely on rumours, taboos, superstitions and other authoritative generalisations.
- Develops inquiry skills and problem solving attitudes.
- Recognises the strengths and limitations of science for advancing human welfare.
- Uses scientific knowledge and skills for responsible social actions.
- Considers the political, economic, moral and ethical aspects of science as it relates to personal and global issues.
- Connects science to other human endeavours e.g. history, the arts and humanities.

The list shows that science for all requires more than the accumulation of the science knowledge. Pupils learning science should also learn about and become scientific in outlook and habits of mind. Basic education and literacy issues have been made more complex by the recent other related literacy such as computer literacy, AIDS literacy, etc. cis.1,5?

Activity 12.3: (i) State two characteristics of a scientifically literate person.
60 What are the two sources of the definition of a scientifically literate person as compiled by Otuka?

12.5 The Teacher

I hope you have followed the lecture sequentially up to this point. You have studied science education, scientific literacy — definition and characteristics of a scientifically literate person. You will now briefly look at the role of the teacher in the scientific literacy programme as discussed below:

The most important resource in the classroom is the teacher. A highly motivated and adequately trained teacher can rise above the constraining circumstances of paucity of material resources and government apathy. There is the need for teacher education to produce self motivating teachers who will continually seek solutions to problems facing them in the classroom, who will initiate changes to improve their teaching and who will not wait for government or external aid to implement changes. Attempting a change of attitude and instilling more appropriate approaches to the teaching of science and technology represent a huge and long term undertakings

Therefore:

- Teachers must know why it is important for all pupils to learn science.
- Many science specialists need to change their outlook, philosophy and practice if scientific literacy is to be more than a stated goal of curriculum developers.
- Teacher trainers must guide trainees to ensure that their teaching methods and strategies promote relevant science.
- Teachers must provide the proper learning environment that will promote new strategies of cooperative learning, problem centred learning and authentic assessment that promote scientific literacy.
- Teachers must first understand how the child builds his/her knowledge base and why some students understand science and other do not.

Activity 12.4: What are the two merits of ensuring that the teacher of science is highly motivated and adequately trained?

12.6 Conclusion

In this unit you have learnt that: science education is education in science and across many disciplines. Its main goals are to produce scientifically literate individuals and lay the foundation for future work in science. There is no one correct definition of scientific literacy but the definitions: Layton (1993) Rollnick (1998) and Rutherford & Ahlgren (1990) were provided. Sixteen characteristic of a scientifically literate person were stated and the role of the teacher as the most important resource in the implementation of scientific literacy programme was also discussed.

12.7 Summary

Science education for all in the 21st century is a survival need therefore all stakeholders in education should give such programme maximum support to ensure that it is meaningfully implemented. Going by the characteristic of a scientifically literate person, the quality of life, governance of the polity etc. will improve significantly if Nigerians become more scientific in their thoughts, plans, F :flans and behaviours.

12.8 Tutor Marked Assignments

- What is science education and who is a science educator?
- State five characteristics of a scientifically literate person.
- What should be the role of the science teacher to ensure that students and the community are scientifically literate?

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UNIT 13

Karl Popper (Philosophical Views)

13.0 Introduction

"Who are the New Philosophers of science?"

The turning point that saw the emergence of the new philosophers was the introduction to the new physics by Einstein .What made Einstein's new physics peculiar was that it was a great improvement on Newton's physics. (The mathematical principles of Natural Philosophy). Einstein's new physics (special relativity theory) explained all of Newton's and even went beyond. One outcome of Einstein's new physics was that the observer and the observed were part of a system and not separate entities. This was an opposite view to Newton's under the influence of Einstein, the new philosophers namely: Popper, Kuhn, Lakatos, and Feyerabrend devoted their efforts to present a more adequate picture of science.

In the next three units i.e. units 13, 14 and 15 you are going to study the works and contributions of these philosophers thus: Unit 13 — Popper; 14— Kuhn; 15 — Lakatos, and Feyerabend. You are advised to note the trend from one unit to the other so that the whole work on 'methodology of science' would be meaningful to you.

In this unit, you will study Karl Popper's work thus: career, basic views on the nature of science, popper's view on scientific method, comparison Popper and Bacon's scientific methods, influence of Popper's work on scientists.

13.1 Objectives

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

- Write about Popper's career.
- Discover **3atoris** views on nature of science.
- Describe Popper's picture of the scientific method.
- Defend Popper's work using specific examples of his work.
- Compare Popper's work with that of the earlier philosophers.
- Discuss the influence of Popper's work on the work of scientists.

13.2 The Career of Sir Karl Popper

Karl Popper was born in Vienna in 1902. lie studied mathematics and physics. In 1934 he published his first book titled: "The Logic of Scientific Discovery." In this book, he presented a revolutionary view of the nature of scientific knowledge and the way in which it is acquired — a view that has subsequently been accepted by most scientist. This idea formed the basis of all Ins later work. Throughout the Second World War, he lectured in philosophy at the University of New Zealand.

During this period, he produced a book which was published in 1945, titled: "The Open Society and its Enemies." In 1946 Popper moved to Britain where he worked as Professor of Logic and Scientific method at the London school of economics until he retired in 1969. He wrote other books namely: The Poverty of Historicism, Conjectures and Refutations and objective knowledge — all his books have had considerable influence on contemporary thought. He was knighted in 1865 and now acclaimed as the greatest philosopher of science who has ever lived.

Activity 13.1: What in your view qualified Popper as the greatest philosopher of science of his age?

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13.3 **Popper**s Basic Views on the Nature of Science

Until 1934, the universally accepted view of the nature of science was basically that which was developed by Francis Bacon in the early seventeenth century. The essence of this so-called Baconian picture of the scientific method is that scientific studies in a particular field start with the open-minded accumulation of data, followed by the development of a hypothesis aimed at explaining or collating the data, followed by the testing of this hypothesis by key experiments. If this hypothesis is verified, it then acquires the status of a law and becomes a permanent addition to the body of certain (or scientific) knowledge. (This will be discussed further later under history of science).

The key step in this process by which a general statement (the hypothesis) is derived from individual observations (the original data) — is the so called process of scientific induction. Before Popper, the inductive method was what distinguished science from non-science. Only statements of observable fact or statements derived from such facts by the process of induction were scientific and only such statements could be regarded as certain knowledge.

The first doubts about the validity of the Baconian picture of the scientific method were raised by the eighteenth century Scottish philosopher David Hume, who showed that induction is logically inadmissible, since no general statement can ever be derived from a finite number of individual observations.

Activity 13.2: • Who developed the earliest view of nature of science and when? • What was the process called?

13.3.1 Popper's Picture of the Scientific Method

The problem of induction remained one of the central problems of philosophy for the next 200 years and its solution proved beyond the capability of some of the Philosophers — Immanuel Kant and Bertrand Russel for example. It was eventually solved by Popper. He showed that it was based on a total misunderstanding of the nature of the scientific methods and the status of scientific knowledge. He contended that scientific induction never actually happens.

The basis of Popper's picture of science was his appreciation of the fact that, although a statement such as "all Swans are white" can never be proved, it can be disproved by the observation of a single non-white Swan. According to Popper, scientific laws should be tested not by attempting to prove them right but by attempting to (in the most rigorous manner) prove them wrong. This principle lies at the very heart of the Propperian view of science and all that follows from it. According to Popper all scientific laws are merely working hypotheses that we should retain only as long as they continue to agree with our observatiOns. As soon as a law fails to do so, it should be discarded and replaced by a new law that fits all the facts that are currently available. Thus according to Popper, scientific laws are purely temporary phenomena. It is inevitable that the disproved laws should be superceeded by better and more powerful laws just as Newton 's law of gravitation was eventually replaced by Einstein's theory of relativity. According to Popper what we call a scientific development starts when someone realises that a problem of some sort exists. The next change is the formulation of a trial solution to this problem, a theory of some sort. Next, the theory is subjected to a rigorous process of testing by attempted falsification. This is done by using the theory to make definite predictions and then checking these prediction by means of experiments.

The testing process can have three possible outcomes. The first is that the experimental results prove to be completely incompatible with the predictions of the theory. This indicates that the theory is fundamentally wrong and should be discarded or drastically modified.

The second possible outcome is that the results prove to be in broad agreement with the predictions of the theory but differ from these predictions in certain important respects. This indicates that the theory appears to be basically sound but requires some modification either by changing its detailed structure or by extending its scope.

The third possible outcome is that the results prove to be in total agreement with the predictions of the theory. This indicates that the theory appears to be sound and can therefore be adopted as a working hypothesis until such time as its predictions fault to be corroborated by future experiments. (The association of science education 1981).

Activity 13.3: According to Popper all scientific laws are merely ________________________
Popper maintains that theories are tested by ________________ gill in the gaps.)

13.3.2 Further Explanation of Popper's View

According to Clem inson (1990), Popper is preoccupied by the logical problems involved in a critical comparison of competing theories. He rejects the classical justificationist position of only admitting to the domain of knowledge those theories that have been "proved". In doing so he breaks with "the dominant tradition in rational thought throughout the ages. He holds that falsification of existing theory is the key to scientific progress, but in postulating this idea he rejects the notion that this can be done with the help of hard facts. This would be to equate falsification with disproof. For Popper these are two different concepts. lie holds that all scientific theories are not only unprovable but that they are equally undisproval. Paradoxically this means its is possible that whilst falsifying a theory means proving the theory false, it does not prove that the theory is untrue. Popper's methodological falsifications separate rejection and disproof.

All propositions are for Popper, fallible, as they can never be proved from experiment; they can only be derived from other equally fallible prior proposition.

Popper's paramount concern according to Cleminson is in developing a firm rational strategy or method to employ when theories clash. What criteria will falsify one theory while leaving the other intact. Essentially this involves selecting the theory with the higher corroborated content and thus which displays the greater degree of consistency.

Activity 13.4: What is the main objective of Popper in setting up the falsification methodology?

13.4 Comparison of the Popperian and Baconian Pictures of Science (Adapted from ASE 1981)

- A scientific development does not start with the open-ended accumulation of data in the areas in which it is hoped discoveries will be made. Popper maintains that it is impossible to undertake such open-minded investigation, since no experiment can be carried out without having at least a rough idea of the sort of result that is expected. In Popper's view all scientific advances start with the realisation that a problem of some sort exists, thus producing both the stimulus needed to get work started and the motivation needed to keep it going until a solution is found.
- Scientific theories are not arrived at by the process of induction — the inferring of general statements from particular observations. Popper maintains that the development of such theories is essentially a creative process. Also he believes that the exact sequence of events which leads to the development of a scientific theory will, in most cases probably be unclear even to the person who produces it (e.g. K aku le's dream in which he saw a snake eating its own tail). This is one of the features that characterize creative work.

- Theories are not tested by attempting to prove them to be true, since, as we have discussed above, such a process is logically impossible. Rather they are tested by trying to think of specific ways in which they can be shown to be false and then carrying out experiments to see whether they are false. Indeed, Popper believes that this is the thing which distinguishes science from other fields of Study such as philosophy and metaphysics. Only theories that make definite falsifiable predictions about the nature of the world should in his opinion, be described as scientific, and only fields of Study which are built around such theories should be described as science.
- A theory that comes through such tests unscathed does not automatically then acquire the status of certain truth to .become a permanent part of the body of scientific knowledge. Rather it should be accepted as a working hypothesis only for as long as it continues to fit in with observations.

Activity 13.5: State the chi ferences between Popperian and Baconian Pictures of science.

13.5 The influence of Poppers Ideas on Scientists

Before Popper the ultimate sin in science was to be proved wrong to publish work that was subsequently discredited this attitude stemmed from the mistaken notion that science advances by the systematic erection of a body of firmly -established facts. Anyone who published a theory that was later shown to be incompatible with experimental results thus felt that he had been a failure, and that his reputation would suffer as a result. This had an inhibiting effect on the work of scientists, and has undoubtedly slowed down many important scientific developments.

After Popper's view of science, it was realised that being shown to have been mistaken is not something to be ashamed of, for it is only when ideas are subjected to stringent testing and falsification that science can advance at all. Indeed a theory that proves to be inadequate can, in some cases, play a far more important role in the development of science than one that is corroborated by the various experiments that are carried out in order to test it.

Activity 13.6: How dicl Popper's work promote .ccientific advancement?

13.6 Conclusion

In this unit you have learnt that: Popper is adjudged the greatest scientific philosopher of his time. Francis Bacon developed the earliest view of the nature of science in the seventh century -the inductive approach. Popper maintains that theories are tested by conjectures and refutations (falsification) there are four differences that can be adduced between the Baconian and Popperian views of science. Popper's view of nature of science helped to promote scientific development.

13.7 Summary

Popper's theory of science shows that criticism is something which should be actively encouraged and gratefully welcomed, because it is only by having ones work, actions and opinions criticized that one can identify areas where there is room improvement or need for modification. In the next unit you will continue the work on the nature of scientific method by studding the works of Lakatos, Bronowski and Toulm in

13.8 TutorMarked Assignments

- Discuss Popper's view of the scientific method and show how it promoted scientific developments.
- (i) Describe the major steps in the Baconian Picture of the scientific method.
  (ii) Compare the Baconian and Popperian pictures of the scientific method.

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UNIT 14

The Philosophical Views of Thomas S. Kuhn

14.0 Introduction

In unit 13 you studied the ideas of Karl Popper. You looked at the ideas that underlie science, examining both the nature of the scientific method and the status of scientific knowledge. In the discussion of Kuhn's ideas, you are going to look at the development of science from a broad historical point of view. Specifically, this unit will be concerned with: the career of Kuhn, Kuhn's basic idea on how science develops, normal science, scientific revolution and some examples of paradigm changes.

14.1 Objectives

At the end of this unit, you should be able to:

- Write a brief report on Thomas Kuhn's career.
- Explain how science develops as stated by Kuhn.
- Define a scientific paradigm.
- Distinguish between Kuhn's normal and revolutionary science.
- Describe some paradigm changes that revolutionized science.

14.2 The Career of Thomas S. Kuhn

Thomas S. Kuhn studied theoretical physics at the university with the intention of becoming a physicist. At graduate level he took a course in the history of science which made him change his career to philosophy of science. He lectured at Howard University in history of science, philosophy and psychology. He also lectured at the university of California and later at Princton as Professor of History of Science. One of his greatest contribution to knowledge is his publication in 1962 of the book titled: "The Structure of Scientific Revolution". This publication according to A.S.E. (1981) had profound impact on contemporary thought and caused an entire generation of scientists to look on their discipline in a completely different way.

Activity 14.1: What was KuhnS major contribution to knowledge?

14.3 Kuhn's Basic Ideas on How Science Develops

14.3.1 The Paradigm Concept

According to Uduigwomen (1996) while Popper believes that the unit of appraisal in science is a single theory, Kuhn is of the view that the unit of appraisal is a paradigm. Kuhn used paradigm as an examplars. This had to do with the accepted ways or patterns of solving a problem which then serves as a model or example for future research workers. The second use is as 'a disciplinary matrix'. Disciplinary matrix to the common possession of members of a professional discipline, composed of ordered elements of some sorts, each requiring further specification. Paradigm can also be defined as the commitments, beliefs, values, techniques and so on shared by members of a given scientific community. A scientific community are practitioners of a scientific discipline -community of physicists. Normally a paradigm is accepted without question by all those working in the field at the time. It forms the underlying theoretical model on which a particular branch or sub-branch of science is based at any given time. It determines the sort of problems that such workers should and should not investigate and it determines the way in which such problems are tackled by giving rise to set procedures, rules and standards.

Activity 14.2: *What is a disciplinary matrix?*

14.3.2 Normal Science

Kuhn presents a picture of science as a pre-paradigm science in his book thus: normal science — crisis — revolution — new normal science — new crises etc. For Kuhn scientific community is essentially a closed society operating for most part in the real of 'normal science'. This involves puzzle solving within the confines of the dominant paradigm: that constellation of beliefs, values, techniques and theories shared by the scientific community at that period of time. Only occasionally is this mental unison shaken by "a collective nervous breakdown" as a period of revolutionary science brings about a change in the dominant paradigm before calm is restored and another prolonged period of normal science ensues (Cleminson 1990). Put in another way as follows:

According to Kuhn, all branches of science start their development by going through an 'immature' phase in which there is considerable disagreement among practitioners regarding the nature of the basic principles that underlie that field, the sort of problems that should be investigated and the way in which such problems should be tackled. Kuhn believes that a branch of science makes the transition from 'immaturity' to 'maturity' when the ideas of one of the competing groups becomes generally accepted by other groups in the field and acquires the status of a paradigm when this happens, scientists are able to stop arguing about the fundamental principles, procedures and conventions that underlie their field. They can instead move on to more detailed, more specialized work, using their newly acquired paradigm both as a base on which to build and as a source of conventions and standards within which to operate. The great majority of scientists spend most, if not all, their careers carrying out work of this type, without questioning the validity of the paradigm on which it is based. This is what Kuhn calls 'normal science'.

Activity 14.3: *Distinguish between "immature" and "normal science".*

14.3.3 Categories of Normal Science

Kuhn believes that the work carried out during normal science falls into three distinct categories thus:

- Using the paradigm to determine interesting facts about the area that it covers
- Finding out how the predictions of the paradigm compare with the actual properties of nature and in particular, trying to find out new areas in which such an agreement can be demonstrated
- Trying to extend the scope of the paradigm (what Kuhn calls 'articulation of the paradigm) by, for example, trying to resolve some of its initial ambiguities or adapting it in order to solve problems to which it had previously only drawn attention .

Activity 14.4: *Try to provide an example of these categories using your subject area.*

The common feature of all these activities is that they do not, in general, produce unexpected results, since the paradigm on which they are based gives fairly good idea of what will occur. When such activities do start to present consistently unexpected result, this is a signal that the paradigm is starting to break down, and that normal science is about to give way to a period of extraordinary science -to a scientific revolution.

14. 4 Scientific Revolution

According to Kuhn, one of the most important characteristics of paradigm is their resistance to change. Once a paradigm becomes established in a particular field, it become such a basic part of the thinking of the various people who work in the field that it is only with great difficulty that they can be persuaded to change to a new paradigm— even if they are confronted with unquestionable evidence that such a change is necessary. However paradigm changes do occur and Kuhn believes that they are an inevitable consequence of the nature of normal science.

As explained in 14.3.3 'normal science' consists mainly of using a paradigm as a jumping -off point for more specialized, more detailed work — employing it as a tool to bush back the frontiers of knowledge. If a paradigm is sufficiently open-ended and productive of new ideas, such work can last for a very long time e.g. Newtonian mechanics lasted for two hundred years. Nevertheless inevitably there comes a time when research generated by a particular paradigm starts to yield results that cannot be explained in terms of its basic concept. As more and more anomalous results are obtained, it generally becomes progressively more difficult to reconcile the new discoveries with the existing paradigm without distorting it out of recognition. When this happens, some of the workers in the field, will start to question it's validity and develop possible alternatives. At this point, normal science breaks down and gives way to a period of extraordinary (revolutionary) science. At this stage the rival theories will be re-examined to determine which one is best suited to explain the new discoveries that gave rise to the crisis. Eventually, one such paradigm becomes most suitable than others as the new paradigm for the field. When this happens, a further period of normal science based on the new paradigm begins.

Activity 14.5: What gives rise to extraordinary science in a scien c discipline ?

14.5 Three Examples of Important Paradigm Changes

The most important paradigm changes that have taken place during the last 500 years are: the Copernican revolution in astronomy, the Darwinian revolution in biology and the Einsteinian revolution in physics. Each of these is briefly discussed below:

14.5.1 The Copernican Revolution

Throughout most of recorded history, the paradigm that dominated astronomy was the Earth Centred-Model that was developed by the Greeks -the so-called Ptolemaic system. The paradigm stipulates that the planets, sun, moon moved round the Earth in complicated orbits that could be broken down into a system of cycles and epicycles, while the fixed stars were carried by a 'celestial sphere' that revolved round the Earth once a day. For more than 2000 years this paradigm was used with great success to explain the movement of the various heavenly bodies. However in 1543, Copernicus published his book titled "On the revolution of the celestial spheres". In this book, he presented a radically new paradigm in which the sun replaced the earth as the centre of the planetary system -the so called 'heliocentric system'.This enabled a great simplification of the Ptolemaic system of cycles and epicycles to be made.

14.5.2 The Darwinian Revolution

Prior to Darwin, the paradigm that underlay biology was the idea that living species were permanent and immutable, having been created in their present forms by God himself. The main task of biologist consisted of gathering data on the various species, and classifying them into their basic groups and sub-groups.

During the late eighteenth century, however the development of the new science of geology and the associated discovery of different types of fossils -began to cause biologists to have doubts about the validity of this paradigm. In 1859 Darwin presented his theory tilted "On the origin of species by means of Natural Selection." This received opposition both from biologists and the church. Evolution took a very long time to gain some acceptance.

14.5.3 The Einstein Revolution

The Einstein revolution undermined the very foundations of physics and caused them to be completely re-built until Einstein's physics was based on the paradigm that was developed by Isaac Newton during the latter part of the seventeenth century and set out in his great book — Mathematical Principles of Natural Philosophy. This paradigm held that space was absolute, unalterable and Euclidean, that time was absolute and linear and that space and time thus formed a rigid frame of reference within which all bodies moved. During the following 200 years, the Newtonian paradigm was used to build up a clear, and seemingly comprehensive description of the physical world as it was known at that time. It was for example used to explain the motions of the various heavenly bodies with seemingly perfect accuracy. Towards the ends of the nineteenth century, however, serious doubts began to arise regarding the validity of the Newtonian paradigm. In 1905, Einstein produced his special relativity paradigm. This banished the concepts of absolute space and absolute time from physics and showed that the results of all physical measurements depend on the relative motion of the observer and the thing being observed (the only exception was the measurement of the velocity of light). Ten years later Einstein produced his general theory of relativity.

Since 1919 Einstein's relativistic world picture has become generally accepted and is now firmly established as the basic paradigm of physics (A. S. E 1981).

Activity 14.6: Through Internet search, library search etc. identifr the latest paradigm shift in any branch of science.

14.6 Conclusion

In this unit you have learnt that: Kuhn was a theoretical physicist who become a professor of history of science. A paradigm is the basic generally— accepted theoretical model that underlies a particular branch or sub-branch oft,eience at any given time. Science develop through the paradigm of normal revolutionary normal etc. Three examples of important paradigm changes are: the Copernican revolution, the Darwin ia44 revolution and the Einstein revolution.

14.7 Summary

So far you have studied Poppers falsification theory in Unit 13 and Kuhn's normal and revolutionary science in this unit. As you were informed in unit 14 you are going to study the philosophical views of Lakatos and Feyerabend as well as the implication of the philosophical views on science teaching and learning in the next unit.

14.8 Tutor-Marked Assignments

- What is a paradigm?
- Use Kuhn's paradigm to discuss his views on how science develops.
- Describe one of the paradigm changes that revolutionized science in the last century.

14.9 References

Association of Science Education (1981). *Nature of Science* Great Britain, Heinemann Educational Books 18-27.

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UNIT 15

New Philosophers of Science: Lakatos, Bronowski, Toulmin and Feyerabend

15.0 Introduction

In Unit 14, you studied the normal science-revolutionary science of Thomas Kuhn. You had already studied Popper's conjectures-refutation (fasification) theory. You were also informed in unit 13 that some common trend runs through units 13, 14 and 15 which discuss the modern or new philosophers of science. You must have discovered so far that they have varying views but a common goal as they are all interested in the scientific methodology and the status of scientific knowledge. In this unit you are going to study the philosophical views of: Lakatus, Bronowski Toulmin and Feyerabend and their implications in science instruction.

15.1 Objectives

At the end of this unit, you should be able to:

- Describe Lakatos competing research programmes and their importance to science teaching.
- Discuss Bronowski's view of science and it's implication for science instruction.
- Prepare an essay on Toulrnin's "post-modern" science theory.
- Criticize Feyerabend's anarchistic conception of science.
- Explain the importance of modern philosophical views of science teaching.

15.2 Lakatos Philosophical View of Science

Lakatos was a Hungarian; he worked in the London school of economics where he came under Popper's influence. He eventually occupied a chair in the school. His most widely read and influential paper is "The Methodology of Scientific Research Programmes"

Like Popper, Lakatos is a rationalist in that he believes that the central problem in the philosophy of science is that of stating the universal conditions under which a theory can be regarded as scientific and when to decide whether the acceptance of a theory is rational or irrational. Lakatos proposed an alternative picture of the nature of science to that of Popper.

According to Uduigwomen (1996), Lakatos does not subscribe to Poppers view that a theory is to be immediately abandoned once it has generated some anomalies. In Lakatos view, an assessment of the relative merits of competing theories should be delayed until proponents of the theories have had time to explore modifications in the theories, which might make them better able to cope with anomalies. He therefore summarized that the unit of appraisal in science must not be a single theory but many related theories in such a sequence that each one is generated by modifying the one preceding it. Lakatos calls such a sequence

Scientific Research Programmes. Research programmes are defined in terms of problems shift thus; Let T,, T. etc. be a series of theories where each subsequent theory results from adding auxiliary clauses to the previous in order to accommodate some anomaly where each theory in the series has as much empirical content as the content of the unrefuted content of its predecessor. For Lakatos it is only when a research programme progressively explains more than its rival that the said rival ought to be shelved.

Activity 15.1 *State One Differences between Popperinn and Lakatos Pictures of Sciences.*

c e

• 15.3 Bronowski's Criteria for Evaluating Scientific Change

For Bronowski, the fundamental premise is that there can be no division between man the thinker, man the receiver of sensations and man the author in the world. According to Cleminson (1990), Bronowski, holds the view that the universe is one total connectivity in which man is but one set of connection. He believes that "there are no events anywhere in the universe which are not tied to every other events in the universe. In attempts to make sense of nature, then assumptions must be made to cut out some parts and so the total connectivity is lost Therefore the best we can hope for in science is to develop better and better metaphors (you studied metaphor in unit 8, you may wish to review it before you continue) which, nonetheless, are necessarily only approximations as they can never embrace the whole of nature.

Bronowski's criteria for evaluating scientific change resonate with those of Popper and Lakatos, although for him the connectedness of the universe must be held paramount. He feels that, if nature is totally connected, we should prefer those languages or systems which shows the highest connectedness, not because they show the connections in nature, but because they are coming closest to it. Bronowski considers the universe as a giant cryptogram. Therefore the function of sciences is to decide the cryptogram. The scientist examines one part of the cryptogram to determine the connectedness there. In doing so, the scientist must be aware of the assumption that he is making; the connectedness of the microsystem that he examines is separate from the macro system that surrounds it. The assumption must constantly be borne in mind, any axions that the scientist presumes for his micro system must necessarily be specific and cannot be generalized beyond that system. For Bronowski, science progresses by a process of continuously expanding the realm of connectedness in nature by man's effort to decode the cryptogram of nature. Thus in scientific progress we have "had to push out the boundaries of the relevant, further and further." Cleminson (1990) quotes Bronowski as summing up his view of science thus: "science is an attempt to represent the known world as a closed system with a perfect formalism. Scientific discovery is a constant maverick process of breaking out at the ends of the system and opening it up again and then hastily closing it after you have done your own particular piece of work."

For Bronowski (1978) this can only be achieved by an act of imagination. The analysis of nature is "a personal and highly imaginative creation." reireiS"

Activity 15.2 • *What does Bronowski consider the universe to be?*
• *How does science progress according to Bronowski?*

/ 15.4 Toulmin "Post Modern" Science

Toulmin is a post positivist philosopher who placed his philosophy in the context of what he calls 'post-modern' science. He defines this era as one that has superceeded 'modern' science starting from about 1900. In this area, Toulmin insists that 'The deterministic set of mechanisms from which the processes and forces of humanity were excluded or exempted which characterized the Newtonian universe, could no longer remain valid assumptions in the light of the many paradoxes that have arisen in science, most particularly in the field of subatomic physics and astrophysics". To Toulmin, it appeared that the notion of the scientist as a value-free, impartial spectator of the material world from which he is apart must be abandoned. He noted that "Fact" can no longer be perceived as an objective statement. Therefore mankind should appreciate that we are a part of, rather than apart from, the natural world, that the scientist is a participant in the world rather than a spectator of the world. While scientific methods remain valid processes for exploring the physical and biological world, he asserts that the 'scientific method' expounded in positivist philosophy is an ephemeral and incomplete description of the scientific activity. (Cleminson 1990).

Activity 15.3: Toulmin suggests that scientific methods should be abandoned- Yes or No.

15.5 Feyerabend's Anarchistic Conception of Science

In discussing Feyerabend's work, it will be limited to a general introduction and his criticism (views) about
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the theories of Popper, Kuhn and Lakatos.

Feyerabend presented his conception of science in his book "Agaitrgt Method". Anarchy means lack of government or control and under such condition, lawlessness and confusion are unavoidable. Feyerabend according to Uduigwomen (1996) is a methodological anarchist because he believes that the whole notion of a methodology of science is an illusion. He acknowledges the fact that anarchy may not be a palatable political philosophy but he believes it is an excellent panacea for philosophy of science.

Feyerabend begins "Against Method" by declaring that he is engaged in an anarchist enterprise. Feyerabend claims that none of the methodologies of science has lived up to expectation. He argues that none is compatible with the history of physics. According to him all scientific methodologies have their limitations and the only rule that really holds is "anything goes".

15.5.1 Criticism of Popper

Feyerabend criticizes Popper's falsification methodology. He claims that its standards of comparison are rigid and fixed and as such eliminate competitors once and for all. According to him, theories that are not falsifiable or have been falsified are inadmissible in science. Only theory that are falsifiable or have withstood crucial experimental tests are acceptable. Feyerabend maintains that many revolutionary theories are unfalsifiable. He admits that falsi liable versions exist, but quickly points out that such versions are scarcely in agreement with accepted basic statements. He also argues that many theories contain contradictions, formal flaws, ad-hoc adjustments etc. Feyerabend conclude that the Popperian standards cannot aid the growth of science but its destruction.

Activity 15.4: What is the main objective of Feyerabend's Anarchist Conception of Science?

15.5.2 Criticism of Kuhn

Feyerabend maintains that although Kuhn's ideas are interesting, they are too vague to result in anything but lots of hot air He distastes Kuhn's view of normal science and argues that Kuhn's idea of normal science is not in consonance with the history of science.

15.5.3 Criticism of Lakatos

Feyerabend maintains that Lakatos methodology of science is immeasurably superior to Kuhn — the first reason is that in place of theories, Lakatos considers research programmes which are sequence of researches or theories conducted by investigators, in which certain methodological rules are adhered to. The sequences of researches or theories are connected by what is called "heuristics." What counts is not the many faults which a theory in the sequence may contain but the tendency displayed by the entire sequence. The second reason according to Feyerabend is that Lakotos tends to bind history and methodology into a single enterprise. By this, historical developments and achievements are to be judged over a period of time rather than the situation of a particular time. He states that a research programme is progressive if it keeps predicting novel thcts otherwise it is degenerating.

Feyerabend criticizes Lakatos methodology by saying that it does not stipulate methodological rules that tell the scientist to either retain or reject a research programme. He went further to say that Lakatos offers words which sound like the elements of a methodology; but he does not offer a methodology in accordance with the most advanced and sophisticated methodology in existence today. According to Uduigwomen (1996) Feyerabend is saying that Lakatos does not offer a methodology and as such he is a fellow anarchist (Uduigwomen 1996).

In the above discussion you have read Feyerabend's views on the works of popper, Kuhn and Lakatos and he ends up condemning the methodologies of the three modern philosophers. It is not unexpected since he claims that none of the methodologies have lived up to expectation.

Activity 15.5: *Give one reason why Feyerabend considers Lakatos work superior to that of Kuhn.*

15.6 Implications of the Philosophical Views to Science Teaching

The only method of finding out whether a statement of law or theory is true or not, according to Popper, is

a theory, one can end up formulating new theories thus helping science to grow. Most of the time classroom teachers and their students only try to verify theories and even when they fail, they try to ascribe reasons for their failure. Teachers and students should have open minds towards experiments and be prepared to accept negative results and attempt to proffer reasons for such results. The inductive method of teaching science through the use of the senses only should be discouraged. Students should be trained to open their minds and senses to possible contradictions when they perform experiments.

Kuhn's view suggests that until some concepts move from normal to revolutionary then normal again school science content should be drawn from normal science. Thus, teachers and their pupils are not concerned pushing forward the frontiers of knowledge.

Lakatos theory calls for accommodation of other views in our teaching and learning and we should be ready to accept modifications to existing theories. Also Lakatos theory supports the teaching of history of science so as to inform students of changes that have taken place in the study of some topics, concepts and theories.

According to Cleminson (1990), new directions could be given to curriculum planning by basing it upon some of the common trends that emerge from the new philosophy of science. Those that are relevant to this unit are:

- Scientific knowledge is tentative and should never be equated with the truth. It has only a temporary status.
- Observation alone cannot give rise to scientific knowledge in a simple inductive manner. We view the world through theoretical lenses built up from prior knowledge. There can be no sharp definition between observation and inference.
- New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry. Such is a personal and immensely human activity.
- Acquisition of new scientific knowledge is problematic and never easy. Abandoning cherished knowledge that has been falsified usually occurs with reluctance.
- Scientists study a world of which they are a part, not a world from which they are apart.

Activity 15.6: *What is the implication of Kuhn's view to science teaching?*

15.7 Conclusion

In this unit, you have concluded the study of the modern philosophers. You have perhaps discovered that though they have varying views, they are working towards the same goal.

15.8 Summary

In this unit you have learnt that Lakatos was like Popper a rationalist, that research programmes should determine which theory should be modified or shelved. Bronowski believes that there is no division between man the thinker and man the receiver of sensations. He considers the universe as a cryptogram which the scientist examines in part, to determine connectedness. He views science as a closed system with a perfect formal ism .

Toulmin is a post positivist philosopher who worked on the context of what he called 'post modern' science. He postulated that we are a part of and not apart from the natural world. Feyerabend is a methodological anarchist who criticized and condemned the works of Popper , Kuhn and Lakatos. The implications of the views of modern philosophers to science teaching were also discussed.

15.9 Tutor Marked Assignments

According to Feyerabend philosophical view point, the whole notion of methodology of science is a relevance of the views of modern philosopher to science teaching.

15.10 References

Bronowski, J. (1998). *The Origins of Knowledge and Imagination*. New Heaven, CT: Yale University Press 10-15.

Clem inson, A. (1990). "Establishing an Epistemological Base for Science Teaching in the Light of Contemporary Notions of the Nature of Science and of How Children Learn Science." *Journal of Research in Science Teaching. 27*, 429-445.

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History of Science
(General Information)

Units 16-20 of this course was devoted to the history of science. You are advised to use a notebook to write down the major ideas as you read each unit. At the end of the units you should read through the chronology of events to have an overview of the entire development of the history of science as discussed in the units. The distribution of the units is as follows:

Unit 17: Science and History
Unit 18: Greek Science, Bacon, Copernicus and Galileo
Unit 19: Darwin's theory, the periodic table and the computer
Unit 20: Newton's classical theory, Einstein's relativity and Genetic Engineering
Unit 21: History of Science in Nigeria

Unit 16 attempts to provide an overview of the entire history of science while units 17-19 discuss some historical landmarks in science.

Matthews (1994) states that a teacher's epistemology or theory of science influences the understanding of science that students retain after they have forgotten the details of what has been learnt in their science classes. It is therefore necessary that every science teacher should be exposed to the study of history of science. Other reasons for the study of history of science are:

- History promotes the better comprehension of scientific concepts and methods.
- Historical approaches connect the development of individual thinking with the development of scientific ideas.
- History of science is intrinsically worthwhile. Important episodes in the history of science and culture should be familiar to all students.
- History is necessary to understand the nature of science.
- History counteracts the scientism and dogmatism that are commonly found in science texts and classes.
- History by examining the life and time of individual scientists, humanizes the subject matter of science, making it less abstract and more engaging for students.
-) History allows connections to be made within topics and disciplines of science, as well as with other academic disciplines, history displays the integrative and interdependent nature of human achievements.

The above arguments for the history of science are salient on what kind of history of science should be included. Historians of science take different approaches to subject. There are internalist historians of science who concentrate upon the development of scientific concepts and external ists historians of science who are concerned to connect the growth of science to its social circumstances.

UNIT 16

The Human Face of Science, Scientists and Society, and Science and Politics

16.0 Introduction

In the closing unit of the philosophical section of this course, it has become necessary to remind you that science is a human activity and deals with society (i.e. people) as well. Though some of these topics might be treated in other courses such as science technology and society, the treatment here is to sensitise you to the importance of science and science education in human and societal related issues. Therefore in this unit, you will study the human face of science, scientist and society and science and politics.

16.1 Objectives

At the end of this unit, you should be able to:

- Recognize that science is a human activity.
- Describe the activities of a scientist in society.
- Discover that science and politics are inseparable in society.

16.2 Human Face of Science

Science as an enterprise has individual, social and institutional dimensions. Scientific activity is one of the main features of the contemporary world and perhaps distinguishes our times from the past centuries. In all parts of the world, men and women of all ethnic and national background participate in science and its applications. A great deal of thought has been devoted by generations of scientists, philosophers and psychologists to the nature of scientific discovery. Flow does a scientist discover something new? There is of course no single, simple answer to the question. Discovery lies between the extremes of dream-like inspiration (for example Kekule's realization of the ring structure of the Benzene molecule through dream) and the endless hours of keen observation and collection of data in the laboratory lies a complete spectrum of different experiences. Within all this variety, there appears one common trend; at some point in the formulation of a scientific hypothesis, there is a step which lies beyond logical, rational explanation. It may be a huge imaginative leap into the unknown, or the mere placing side by side of two pieces of experimental evidence. However it always produces something that is more than just the sum of the observable experimental facts. It contains the seed of something new. At some point, the scientist — a person has to step into the process and ask "I wonder if ... or what would happen if ...?" This shows that there is a human dimension in scientific discovery.

Science is a human activity not just in terms of the work of individuals but also in terms of the community/ society in which they work. It is common knowledge that certain lines of scientific investigations are discouraged in certain societies, for example Biology students cannot use toads and other animals in communities and societies where it is a taboo to handle them. In Russia little was done in genetics till 1960 because of the disgrace brought by the work of the plant geneticist, Lysenko, who falsified experimental results to make them politically acceptable. Research is at times due to some compelling national need e.g. navigation in Italy in Galileo's time, AIDS studies to avert numerous deaths etc. Strictly speaking the very nature of a society seems to determine the direction of scientific research.

Activity 16.1: *State two examples that show the human face of science.*

Science is essentially about concepts -force, motion, atom, energy etc. -which are 'models' that we use to rationalize observed behaviour. For example it is really impossible to talk of lifting objects without the idea of force. Science concepts make sense of and tie together what we know, they inter-relate and enable us to make predictions about what is still unknown. Concepts are human inventions: they are part of human language and communication. No doubt the physical world would still be there in our absence but science represents our human way of making sense of it.

If the language of science, its methods, and its motivation are all part of human experience, then it is not unreasonable to expect scientific activity to remain under human control. But in matters of public interest, scientists can be biased where their own personal, corporate, institutional or community interests are at stake.

Activity 16.2: *With the above examples suggest at least three more issues or activities that show the human face of science.*

16.3 Scientist and Society

As a social activity, science inevitably reflects social values and viewpoints. The direction of scientific research is affected by informed influences within the culture of science itself. Scientists have never fitted comfortably into the society of their time. This is true whether we think of society, in terms of its political and religious establishments or of the ordinary man on the street.

Society has always been ready to accept the benefits of science, but finds it hard to go with the dangers that go with them. Humankind finds it difficult to a reality, which is never clear-cut and often a messy compromise of advantage and disadvantage. The result is often hatred rather than a search for compromise. Public opinion has never had much sympathy for the scientist. Always the situation is confusing and complex.

Activity 16.3: *Provide two examples of events in Nigeria showing that public opinion never sympathises with the scientist.*

The society should feel relieved that tension exists between the scientist and society because they indicate society's attempt to exercise control over its scientific activity. This control will last longer if it is based on information, discussion and understanding and not on an historical legacy of mutual suspicion.

16.3.1 Ways Through Which the Quality of Scientific Debate could be Improved

- Science must be taught to pupils in schools in a manner that is true to its nature. If there are several distinct forms of knowledge that contribute to our full understanding of the world then this must be reflected in the full curriculum of the people. To do otherwise is to risk a dangerous bias in outlook and viewpoint.

- Every encouragement must be given to the media's effort to provide more articulate expression to scientific issues.
- Some of the unacceptable barriers that conceal the truth about scientific matters must be broken down. This is because when issues are crucial and decisions irrevocable then it is worth discussion to make the right move.

Activity 16.4 *What steps should be taken to ensure that societal control over scientific activity last longer?*

16.3.2. A Framework for Humanized Science Teaching

There are three main ways in which science can fulfil human needs: as a human activity, as a model for problem solving, as a world view or view of reality. Each of these ways has moral and philosophical aspects. Each way has consequences, some good, some arguably bad and some a matter of indifference. (Newton 1986).

As a human activity at the individual level, science offers the possibility of achievement, aesthetic satisfaction, approbation and a feeling of competence. At a wider level, it can offer the security of affiliation, prestige and influence. Science is often taught and written as though it is practised by calculating automata. Teachers and textbook writers need to remind students that science is done by people who share needs, feeling and motives with the rest of humankind. The popular image of the scientist is often wide off the mark.

Science codifies and organizes a body of knowledge into a worldview The fulfilment of human needs often leads to consideration of ethics and morality. Science as a human activity calls for an honest integrity of purpose, a suppression of the self and open-mindedness. If these are lacking, the activity is not science. At the same time, because science is a human activity, the patterns we observe in nature, are intimately connected with the patterns of our minds. So for a philosophical viewpoint, it might be argued that electrons, for example, do not have objective properties independent of the mind, whatever the degree of self-suppression. Without a moral input, a depersonalised, dehumanised culture develops, lacking in human sympathy and indifferent to feelings. Teachers might humanize their science teaching for very different reason. Those who want to prepare their students to make decisions of a political, social and economic nature might concentrate on problem solving. On the other hand, if the aim is to humanize the individual, the emphasis might be on moral aspects.

Activity 16.5: *What are two attributes of science as a human activity?*

16.3.3 Aims of Humanizing Science Teaching

Educating about and through science should develop the following :

(i) An appropriate image of a scientist,
- that science offers a chance to fulfil personal needs.
- that there is an essential commonality between those needs and sensibilities and those of own scientists.
- that the practise of science involves basic moral qualities of honesty, integrity of purpose, open-mindedness and suppression of the self.

(ii) An appreciation that science through technology contributes significantly to the ways in and means by which humankind now adopts to the environment and
- that this way of adapting to the environment generates choices, some with beneficial and detrimental consequences and others of marginal or questionable utility and
- because of the complex nature of the environment and interdependence of its parts, choices must be well informed and have regard to the quality of the evidence and
- that such choices often involve values and questions of morality

(iii) An appreciation of the physical view of reality and that such models can pervade a culture and can direct thought and action.

- that they are not fixed and unchanging
- that they have inherent limitations in application which can involve questions of morality Each of these necessitates some understanding of what is meant by moral behaviour. Its presence cannot be assumed and yet, it is considered the responsibility of all teachers to contribute to the development of moral capacities in their pupils. Science, as a humankind activity, can illustrate the humankind situation in this respect as well as most areas of the development of

(iv) Moral capacities such as:

- an awareness of sensitivity to and appropriate response to the sensibilities in self and others.
- a willingness to take another's perspective and to see something from another's point of view and
- an ability to consider the moral acceptability of choice and a willingness to temper rationality with humanity when making that choice.
- widening the aims of science education like this brings into it some aspects of the philosophy of science.

For those who do not have a test for humanized science teaching, the danger is that they might not push the humanized aspects far enough to achieve the higher aims. Reasoned value judgments and considerations of morality, for example could be absent in their approach. At best the science teaching might be nothing more than 'personalized' rather than humanized and humanizing (Newton, 1986). All sorts of reasons are given for humanizing science teaching among which is to prepare people to make reasoned, humane decisions in society.

Activity 16.6: *State two aims of humanizing science teaching.*

16.4 Science and Politics

Politics is about the organization of the state and in a country where the central government controls almost everything, then everyone including the scientist has a stake in politics.

The state have every right to ensure that the action of the individuals or groups does not violate the principles of the state itself Since science is a social activity, it can therefore claim no right to exemption from the rules that try to ensure social responsibility.

It is a truism that scientific development is expensive and it is usually only governments that can fund it adequately. In this sense, they already control the situation but it is important that those who make the decisions are correctly informed. To this end therefore political institutions must be open to allow important matters to be debated fully even if decisions have to be delayed. More importantly those who work in these sensitive areas must be allowed to make their contributions to the debate and not remain silent. This is through laws designed to safeguard national interest at a time when there is no threat to the nation. Science and politics in a developing country requires a greater understanding than what is happening now.

The scientist such as the chemist, physicist and biologist are contacted or employed by the state (politics) to research and find out the best way of solving societal problems. Often the scientists pass their findings to the technologists, engineers etc. who put them into usable forms to arrest the situation e.g. family planning techniques, drugs and materials to control population growth, drugs to control or cure diseases, electromagnetic waves to improve communication among others .

The scientist is a key to political stability and growth. The developed world is so powerful and stable because of its science and technological development. The need to give science special attention in the scheme of things requires no emphasis.

Activity 16.7: *How should government treat scientific issues to ensure development in the face of scarce resources?*

16.5 Conclusion

In this unit, you have learnt that science has individual, social and institutional dimensions. There is a human dimension in scientific discovery, the community/societies in which scientists work affect the type of activity they carry out, the very nature of the society seems to affect the direction of scientific research. Concepts are human inventions and part of human language and communication.

As a social activity science reflects social values and viewpoints -scientists never fit comfortably into the society of their time. Society is more interested in the benefits of science and hardly with the dangers that go with them. There are three ways through which quality of scientific debate could be improved. Politics is about organization of the state so the state that funds scientific activities should control them.

16.6 Summary

This unit is the end of the section that deals with philosophical, psychological and social aspects of the foundations of science. In the next unit you are going to start the study of history of science. You were informed by the study guide that there will be three term paper topics out of which you will select one. Two of these topics will be provided after references in this unit.

16.7 Tutor Marked Assignments

Write an essay of not more than four A4 pages on any one of the followings:

(a) The human face of science.
(b) The responsibility of the scientists to society.
(c) Science and politics.

16.8 References

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UNIT 17

Science and History

17.0 Introduction

Science as we know it today, was comparatively late product of the general development of human civilization. Prior to the modern period of history we cannot say that there was much of a scientific tradition, distinct from the tradition of the philosophers on the one hand and that of the craftsmen on the other. No matter how far back in history we go, there were always some techniques, facts and conceptions, known to craftsmen or scholars which were scientific in character. Science had its historical roots in two primary sources. Firstly, the technical tradition in which practical experiences and skills were handed on and developed from one generation to another. Secondly, the spiritual tradition in which human aspirations and ideas were passed on and augmented.

17.1 Objectives

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

- Describe science before there were scientist; 2,400,000-599BC
- Tell Greek and Hellinistic Science: 600BC-529AD
- Identify the renaissance and the scientific revolution era: 1453-1659
- State the Newtonian Epoch: 1660-1734
- Describe Nineteenth Century Science: 1820-1984
- Write the Twentieth Century Science through World War II; 1895-1945

17.2 Science before there were scientists: 2,400,000.599 BC

Science as an organized body of thought is generally considered to have begun with the Ionian school of Greek philosophers about 600BC. Discoveries or inventions prior to this period were nearly always examples of technology since they are specific devices or techniques. The men of the stone age developed a wide variety of tools: firstly stone tools, then followed by metal tools. These tools were for farming, hunting and self-defence from wild animals. At these period people started to domesticate animals settlements arose for the purposes of trade. Towns arose at the juncture of trade routes or near supplies of goods that could be traded. The earliest metal objects known were: gold, copper and some silver. They were discovered in their elemental form. Within this period some form of writing developed in Egypt. Within this period some scientific development had taken place in Egypt and Mesopotamia namely: Mathematics for keeping accounts and surveying, astronomy for calendar making astrological prognostication, medicine for curing diseases and driving away evil spirit.

Activity 17.1: *What tools did the early man develop and mention one of their uses?*

17.3 Greek and Hellinistic Science 600 BC -529 AD

Greek culture and scientific thinking first developed on the Ionian coast. Early Ionian science was materialistic. The atomists such as: Leucippus, Democritus believed reality to be embodied by matter. The pythagoreans viewed the universe differently; to them it was to be found in form and number pythagorean ideas strongly influenced the school of Plato and scientific thinking became more metaphysical in nature. Around the fourth Athens became the centre of Greek intellectual activity. Aristotle who lived in Athens and led the Lyeum (a school of thought) was the most important school in Greek antiquity. He was the first true philosopher of science, introducing the inductive - deductive method — a scientific method that still plays a role in scientific thinking today. Aristotle was the teacher of Alexander the great who conquered the world. The Ionian philosophers were: Thies, Anaximander and Anaximenes. They were all born in Miletus. These Ionian philosophers were the first to believe that people could understand the universe using reason alone rather than mythology and religion. They searched for a prime cause of a natural phenomenon. No personal forces of gods were involved, only impersonal natural processes.

Aristotle is also considered the father of life sciences. Alexander the Great became his patron, funded his work and arrange for Aristotle to receive samples of plants and animals from all corners of the Alexandrian empire. He classified organisms into a hierarchy ranging from most imperfect (plants) to most perfect man. He studied over 540 species and compared anatomy of 48 species by dissecting them. He discovered that the contribution of the mother was as important as that of the father in procreation.

Also many Greek philosophers including Anaxgoras, Empedocles, Democritus and Ph ilolaus were interested in medicine. Mathematics occupied an important place in Greek Science and was further developed than any other science. Mathematics is based entirely on reasoning the scientific activity Greeks preferred most-and does not require observation or experimentation as the basic sciences do. Archimedes is ranked as one of the first rank mathematicians in history. This write up shows that the Greeks played major roles in the development of science using reasoning rather than experimentation.

Activity 17.2: Name three great philosophers and their major contributions to knowledge.

17.4 The Renaissance and the Scientific Revolution 1453 .1659

You have so far studied the pre-scientific era and the Greek Science era. I hope you are making special note of the highlight as you were advised. Now you are going to read about the renaissance period in Europe.

The early renaissance was a period of change in arts than in science. This was the era of Leonardo da Vinci and Michelangelo. Alchemy and astrology were more important than chemistry and astronomy. The publication of Copernicus's heliocentric theory and Vesahis's anatomy (1543) was a good point for the scientific revolution. Throughout the west modern science began to take shape in many ways. The first scientific societies were founded. The church however opposed views of Corpenicus. The catholic forced Galileo to a house arrest during this period. Throughout this period, mathematicians introduced various symbols and conventions. They made mathematics almost a universal language. The telescope was also invented within this period. Galileo played a major role in science during this period: he constructed one of the first thermometers, introduced experimentation into science. He opened the way for Newton's discovery of universal gravitation. Galileo's introduction of astronomical telescope in 1609 changed the study of astronomy forever. Also Kepler advanced Copernicus idea by working out detailed movement of the planets. He also found empirical laws that governed these movements. The invention of printing led to the publication of books in medicine particularly in surgery and medicine. It was also during this period that Harvey discovered the circulation of blood. The renaissance era brought tremendous change in medicine, mathematics and arts in particular.

Activity 17.3: Name one scientist who played a major role during the renaissance era and state two of his contributions to knowledge.

17.5 The Newtonian Epoch: 1660 -1734.

As indicated in section 17.4 science developed fully during the years of scientific revolution but between the period 1660-1734, it found the forms of organisation it lacked before, prominent among them is the foundation of royal society in England and the Academic des science in France.

The most important work within this period was Newton's Princip ia. Not only did it become the foundation of physics for the next 200 years but it also formed the basis of scientific method that slowly made its entry into the study of natural phenomena. Newton based his theories on the careful examination of natural phenomena. He called his method the "method of analysis and synthesis" a procedure that included both an inductive and a deductive stage. Newton's most important discoveries were probably the product of intuition, which he later backed up with experiment, reasoning and mathematics. It is during this period that the separation of physics and metaphysics (or philosophy) took place. During this period observation and experimentation became the pillory of scientific activity. As a result of the scientific method, scientists ceased to rely on the old masters, such as Aristotle and started to study the results of their own observations and experiments when formulating theories and scientific instruments became available. It was recorded that the wide experimentation of this period resulted in many observed phenomena that were not understood. However these experiments formed the basis for the theoretical advances in physics and chemistry at the end of the eighteenth and beginning of the nineteenth centuries. Newton's work will be discussed further in unit 19 of this course.

Activity 17.4: The most important scientific work during the period 1660-1734 is________________
Try to fill the gap without checking from text

17.6 The Nineteen-Century Science 1820-1 4 [1]-

By the nineteenth century, experimental science had started to flourish in Europe and science became an acknowledged discipline. The nineteenth century started with the discovery of electromagnetism. During this century science and the teaching of science underwent a number of changes giving it much of the forms it has today .Many new fields of science, such as: anthropology, archaeology, cell biology , psychology and organic chemistry originated during this period. Also the teaching of science became linked to scientific research, a practice that later was followed by most of the universities in the world. Although the American Association for the Advancement of Science (AAAS) was founded during this period, theoretical science remained prominent till the beginning of the twentieth century. "Positivism" the use of scientific principles to explain the laws governing all phenomena became the dominant philosophy and scientific thought Was not only much better known but for the first time was opposed by segments of the public particularlythose who held certain religious beliefs. The major advances in science during this period include the following: the development of geology, theories of evolution of the species, the atomic theory of matter, the theory of light, the development of electricity and magnetism, thermodynamics. It is not surprising because the experimental approach to scientifical studies paved the way for all these discoveries.

Activity 17.5: Mention three new fields of science that originated during this period.

17.7 The Twentieth Century Science through World War II 1895 1945

This is an era of rapid development in the various fields of science. The scientific revolution and the experimental approach to science of the nineteenth century started to bear fruit. A little before the twentieth century, some remarkable developments occurred in physics i.e. the discovery of x-rays, radioactivity, subatomic particles, relativity and quantum theory. These developments affected, to various degrees, other subjects such as chemistry, biology, medicine among others. By nineteenth century, only few persons were full time scientists. However during the twentieth century, the number of scientists became so large that it is estimated that more scientists have lived in the twentieth century than all in previous eras put together.

Science became much of a communal effort than ever before. During this period, many of the observations that were made during the nineteenth century were now explained by new theories that emerged. The size of the scientific enterprise increased as well as its influence on society. As a result of its discovered usefulness, scientific research became not only firmly entrenched in universities but also in industry. Generally, much of the methodology worked out by the great scientists during the nineteenth century started to bear fruit e.g. the microscopic staining techniques develop,d in the nineteenth led to the discovery of many new organisms that cause diseases. Also science in the first half of the twentieth century became highly successful in explaining the nature of matter mechanisms of chemical reactions, fundamental processes of life, and the general structure of the universe. These successes of science started to exert a profound philosophical influence on the outlook of human beings. During this era, Darwin's theory of evolution became a principle accepted in the social sciences and psychology. Also the introduction of the Heisenberg's uncertainty principle affected the way scientists viewed reality in fundamental ways. Surely there is no way all the highlights of science in the twentieth century can be summarized bearing in mind the explosion of scientific activity within this era.

Activity 17.6: *State two reasons that contributed to the increased scientific activities of the twentieth century*

17.8 Conclusion

In this unit, you have learnt that the pre-science individual developed stone and metal tools with which he fanned, hunted and defended self from wild animals. The Greeks science was speculative and based on mental reasoning only. Aristotle, Archimedes and Thales were few of the great Greek scientists. The Greeks did not contribute much to science because of their approach to science. The Renaissance and the scientific revolution era saw the emergence of experimentation in science as introduced by Galileo. Copernicus heliocentric theory was published and modern science began to take shape in many ways. The introduction of the astronomical telescope revolutionized astronomy. The most important scientific work of the middle of the seventeenth century was Newton's principia which was the foundation of physics for the next 200 years. Observation and experimentation became the pillars of scientific activity. Nineteenth century science started with the discovery of electromagnetism. Science and teaching of science underwent a number of changes. The twentieth century science saw an unprecedented increase in both the number of scientists and their products e.g. Darwin's theory of evolution was accepted by social scientists and psychologists.

17.9 Summary

You would recognise from above that most of the major scientific breakthroughs took place mainly within the twentieth century. With the ever increasing number of scientists, one could predict with some certainty that science might be capable of controlling most of the physical, health and environmental problems that may arise within the twenty-first century.

17.10 Tutor-Marked Assignments

Briefly trace the history of science from the Greek period to the 20th century. What are your expectations for the 21st century?

17.11 References

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UNIT 18

Greek Science, Bacon, Copernicus and Galileo

18.0 Introduction

You have gone through the overview of history: of science from before there were scientists to the twentieth century. You must have discovered that there was a progressive trend (as you read the unit) culminating in what I may term a 'scientific explosion in the twentieth century'. Before you start the unit, read through the conclusion of unit 16. Read also the sections that discussed issues that concerned the Greeks, Copernicus, Galileo and Bacon. In this unit, you are going to discuss these topics in greater details.

18.1 Objectives

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

- Identify the highlights of Greek history.
- Tell what led to the demise of Greek history.
- Describe Copernicus heliocentric theory.
- Explain Bacon's scientific method.
- Recognize Galileo's contributions to Astronomy.

18.2 Greek Science

18.2.1 The School of Miletus

The history of Greek science begins in the sixth century B.C. The beginnings of Greek Science took place in the Ionian city of Miletus in the first half of the sixth century BC. The chief concern of the founders was with cosmology and with the behaviour of the four popularly recognized elements: earth, water, air and fire. The new mode of thought spread rapidly to various centres of Greece. After about 150 years of speculation, the endeavour culmination in the atomic system which was taught about 420 B.C. by Democritus. The school of Miletus where this new way of thinking began consisted of a succession of three men: Thabes, Anaxirnander and Anaxirnenes.

18.2.2 Thales c625 — 545 BC

Thales was a statesman, merchant and engineer, who learned some geometry from the Egyptians, some astronomy from the Babylonians and some navigation from the Phoenicians. He postulated that earth, water, air and fire are all modifications of one substance, water. As water becomes colder it turns in earth. As it becomes hotter it becomes air and fire that is, either steam or the invisible vapour that fills the region above the clouds. The account is simple but it is without mythical element.

18.23 Anaximander c611 — 547 BC

He was the disciple of Thales. He wrote a book titled "On the nature of things". He is credited with being the first man to make a map of the world. He rejected the choice of water as the fundamental substance, and gave it as his opinion that the first principle of things was an indeterminate substance, infinite in amount, which had the capacity to appear to us as earth, water, air and fire under certain conditions.

18.2.4 Anaximenes c550 — 475 BC

He chose mist or air as his first principle, because air is the breath of life and derived the other elements from it. By rarefaction mist became fire, also by condensation mist became first water and then earth. The differences between the elements were therefore quantitative the elements being mist condensed or rarefied to varying degrees.

18.2.5 The Pythagoreans c.582 —500 BC

Once the Milesian thinkers had broken the mythological spell, developments followed rapidly all over the Greek speaking world. In Croton in Southern Italy, Pythagoras, a refugee from Samos, had founded a community with religious, ascetic and scientific aims. Under him, arithmetic and geometry, to which the Milesians also had been no strangers, leaped forward. Pythagoras was not satisfied to say simply qualitative differences depended on quantity. He gave precision to the notion of quantity by introducing the concepts of number and pattern. With the Pythagoreans, mathematics and physics were not yet clearly distinguished.

Activity 18.1: *What was the Chief concern of the School of Miletus?*

18.3 The Eleatic School

An ex-follower of Pythagoras called Parmenides made a starting advance by applying a more rigorous logic to the fashionable pastime of world making. He altered the rules of the game. It was clear to him that both the rarefaction and condensation of Anaximenes and the number of patterns of Pythagoras implied the reality of empty space. For the former differences between things resulted from there being more or less air in given space, for the latter the number units were patterned in space.

18.3.1Empedocles c.500 — 430 BC

He held that all things were composed of quantitatively different proportions of the four elements. The agencies which combined the elements and separated them from their compounds were Love and Hate, both forces being inherent in the very nature of the elements. Water was allied to earth because they had the quality of coldness in common, yet they were at the same time different for water possessed the quality of wetness and earth that of dryness. Similarly air and fire were both hot, but one was moist while both have common quality and opposing qualities. He established the fact that air, a substance too fine to be perceived by the keenest of senses may yet occupy space and repel intruders. This was a milestone on the path to experimental science.

18.3.2 The Atoms of Democritus

The early atomists were Democritus 420 BC and Leucippus 440 BC; their contributions were inseparable. They believed that everything in the universe was composed of atoms, which were physically indivisible. There were infinite number of atom and they moved perpetually in an void. They had existed from eternity for they had not been created, and could not be destroyed. Atoms differed as to their size, shape and perhaps their weight.

18.4 Limitations of Greek Science

The Greek science was based on speculative philosophy. The Greeks detached themselves and tried to formulate general theories that would explain the universe. The Greek philosophers' search for understanding was not inspired by religion or practical application. It was entirely on the wish to know and understand.

Most of the time theories were based on very unsound data and this eventually led to the demise of Greek Science. When experimental science started scientists hardly referred to such speculative pronouncements anymore.

Activity 18.2 *Who is the father of the atom?*

Thies
Anaximenes Democritus
Empedocles Choose the correct answer.

18.5 Francis Bacon 1561 – 1626

Francis Bacon is the father of 'Inductive Science'. Bacon's view of scientific method was essentially experimental, qualitative and inductive. He distrusted mathematics and the art of deductive logic that went with it. He was not unaware that mathematics were a useful tool in science but he thought they were already well developed, like logic. According to him "these have not been the handmaids of science, but have exercised dominion over it." He was adverse to the method which was being developed by Galileo, of isolating phenomena from their natural context, studying only the aspects of such phenomena that were measurable, and then erecting a vast body of mathematical theory upon the results. Bacon wanted a consideration of all facts that might be relevant to the matter on hand -the physical nature of the heavenly bodies in astronomy, which Copernicus had not thought important, or the role of air resistance in gravitational fall, which Galileo ignored. To support his inductive approach, Bacon rejected a number of views and findings such as the following: On Aristotle's philosophy he said

> *This philosophy, (fit be carefully examined, will be found to advance certain points of view which are deliberately designed to cripple enterprise. Such points of view are the opinion the heat of the sun is a different thing from the heat of afire, or that men can only juxtapose things while nature alone can make them act upon another*

Bacon also rejected the views of the Greeks that the motions of the heavenly bodies are circular and uniform. To Bacon, this was merely a thing feigned and assumed for ease and advantage of calculation. Even then progress in science during the seventeenth century was achieved mainly by the mathematical-deductive method developed by Galileo and elaborated by Descartes, and it was only in the nineteenth century with the development of evolutionary geology and biology that the qualitative — inductive method of Bacon came into its own. It was then that vast stores of facts, mainly of a qualitative nature, were collected together from all over the globe, and inductive reasoning applied to elaborate the theories of geology and biology.

In applied science, Bacon was interested mainly in craft and industrial processes. Indeed he was termed 'The philosopher of industrial science' and was not so much concerned with the commerce and navigation that flourished in his own day. Bacon' s method was a development and clarification more of the values and procedures of the craft tradition than those of the scholars. However Bacon is remembered more as the father of the inductive method.

Activity 18.3 *What was Bacon's major reason for rejecting Aristotle's Philosophy and Greek Science?*

18.6 Copernicus 1473 — 1543

Copernicus was the son of a prosperous merchant and municipal official. His father died while he was ten years of age and he was adopted by his uncle Watzelrode who became Bishop of England in 1489. During the years 1496 -1506 he studied in Italy, returning to take up a canonry at Baltic when his uncle died in 1512. According to Mason (1962), the activities of Copernicus for the next thirty years were many sided as they touched upon medicine, finance, politics, and ecclesiastical affairs, but he seems to have been primarily concerned with the new system of the world which he thought of when quite a young man.

His new system of the world placed the Sun in the centre of the universe, and ascribed three motions to the earth, a daily spin on its axis, an annual orbit round the sun and a gyration of the earth's axis of spin to account for the precision of the equinoxes. Copernicus regarded his system of the world real, for he discussed questions that were not of a mathematical character, such as the physical objections to the theory of the motion of the earth, which need not have been considered were the theory regarded as hypothetical. The most important criticism Copernicus made of the ancient astronomers was that given their `axioms of 'physics' and the necessity of 'saving the appearances' they had either failed to explain what was observed in the heavens, or had unnecessarily complicated their systems of the universe. In his work, Copernicus reduced the number of circles required to explain the apparent movement of the heavens from the eighty or so used in the elaborate versions of the Ptolemaic system to forty-eight.

Moreover, Copernicus emphasized the similarity of the earth to the heavenly bodies by suggesting that they all possessed gravity. He added that the gravity did not act across space it only existed within aggregates of matter, like the earth and heavenly bodies, providing their binding force, and bringing them into the perfect form of a sphere.

Copernicus thus provided the answer to the Greek problem of how to explain the apparent movements in terms of motion that were circular and uniform. Copernicus book titled "De revotionibus orbium coclestium (On the revolutions of celestial bodies) was completed in the 1530s but he was reluctant to publish it because of fear of reprisals from the church. As Copernicus neared death, he was finally persuaded to publish by the mathematician Rheticus. Galileo, an astronomer and philosopher supported Copernicus work.

Activity 18.4: *What was the difference between Copernicus system of the world and that it sought to replace?*

18.7 Galileo Galilei 1564 - 1642

Galileo was born in Pisa. In 1610 he moved to Florence as the Philosopher and First Mathematician to the Grand Duke of Tuscany, and there he carried out his investigations in astronomy with the telescope. He also studied mechanics. Galileo's two great works are the dialogue concerning the two chief systems of the world, the Ptolemaic and the Copernican published in 1632 and his discourses on two new sciences published in 1638. Galileo's work in mechanics was_stimulated by the problems experienced in engineering. He specifically stated that it was the flight of projectiles that led him to study the gravitational fall of bodies.

The aim of promoting the Copernican revolution was primary for Galileo. Also Galileo was more effective historically in disseminating the Copernican system among the men of his time than Kepler. He brought simpler proofs to the wider public. His introduction of astronomical telescope changed astronomical practices for ever .

It is noteworthy that Galileo's work was not confined to astronomy only. Initially he developed investigations about pendulums and clocks, simple machines, thermometers and lenses. Because of Galileo's support for Copernicus work, he suffered victimization by the church and in fact died in detention.

Activity 18.5: *What stimulated Galileo 's work in mechanics?*

18.8 Conclusion

In this unit, you have learnt that the Greeks were concerned with cosmology and the behaviour of the four popularly recognized elements: Earth, Water, Air and Fire. The school of Miletus concerned itself with these studies. The Greek science was based on speculation and mental reasoning. Democritus is the father of the atom. Also Copernicus brought in a revolution both in the church and astronomy by showing that the sun and not the earth in the centre of the universe. Galileo the astronomer, physicist, and politician revolutionized astronomy by introducing the astronomical telescope. He is a strong adherent of Copernicus ideas for which he paid dearly by dieing in incarceration. Bacon is the father of the scientific method. He reject the works of Aristotle and the early Greeks because they were based on unsound data.

18.9 Summary

This unit has treated in greater details some of the issues raised in Unit 16 where you had an overview of the entire history of science. The treatment of such topics will continue for the next two units i.e. (18 and 19). Therefore in the next unit you will study: Darwin's Theory, Atomic theory, and the Computer.

18.10 Tutor Marked Assignments

1. Discuss the works and contributions to science for any two of the following:
   Francis Bacon
   Galileo
2. Explain why we should/should not study Greek science in the 21st century.

18.11 References

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UNIT 19

Charles Darwin's Theory of Evolution, the Periodic Table and the Computer

19.0 Introduction

The intellectual revolution initiated by Darwin sparked great debates. This issue scientifically was known to explain the great diversity of living organisms and of previous organisms evident in the fossil record. The earth was known to be populated with many thousands of different kinds of organisms, and there was abundant evidence that there had once existed many kinds that had become extinct. How did they all get here? Prior to Darwin's time, the prevailing view was that species did not change, that since the beginning of time all known species had been exactly as they were in the present. Perhaps, on rare occasions, an entire species might disappear owing to some catastrophe or by losing out to other species in the competition for food; but no new species could appear.

Nevertheless, in the early nineteenth century, the idea of evolution of species was starting to appear. One line of thought was that organisms would change slightly during their lifetimes in response to environmental conditions, and that those changes could be passed on to their offspring. (One view, for example, was that by stretching to reach leaves high on trees, giraffes — over successive generations- had developed long necks). Darwin offered a very different mechanism of evolution. He theorized that inherited variations among individuals within species made some of them more likely than other to survive and have offspring, and that their offspring would inherit those advantages. (Giraffes who had inherited longer necks, therefore, would be more likely to survive and have offspring). Over successive generations, advantageous characteristics would crowd out others, under some circumstances, and thereby give rise to new species.

You were told that apart from giving an overview of the entire history of the science, effort will be made to ensure that some of landmarks in history of science are discussed in greater details. In the selection of these landmarks, current issues and distribution of topics according to the major areas of science are taken into consideration. It is for these reasons that in this unit, you are going to study:
Charles Darwin's theory of evolution, the periodic table and the computer.

19.1 Objectives

At the end of this unit, you should be able to

- Assess the acceptability of Darwin's theory of evolution.
- Defend/not defend Darwin's theory of evolution.
- Discover how the periodic table was formulated.
- Name key features that worked on the periodic table.
- Tell who played the most important role in the invention of the computer.
- Describe the genesis of the invention of the computer.

19.2 Darwin's Theory of Evolution 1731-1802

Charles Darwin could be regarded as the most influential biologist of the nineteenth century. Darwin, in 1859, published his book titled "On the Origin of Species" by means of natural selection. During the years that followed, Darwin and the evolutionists had to face prolonged and bitter opposition both from their fellow biologists and from the church. The biologists saw their paradigm being challenged, the church saw the theory as an attempt to remove man from his God-given place at the pinnacle of creation and reduce him in status to a mere animal. According to Hellemans and Bunch (1988) there was no point explaining the origin of species until a species was defined. John Ray's 1686 definition of species: a species is a group of interbreeding individuals who cannot breed successfully outside the group (Buffon 1749).

The concept assumed that species are immutable. That means that one cannot develop a breed of goats that is of sheep's species. Ancient authors believed that nature is capricious. They also argued that scientists of the seventeenth and eighteenth centuries believed in a doctrine called preformation. This could be explained in two ways that the adult was preformed in the egg and that the adult was preformed in the sperm.

Activity 19.1: Who were the bodies that opposed the idea of evolution?

The preformation theory was replaced by embryologist with epigenesis to remove the barrier to the theory of evolution. While preformation would appear to preclude one species giving birth to a member of another species, the theory of epigenesis favoured the development of the embryo from undifferentiated tissues. Also the emerging understanding that fossils are the remains of living creatures and that some no longer exists favoured the possibility of evolution. Also in the eighteenth century a third condition emerged - an understanding that the time required for evolution to occur was present in Earth's history.

According to Heileman and Bunch, with this background, many scientists of recent times believed in some form of evolution. After the publication of "Origin of Species" many, although not all scientists, were converted both to evolution and to the Darwin -Wallace theory of natural selection. Many people also rejected Darwin's explicitly stated idea that humans and great apes share an ancestor. Two strong opponents of natural selection, were Samuel Butler the author of "The Way of all Flesh" and George Bernard Shaw. Later developments show that both Butler, Shaw and most other biologists were won by the theory of evolution and natural selection except those who continued to think that it contradicts the biblical stance on creation. It is noteworthy that there are modern evolutionists some who continue to improve upon Darwin and Wallace work and others who have rejected their ideas and possibly advanced their own. The new ideas combine with natural selection to form the basis for neo-Darwinism, the prevalent theory of evolution during most of the twentieth century.

Activity 19.2: What are the evidences that favoured the possibility of evolution?
Explain Neo-Darwinisni.

19.3 The Periodic Table

According to Helleman's and Bunch (1988) the ancient Greeks developed theories based upon four elements — earth, air, fire and water. The modern conception of element which is quite different from the Greeks was proposed in the seventeenth century by Robert Boyle, a chemist, who defined an element as a chemical that cannot be broken down into another substance. Some substances that were elements were rightly classified as elements while some that were not were wrongly classified as elements thus rightly classified — carbon, copper, zinc etc. wrongly classified - water, potash and air.

In 1799, Joseph-Louis Prohist, established that the compound copper carbonate always has the same proportions of copper to carbon to oxygen by mass; no matter how the compound is prepared. He proceeded to carry out similar analyses of other compounds for a period of about ten years. He discovered that in each case the proportions of the elements by mass stayed constant for a given compound. This became Proust's law of definite proportions. Dalton explained why this law was correct by postulating that the chemical elements are made from atoms that differ largely by mass. And if the mass of an atom of hydrogen (the lightest element) is taken as 1, then the other elements have atoms whose masses are multiples of hydrogen. Dalton could not calculate these masses because he was not sure of the exact composition of compounds such as water.

Around 1860, Kekule arrived at the conclusion that the subject chemistry was in a serious state of confusion because different formulae were being used for the same compounds. He then organised the first international scientific congress, the First International Chemical Congress to Straighten things out.

A little after these congresses, some of the scientists began to list the known elements in the order of their atomic masses. When they did, they found out that roughly every eighth element was similar. Some chemists attempted to publish this information but their publications were not satisfactory to the community of chemists.

Activity 19.3: *Define Proust law of definite proportions. Why did Kekule arrange for an international congress?*

However, in 1869 and 1870 two chemists, Mendeleev and Meyer, published clear satisfactory version of the idea. As a result of Mendeleev publication, he discovered three specific gaps in his periodic table in 1871. Mendeleev was highly recognized for his work particularly when the elements to fill the gaps were discovered within a short time i.e. between 1875 and 1885.

After the discovery of electrons and protons, Henry Moseley showed in 1914 that each element had a finite number of protons, that corresponded to the same number of electrons. Therefore it was concluded that atomic number not the atomic mass is the basis of the periodic table. Moseley's work showed that gaps existed between whole number of protons.

The existence of gaps provides opportunities for discovering new elements. When new elements were discovered it was found that they fit right into the blanks in Mendeleev's table. Moseley's work showed that seven "holes" were left in the periodic table. Within a short time five of these elements were discovered and they fitted the 'holes' as predicted. Also the presence of 'holes' led to the creation of elements by the use of radioactive materials (the explanation is beyond the scope of this course). While there were 92 known elements by 1940, the number increased to 109 by 1984.

Activity 19.4: *What was the conclusion arrived at as a result of Moseley's findings?*

19.4 The Computer

In the history of technology, the development of computers is unique. No other technical device underwent such rapid development after invention.

For a long time scientists have been fascinated by machines that would be able to perform calculations. During the seventeenth century, Blaise Pascal invented a machine with geared wheels that could add and subtract. Gottfried Wdhelm Leibniz a few years later, developed one that could add, subtract, multiply and divide. These machines and others like them required that a human operator direct the operation at every stage.

In the nineteenth century the Englishman Charles Babbage designed, but never completed a working model of a different kind of computing machine called the Analytic Engine. It had an important feature of the present day modern computer: it was designed so that it would perform mathematical operations from a set of instructions or a "program" supplied to the machine. The machine would "read" the instructions from perforated cards similar to those controlled by the looms that had been developed by Joseph Marie Jacquard about 20 years earlier. The Analytic Engine was to be equipped with a memory which Babbage called the "store" and a central processor, which he called the "mill". A long sequence of different operations could be performed with no human intervention after the punched cards were fed in. One of the reasons the Analytical

Engine was never completed was that it operated mechanically and technicians could not produce sufficiently accurate parts for the mechanical operation. The intervention of the vacuum tube however led to a revolution in technology during the 1920s. During the 1930s scientists investigated how the vacuum tube could be used to replace the mechanical gears and levers in the calculators of the day, descendants of Pascal's and Leibniz's machines.

The computer is one of the greatest inventions of our time. It is not definite on who invented the modern computer, it is however generally known that John V. Atansoff and his assistant Clifford Berry in 1942 built the first operational computers that used vacuum tubes to perform mathematical operations. This was called Atanasoff Berry Computer or ABC.

Around this period several other scientists and engineers started devising and building electronic computing machines. As in many other inventions, the development of computers was accelerated because of defence needs. During World War II, Ballist Research Laboratory in Aberdeen needed a faster, non-mechanical computer to keep up with the calculation of trajectories of projectiles that were required for the firing tables for gunners. For this purpose the construction of the computer ENIAC began in 1943 and was completed in 1945. It was an improvement on the ABC computer. ENIAC successor EDVAC as completed in 1952 by John von Neuman.

An important innovation was that programs could be stored in memory. Contrary to the ENIAC, which had several specialized processing units, the EDVAC had a central processor and a random- access read - write memory. It processed binary numbers serially and its functioning was based on Boolean logic.

According to Hellmann's and Bryan (1985) the development of electronic computers started because of the war effect. British engineers completed automatic computing engine by 1950. The first computer operating on a programme fully on memory was completed in Manchester in 1948. The 1950 and 1960s saw a rapid development in the production and use of computers. Some of the improvements were: introduction of computers to replace vacuum tubes, integrated circuits to replace circuits made up of discrete components. Solid state memories replaced bulky vacuum tube ones. The development in hardware is such that present-day desktop computers surpasses in memory, speed and power the large mainframe computers from the 1950s and 1960s. It is my view that we are yet to see the end of developments in computers.

Activity 19.5: *Who developed the first sophisticated computer?*

19.5 Conclusion

In this unit you have learnt that; Darwins evolution theory has received much acceptability operates under the name —Neo Darwinism. The periodic table provided opportunities not only for discovering elements but also for creating them. The first persons to invent a computer were; John v. Attanasoff and his assistant Clifford Berry. The first sophisticated computer was invented by John von Neumann.

19.6 Summary

The essence of these topics is to sensitise you to the works of people who have contributed significantly to the development of science.! do hope you are keeping the record you were initially advised to keep. Perhaps you are surprised like me to notice that the evolution theory is still gaining ground even among Christians. In the next unit you are going to study the last topics on people and events that made special marks in the history of science. The unit will comprise Newton's classical mechanics and Einstein's theory of relativity.

19.7 Tutor Marked Assignment

Discuss the development of the periodic tables and how it contributed to the discovery and creation of elements.

19.8 References

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UNIT 20

Newton's Classical Theory and Einstein's Relativity

20.0 Introduction

A close examination of topics that you have studied from units 16-18 will show that efforts have been made to select topics from the different disciplines of science. You should take special note of the topic distribution and refer to relevant textbooks for assistance particularly in topics that are not within your special subject area. You may have to read this unit several times to make sure you understand the basic concepts and theories discussed. In this unit you will study Newton's theory and Einstein's relativity.

20.1 Objectives

At the end of this unit, you should be able to:

- Explain what a scientific paradigm is.
- Discover that Newton's classical mechanics was used as the major paradigm in physics for 200 years.
- Tell exactly when Newton's paradigm started to fail physicists in trying to explain their research findings.
- State the major differences between Newton's theory and Einstein's relativity.
- Enumerate the contributions of these theories to science (physics).

20.2 Newton's Principia

For greater part of the last 300 years, Newton has been regarded as the greatest scientist of all time, and Mathematical Principles of Natural Philosophy as his greatest work. Everyone who has read up to ordinary level physics should have read or heard of Newton and his works. The Principia will be discussed rather than the man Newton because it is the book that made him famous. The Principia was written in the international scholarly language of Latin at a time when natural philosophers were increasingly communicating in their own languages. It used a classical form of geometric demonstration in dealing with such mathematical concepts as limits, infinite series, and the method of the fluxions. These were all more convenienti pressed algebraically, particularly the ideas that were suited to the competing continental notation of tk: calculus. Those who are competent and have studied the Principia speak of its superlative combination of precedent-creating originality and inescapable mathematical rigour. Newton changed the philosophical intentions of the Principia thrice in his life time.

20.2.1 Why the Principia is Important

- Principia is an especially successful mathematical representation of nature.
- By representing nature mathematically, Principia was able to extend dramatically the honourable tradition of using mathematical proof as a form of physical argument.

- The particular method Newton used was to start with definitions and inductively based axioms and then build up a deductive structure modelled on Euclidean geometry.
- Princ i pia is an outstanding example of a scientific treatise which sets out to establish the mathematical laws of phenomena without seeking the underlying cause.
- Principia made substantial contribution to the development of whole branches of mechanics, in particular the general laws of the motion of bodies, bodies at rest, media and the system of the world.
- By its general example and in its rules of philosophising, the Principia provided a general theory of scientific procedure which was a major stimulus to subsequent theories of knowledge and of scientific method.

In the general framework of Principia and in the commentaries, Newton developed his own distinctive philosophy of nature, with its clearly articulated conception of the relationship of God and nature. The philosophy was of great influence in the 18th century, but the various strands of discussion soon diverged considerably from Newton's conception and from one another.

Activity 20.1
- *What is the Principia?*
- *State twh reasons for the importance of the Principia.*

20.3 The Context of Principia

Judgements such as these can only be made by evaluating the Princi pia in context. On the whole, the scientific tradition has judged it by looking back through the tradition which grew out of it, while the modern discipline of history of science has sought to understand Newton's actions in the intellectual and social context of his own time and the earlier work upon which it drew.

The Private and Public Newton

Newton was a genius. The public Newton was an image initially carefully constructed by Newton himself and publicized further by Voltaire.

He worked long and hard at his theological interests. He believed that the ancient had known all about the physical nature and future history of God's creation by direct revelation.

Newton was extremely secretive. His obsessions were largely driven by private satisfactions and when he wanted to make work public he was ambivalent between the desire to have the priority of his work recognized and the desire not to tell anyone anything that might be exploited in future priority dispute.

He made no provision for doubt over the conclusiveness of his publicly presented work. He insisted that there was no room for hypotheses in experimental philosophy. Newton created an image of himself as a producer of unchangeably authoritative scientific knowledge. The importance of the public Newton was increased by publication by the philosopher John Locke on his essay concerning human to understanding.

Newton ian ism: traditionally, the study of the influence of Newton has been linked to the spread of a unified form of natural philosophy labelled Newtonianism.

Rotational Mechanics: the judgement of history is that Newton's mathematical influence was most productive among those mathematicians in the continent of Europe who made use of his ideas.

Many people found inspiration in Newton particularly in his experiments with the prism and his deductive presentation of his reasoning. In astronomy, Newton's influence was considerable, not merely from his system of the world but also from his contributions to optics. The enlightenment image and its wider influence on science, and in particular the achievements of Newton came to symbolize the pinnacle of achievement.

Activity 20.2: In the context of the Principia, give one example each of the strengths and weaknesses of Newton's character.

20.4 From Newton to Einstein

You may have to read this section several times before you understand it if you are not physics biased. As has been mentioned earlier, until Einstein, physics was based on the paradigm that was developed by Isaac Newton during the latter part of the seventeenth century and set out in his great book, "Principles of Natural Philosophy". This paradigm held that space was absolute, unalterable and Euclidean (flat), that time was absolute and linear, and that space and time thus formed a rigid frame of reference within which all bodies moved. Furthermore it held that all physical phenomena could, in principle, be explained in terms of interactions between bodies moving through absolute space and time, bodies that obeyed natural laws such as the three laws of motion and the law of gravitation. (You should consult a standard SS 3 text to familiarize yourself with these laws)

Activity 20.3: State two statements of Newtonian paradigm

During the following 200 years, the Newtonian paradigm was used to build up a clear exact, and seemingly comprehensive description of the physical world as it was known at that time. It was for example used to explain the motions of the various heavenly bodies with seemingly perfect accuracy, and was even used to predict the existence of a new planet - Neptune which was duly discovered exactly where Newton's theory said it would be. The paradigm had similar success when applied to terrestrial phenomena, and, when combined with the atomic theory developed during the nineteenth century, formed the basis of the kinetic theory of matter that led to the integration of thermodynamics and mechanics .

Activity 20.4: Mention two physical concepts that were explained using the Newtonian paradigm.

Towards the middle of the nineteenth century however, serious doubts began to arise regarding the validity of the Newtonian paradigm. During the previous decades numerous attempts had been made to detect motion through ether (the all-pervading medium through which electromagnetic waves were thought to propagate) and hence through absolute space. All such attempts failed, but, until, then, had been accommodated within the paradigm by making the assumption that a moving body drags some air along with it -just as a body that moves through air drags some air with it. Around 1890, however, it became apparent that the new electromagnetic theory had been developed by James Clerk Maxwell did not allow for ether drag, and so it was realized that something was fundamentally wrong.

Activity 20.5: What led to the fear that something was going wrong with the Newtonian paradigm?

Following a period of deepening crisis and confusion, the problem of ether drift was finally solved by Einstein in 1905 when he produced his special theory of relativity. This banished the concepts of absolute space and absolute time from physics, and showed that the results of all physical measurements (with sole exception of measurement of the velocity of light) depend on the relative motion of the observer and the thing being observed. The need for ether drag thus disappeared, since, according to Einstein's theory, there was no such thing as absolute motion.

Ten years later Einstein produced his general theory of relativity. This maintained that space-time was not 'flat but had curvature that depended on the amount of matter it contained, and that gravitational attraction could be explained in terms of curvature. One of the predictions of this new theory of gravitation was that light would bend when it passed close to a massive body like the si:n. This prediction was verified by Eddington during the total eclipse of 1919 — a result that made Einstein a world-famous figure overnight and led to his theories being taken seriously by scientists.

Since 1919, Einstein's relativistic world picture has become generally accepted, and is now firmly established as the basic paradigm of physics. (A.S.E., 1981).

Activity 20.6: What was the significant effect of Einstein's theory on Newton's? (Just mention one).

20.5 Conclusion

In this unit you have learnt that Newton was regarded as the greatest scientist of all time. That his fame is a result of his book Principia and its theories and statement. The Principia is very important for which six reasons were advanced. The man Newton (private and public) life could be discussed in the context of the Principia, Newton was religious and secretive, Newton's theory of absolute, unalterable and Euclidean space, absolute and linear time, space and time as one rigid frame gave way to Einstein's relativity theory which showed that all physical measurement (except the velocity of light) depend on the relative motion of the observer and the thing being observed. The general theory of relativity predicted that light would bend when passed through a massive body.

20.6 Summary

The theory of relativity revolutionized science in general and physics after 1919. The concept requires a lot of imagination to understand. Effort has been made to discuss purely from a philosophical point without involving any mathematics. However a good ordinary level physics may be useful or books on relativity treated on a non mathematical manner. Let me congratulate you on the effort you have made to reach this stage. I am sure you are happy to now turn to the last unit in this course which deals with the history of science education in Nigeria.

20.7 Tutor Marked Assignments

There will always be changes in paradigm as long as science advances.

- Discuss the statement with special references to Newton / Einstein paradigm shift.

20.8 References

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UNIT 21

History of Science Education in Nigeria (1)

21.0 Introduction

The unit will examine the historical perspectives of the development of science education in Nigeria. The history of science education in Nigeria runs from about the middle of the nineteenth century till date. You will be part of writing the history. In this unit, you will be exposed to some aspects of the history of science education in Nigeria.

In this unit you will study the following aspects of history of science in Nigeria:

- The early activities of Christian missions
- The beginning of colonial government participation and the missionary era
- Local community and government era.

21.1 Objectives

At the end of this unit, you should be able to:

- Arrange the whole period into specific periods of development.
- Identify the key individuals and organizations that took active part in the development of science education in Nigeria.
- Write a comprehensive report of the development of science education in Nigeria.
- State the contribution of the military to science education in Nigeria.
- Defend/not defend the call for handling over former missionary schools to their owners.
- Determine the quality of science education in Nigeria.
- Tell the contribution of the community to science education.

21.2 The Early Activities of the Missionaries

To state exactly when the teaching of the science started in Nigeria may not be possible, however, it could be traced to about 1859 when missionary secondary schools were established in Lagos. According to Omelewa (1977) such schools taught primary school subjects like languages, writing, geography, drawing, hygiene, singing and history to the exclusion of sciences. Later geometry and Algebra were introduced.

Abdullahi (1982) claims that the foundations for science teaching were laid in Nigeria between 1861 and 1897 when rudiments of science were introduced in both secondary and teacher training colleges. Notable among the schools are: Church Missionary Society (C.M.S.) Grammar School Lagos founded in 1859, C.M.S. Girls School Lagos in 1869, Saint Gregory's College Lagos by the Roman Catholic Church (R.C.M.) in 1876 to mention but a few. Three major patterns emerged in the establishment of post -primary institutions by the missions during this period. These were the grammar or classical educational schools, the teacher training and pastoral institutions and the vocational and agricultural schools. The school increased and spread to other parts of the country. Most importantly some schools later included such subjects like botany, nature study, physiology and natural philosophy.

Activity 21.1: State the three types of school that emerged in the early development of science in Nigerian schools.

During this period, the number of schools offering science increased but the population of students taking science course was unfortunately low. Nature study was the main science subject taught and the immediate school environment constituted the major laboratory. The major problems with science teaching at this period were:

- lack of qualified science teachers
- lack of interest or enthusiasm by the government (a colonial repressive government)
- lack of science textbooks
- lack of funds to promote science education
- lack of any uniform curriculum in science.

Activity 21.2: State two problems facing the schools during the period 1859 -1882.

21.3 Missionary Efforts and the Beginning of Colonial Government Participation

As mentioned in unit 21.2, the various Christian missions played pioneering role in the introduction of rudiments of science in the curricular of schools. However, the position changed when the colonial government began to establish secondary schools (Adelabu 1971).

The education ordinance was passed in 1908 and it stipulated among other things that the conditions to be satisfied by missionary schools for grants. The grant enabled some of the missionary schools to acquire some basic materials for science teaching. During this period the first government school was established in 1909. For a long time this remained the only college that consistently fulfilled the requirements Cambridge University Senior Local Examination (Taiwo, 1975). Science education was not popular at this period so only a few students offered it at the external examination. However many more missionary schools were established in Lagos.

Activity 21.3: Name the first government school that was established and when.

With the establishment of many more schools the study of science improved in the southern part of the country. However attempt to open some missionary schools failed because of the intolerance of the Muslims. The government on its part was hesitant to start teaching science in the North (particularly biology) so as not to offend the Muslim north. According to Abdullahi (1982) the first colonial government secondary school in the north was established in Kaduna i.e. Kaduna College in 1938. Prior to that Katsina College has existed as far back as 1922. According to Ogunleye (1999), the pace of development during the period (1883 -1993) was not very encouraging owing to the following reasons:

- The uncooperative attitude and reluctance of both the missionaries and colonial government to disallow Nigerians from learning science as they both believed that Africans were biologically inferior to and incapable of learning science.
- Inadequate financing of science education.
- Insufficient time devoted to science teaching in the school time-table.
- Lack of suitable qualified science teachers.
- Absence of science textbooks on school.
- Lack of laboratory facilities and science equipment in schools.

Other important events occurred within the educational system during the period. These are:

- The Africans education commission was set up in 1920 under the sponsorship of Phelps- Stokes of the United States of America (U.S.A.). This commission visited some African colonies under the initiative of the American Baptist Mission. After the visit the Commission expressed complete dissatisfaction with the quality of science education in Nigerian schools and directed that science subjects should be included in the curriculum of all secondary schools. The report also proposed the development of education through the introduction of vocational and agricultural subjects as well as establishing farm demonstration schools in the rural areas.
- The second event is the decline in the study of Nature because it was no longer popular among the students as it was not consistent with the psychology, philosophy and methodology of the time. While Nature study was then popular in teachers' college and in some primary schools. General science started to gain attention in the secondary schools and the objectives of general science were:
  - as a means not merely of giving the child a lot of scientific information, but also of developing in him certain attitudes and skills such as accurate observation, logical reasoning and a desire to experiment
  - general science deals with everyday application of science
  - general science show the unit of science rather than the compartmentalization of science h.to separate disciplines such as physics, chemistry and biology. (Abdullahi, 1982).
- The third event was the introduction of the West African School Certificate Examination (WASCE) in 1928 with Oxford and Cambridge boards as moderators. With this development Nigeria started to adopt syllabus for English high schools for the teaching of science.

Activity 21.4: Mention two events that occurred around 1930 that improved science teaching in Nigeria.

21.4 Government Efforts and Community Participation

Before this period only few students offered science in schools. However some remarkable improvement was made between 1931 to 1959. Some of these will be highlighted below.

The Yaba College was established in 1932 to provide well-qualified assistants in engineering, medicines and other vocations as well as provide teachers for science subjects in the secondary schools. Initially the college offered sub-degree courses in science, engineering, agriculture, medical studies, survey, and teacher training to fill vacancies in relevant government departments. The colleges programmes were completed by students within four years leading to the award of Diploma in the various subjects. The first set of graduands according to Abdullahi (1982) were recruited into the secondary schools and they played a major role in laying the development of appropriate curriculum for science in the secondary schools.

- It is also noteworthy to mention that between 1931-1959 there was a lot of community effort to improve science teaching in Nigeria. During this period about eleven secondary schools were established by individuals and about three were established by communities.

The education ordinance was enacted in 1948. This was the first document to provide an education policy and practice in Nigeria. This policy decentralized educational administration by classifying education as a regional service. According to Adesina other highlights of the ordinance were:

- appointment of a director of Education for Nigeria.
- establishment of regional boards of education and a separate one for the colony
- establishment of Native Authority and government schools
- Registration of teachers among others
- Establishment of a Central Board of Education in Nigeria.

Activity 21.5: What was the major contribution of the community to education during the period (1931—1959)?

Another important milestone in education within this period was the establishment in 1948 of the University College, lbadan as college of University of London. The Elliot Commission an Higher Education report which recommended the establishment of a University college in Nigeria was a major factor in establishing the college. It is gratifying to note that out of the initial two hundred and ten students over one hundred and twenty students were admitted to study science.

The third event was the introduction of Higher School Certificate (HSC) in 1951. Among other subjects, Physics, Chemistry, and Biology were offered.

Another important event was the setting up in 1952 of an examining board with the headquarters at Accra Ghana. This followed Jeffrey Report of 1950. This board later became West African Council (W.A.E.C) with Nigeria, Ghana, Sierra-Leone and Gambia as member nations. The council review curriculum and foreign examination bodies stopped moderating our examination at this level.

Within this period, the Science Teachers Association of Nigeria STAN was founded and this organization plays a major role in the popularisation of science in Nigeria.

Many events took place within this period as the politicians were getting ready for an independent government to be set up in Nigeria. Some of these other events are:

- The western region saw a lot of educational development within this period in comparison with the other two regions such as free primary education, secondary modern schools, comprehensive schools, commercial schools. These schools enrolled students for both academic and vocational science related disciplines.
- The Federal colleges of Arts and Science and Technology were established during this period. The establishment was as follows: Ibadan, 1950, Zaria 1952, and Enugu 1954. These schools maintained a comprehensive curriculum in science education and science related fields such as engineering, architecture etc. These colleges continued to provide students in science for the university college in lbadan until they became full-fledged universities later i.e. University of Nigeria, Nsukka; Alimadu Bello University, Zaria and University of Ife.

Activity 21.6: *When and where was the first university established in Nigeria? What was it called?*

21.5 Conclusion

In this unit, you have learnt that science started as Nature Study and later General Science, that the missionaries established the first schools in Nigeria. That both the missionaries and the colonial masters were hesitant to provide science courses in our school system. Communities contributed to educational development by building schools. University College, lbadan, was established in 1948. Federal College of Arts, Science and Technology fed the only university then Ibadan with science students and these colleges later became full-fledged universities.

21.6 Summary

This unit has discussed the development of science education in Nigeria up to 1959. This topic is continued in the next unit 21 as history of science in Nigeria.

21.7 Tutor Marked Assignment

Describe the Efforts of Missionaries and Colonial Government in the Development of Science Education in Nigeria.

21.8 Reference

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UNIT 22

History of Science Education in Nigeria (II)

22.0 Introduction

In unit 21 you studied the history of science in Nigeria from the arrival of the missionaries in 1859 to 1959. You learnt that the earliest schools in Nigeria were established by the missionaries and science was introduced first as Nature Study and later as General Science. You got such information as when the first government college was established, when the first university was built, how the other universities emerged etc. Some of the meetings, conferences in which specific decisions were taking about the future of science education in Nigeria were also discussed. In this unit you are going to study the history of science education in Nigeria from post independence to the period of technological awareness.

22.1 Objectives

By the time you complete this unit, you should be able to:

- Write the history of science education in Nigeria from post independence to the period of technological awareness.
- Compare the pre-independence era with the post independence era.
- Assess the contribution of the military to education during the period under review.

22.2 The Post Independence Era 1960 1969

According to Ogunleye 1999, the year 1960 when Nigeria gained political independence brought along with it national consciousness and awareness among Nigerians. This awareness was informed by the number of panels and commissions that were set up to study the educational priorities of the country and the major ones are the following:

- The Western Region of Nigeria Banjo Commission of 1960. This commission examined the structure of education in former western region of Nigeria and made recommendations that helped to move the region forward.
- The Ashby Commission of 1960 (Ashy Report). This commission was set up by the federal government of Nigeria to conduct an investigation into Nigeria's manpower requirements up to 1980. This report contributed significantly to the development of education in Nigeria including science education. This report showed that there was a general weakness of the educational system as consisting of lack of balance both in structure and its geographical spread between the north and southern part of the country. The report also frowned at the total neglect of science and technology education in Nigeria.

Ashby made special recommendation for the improvement of science education in Nigeria as follows:

- A progressive increase in the enrolment of primary school children in Northern Nigeria.
- The introduction into secondary school system of vocational/technical courses to reduce the bias

for literary studies and the expansion in enrolment into secondary schools.

- The introduction of more courses in technical schools and establishment of more technical institutes
- The establishment of a national universities commission to secure and distribute funds to universities and also co-ordinate their activities.

Activity 22.1: Mention one of the influence of independence on Nigerians

The university of Nigeria was officially declared open on the independence day while Ahmadu Bello University (North), University of Ife (West) were all established in 1962.

Also the Ashby report led to the establishment of Advanced Teachers Training College (ATTC) one in the east, one in the West and 2 in the north. Between 1960 and 1970, there was very encouraging increase in enrolment in all states of the federation, for example 1960 and 1970, the number of secondary schools rose from 883 to 1,155. Also the number of universities increased by 100% i.e. 3-6.

Abdul lah i (1986) reported that with the steady flow of science teachers from the universities education in science had grown in popularity at rates that seemed to be out-stripping the resources and facilities that were available for science teaching.

Also between 1960 and1969 with a grant from Ford Foundation, the Federal Government of Nigeria established a body charged with the responsibility of evolving a curriculum that was related to the needs of the country.

One major landmark in the history of education in Nigeria that occurred within this period was the National curriculum conference of 1969. This conference produced a blueprint for developing relevant curricula and national goals for all levels of education in Nigeria. The conference came up with a national philosophy in education. From this point onwards, Nigeria had a clear-cut policy on primary, secondary and post secondary education.

Activity 22.2: What was one of the major achievements of the national curriculum conference of 1969?

As a result of the Ashby report, a National Universities Commission (NUC) was set up in 1962. But it only became a full-fledged commission in 1975 under the chairmanship of Chief S. 0. Adebo. The main objective of the commission was to ensure the orderly development of university education in Nigeria, to maintain its high standard and to ensure its adequate funding.

The period immediately after independence was very eventful and yielded results in the area of population explosion in student enrolment but teacher supply and funds remained very poor thus affecting the quality of science education in the country.

Activity 22.3: Who was the first Executive Secretary of National Universities Commission?

22.3 Period of Rapid Expansion and Curriculum Innovation in Science Education

According to Ogunleye (1999), the period (1970-1980) was a relatively crowded one in the history of the development of science education in Nigeria — Six major events were responsible for this assertion.

It is necessary to mention that between 1967 and 1970, there was a way of survival in Nigeria where the oppressed Ibos had no choice but to fight for survival. This war ended in 1970 with no victor no vanquished though eastern was forced back to the mainstream of one Nigeria. Therefore 1970 was a post war year. Unity schools were established all over the Federation as a means of promoting national unity. The second major event that occurred with the period under review was the establishment of the National Youth Service Corps (NYSC) programme launched in June 1973. The one year national service provided sufficient opportunities for science and technology graduates of our universities to assist in teaching science in the schools thus improving the quality of science education in the country.

The third major event was the population explosion of students enrolment in various institutions of learning as well as expansion in terms of the number of such institutions. As a result, the Federal Government of Nigeria launched the Universal Free Primary Education (UPE) in 1976. As at this period 1976 there were 5,930, 296 primary school pupils, 704,917 secondary school pupils, 31 511 university students. As the U PE graduants qualified for secondary education, there was an unprecedented jump in enrolment in 1982183 when the UPE showed up for enrolment.

Also as a result of a large number of students qualifying for university education, the second generation universities were established in Nigeria in 1975. These are universities of Maiduguri, Jos, Calabar and Sokoto. Another major educational event that took place within this time was the establishment of the Joint Admissions and Matriculation Board (JAMB), a body that was charged with the responsibility of conducting entrance examination and placements of candidates into the various universities in Nigeria. This body was mandated by the Federal Government to admit students into the universities in the ratio of 60% for science and 40% for arts. This ratio has never been met since it was handed over to JAMB. There have always been more arts students than science students seeking for admission into the Nigerian universities. Within the period 1970-1979, a number curriculum innovation projects were carried out in Nigeria. The major bodies involved were

- The Comparative Education Study and Adaptation Centre (CESAC)
- The Nigerian Educational Research Council
- The Science Teachers Association of Nigeria
- The Test African Examination Council

Activity 22.4: *When were the second generation universities established? Which are the universities?*

These bodies out were involved in major curriculum changes such as designing and producing new curricula, production of textbooks among others. Also about this time, the National Teachers Institute was established. This institute concentrated on improving the qualifications of teachers needed for the primary school system. Till date NTI is still preparing teachers for the primary school level and the training is virtually by distance learning. By the end of this segment, by January 1977 the National Board for Technical Education was established. It was charged with among other things the responsibility of coordinating all aspects of technical and vocational education outside the universities.

22.4 The Period of Technological Awareness

A new National Policy on Education was published in 1977. One major feature of the policy was stating in clear terms objectives of education at all levels which are related to the overall national objectives. The national objectives are: building a free, democratic egalitarian, strong, just and self reliant Nigerian society full of opportunities for all citizens. Also the policy stipulated the number of years that should be spent at every level of the Nigerian education as follows: primary education—six years, junior secondary education — 3 years, senior secondary education — 3 years, and four years at the university. The became popularly known as the 6-3-3-4 system of education. The emphasis on technology at this period was shown in the introduction of introductory technology into the junior secondary schools. Another landmark was the establishment of Federal Universities of Technology as follows:

- Federal University of Technology Owerri 1980
- Federal University of Technology Akure 1981
- University of Technology Minna 1982
- Federal University of Technology Yola 1988

With these additional universities, the number of universities increased from 13 in 1975 to 27 in 1983. The emphasis at this time was information and technology transfer. To this end many polytechnics and technical colleges were established by both the Federal Government and the States. According to Ogunleye (1999), there about 45 polytechnics, over 130 government technical and vocational institutions and about

442 private technical and commercial institutions all over the country. To ensure availability of science students to the universities, the school of basic studies was established all over the Federation with greater emphasis on science subjects i.e. physics, chemistry, biology and geology. This era is regarded as the era of technology awareness and the establishment of technological oriented institutions reflected that adequately.

Activity 22.5: *State the all national objectives as spelt out in the National Policy in Education*

22.5 Conclusion

In this unit you have studied that the Ashby report provided a working document for the improvement of education after independence. That three additional universities were established between 1960 and 1962. Also second generation universities were established at this time between 1975 and 1983. The universities increased from 13 to 27 and there are over 40 universities in the country today. JAMB, ATTCS, NUC and many other educational institutions and commissions were established during this period. The launching of the National Policy on Education which spelt out clearly the objectives of education at all levels was a major development.

22.6 Summary

The period between 1960 and 1985 could be regarded as a period of educational take-off for Nigeria by Nigerians since these decisions had to be taken exclusively by Nigerians for the first time.

Any assistance by the colonial masters at this time was in advisory capacity. Let me congratulate you for completing this course. I hope you have benefited from the exposures in the various units. However there is yet unit 23 which is expected to help you present a scholarly term paper in this course.

22.7 Tutor.Marked Assignment

Describe the major educational changes that took place immediately after independence (you are expected to lay emphases on science education related issues).

22.8 References

Abdullahi, A. (1982). *Science Teaching in Nigeria.* Ilorin Atoto Press 10-25.
Ogunleye, A. 0. (1999). *Science Education in Nigeria.* Lagos, Sunshine International Publication (Nig.) Ltd. 16-42.

UNIT 23

Writing an Academic Paper

23.0 Introduction

As part of the requirement for this course you will be required to write a long essay. You might have discovered a pattern in the presentation of the units of this course. Such an organized presentation is known as a format. I am convinced that no matter where you are located in the country, you will surely have a library or an internet centre where you can go to search for information to enable you write a standard essay. This is the main goal of this unit.

23.1 Objectives

By the time you complete this unit, you should be able to:

- Look for information in the library or internet
- Write an essay using a provided format
- Discover that the type of topic determine the type of information to be sought for
- Employ the appropriate language in writing an essay
- Write appropriate references to the essay
- Carry out some assessment of your essay

23.2 Choosing a Topic

In a normal face to face situation where the library is easily accessible, you could be permitted to search for a topic related to the course and present it for discussion with the lecturer. However in a distant course like yours, the lecturer could decide to save you the problem of searching or formulating a topic. This however will not stop the discussion on how to choose a topic. You may have an idea or a particular area of interest within the course that you would like to explore. You may have several ideas, all equally interesting. If so write them down. All are good topics but before a decision is made about which to select, some works needs to be done. You will have time to read extensively on each topic. For example the topic you will be given will require some directive on how to secure the required materials since you are learning from a distance or it may even happen that some specific materials will be sent to you or you are directed to a website in an Internet if you have access to one. If a big library is near you such as a university library or a state public library. You will not have time to read extensively on each of the topics, but consult the library about books, journals or other articles that must have been written, you may consult the library catalogue to see how much have been written in the area. If that will be your first time for such consultation, you will need to request the assistance of the library officer on duty to assist you. It is also advisable to talk over your problems with colleagues. Though you are learning from a distance, I am very convinced that within the contemporary Nigerian set up, it will be possible to find someone either within your immediate locality or not very far a distance someone whom you can discuss with. At times the view you will obtain could differ from yours and may lead to alternative line of inquiry. Such a person or persons may know of recent publications which are not yet listed in the library catalogue. If you have people who are knowledgeable in your area around where you live, another good reason to consult them on time is that you might probably be asking for their support and collaboration. Early consultation is essential if you are to avoid difficulties later. Often selecting a topic is more difficult than it seems at first. With limited time at your disposal there is a temptation to select a topic before the groundwork has been done, but try to resist the temptation. Prepare the ground work well and you will save time later. Your discussions and inquiries will help you to select a topic, which is likely to be of interest, which you have got a good chance of completing, which will be worth the effort and which may even be of use later on.

Activity 23.1: *State two steps you will take to select an essay topic.*

23.3 Developing the Topic

Selecting a topic is just the beginning of any essay. Whether the topic is given to you or you select it there are some necessary steps that are important to the development of the topic. Now that you have chosen a topic the next exercise is to search for relevant materials that will enable you to develop the topic properly. For this purpose you have to search for relevant materials again from the library, the intemet, or from colleagues. In fact if you have the address of your course tutor you could consult him. Also while searching for a topic it is always advisable to ensure that there are enough materials you could refer to later. The first step in developing the topic is to select related materials and read them. At this point of your educational development, you should be familiar with method of keeping records or making notes from a text.

Finding information in the first place can be hard enough. Finding it again sometime afterwards can be even harder unless your methods of recording and fitting are thorough and systematic. When we are reading we always remember, but after several hours, weeks of reading, analysing and selecting, memory becomes faulty. So everything read and found important must be noted and the sooner some systematic system of record keeping is started the better. You must bear in mind that in any academic investigation there is never enough time to do everything that has to be done.

Most of the time people suggest card index but the ready alternative is a notebook or exercise book with which you can record everything you have read.

In addition to recording bibliographical details, you will need to devise a system of note-taking which records the actual evidence obtained from your sources. Some writers prefer notebooks as I have suggested some prefer loose sheets of paper while others prefer note cards. If you use a note book, information will be recorded as it is obtained. Leave a wide margin. At a later stage you may wish to cut up the notebooks, preferably into pieces of uniform size, to enable you to sort out materials into sections ready for planning the format for your essay.

Activity 23.2: *Why is it necessary to ensure that there is enough materials for the topic you might select?*

233.1 Categorization of Evidence

All your preliminary work is leading up to the writing of your essay. If you already mapped out chapter or topic headings (at times this is provided as style or format for the essay), you will have the basis of a system of categorization of evidence. If not, categories will emerge as you read. Your first choice of categories when recording information may in any case prove to be unsuitable and alterations may be needed as your understanding of the subject grows, so write the subject key in the left hand corner of the notebook/card so that it can easily be re-categorized if possible.

Sorting the cards into categories will help shape the essay's structure. At the writing stage they can be placed in the order in which the points will be made and divided into small manageable sections ready to be written up. Examples of categories could be drawn from the way section three of each unit of your course work is organized. You could have 3.1 which is a topic of its own or 3.1.1 which is a sub-topic but you discover that in each case the topic contains information that is specific. (Look at any particular subunit of section 3 of a course and observe this cohesion).

Activity 23.3: What is the importance of categorization?

23.3.2 Timing

There is never enough time to do all the work that seems to be essential in order to do a thorough job, but if you have a handover date (which for this course you will surely have), then somehow the work has to be completed in the specific time. It is unlikely that you will be able to keep rigidly to a timetable but some attempt should be made to devise a schedule so that you can check progress periodically and if necessary, force yourself to move from one stage to the next.

If you have to complete more than one project as in this course, it is particularly important to produce a chart indicating the stage of which all data should have been collected. Some attempt at planning progress should be made. One of the most common reasons for failing behind is that reading value takes longer than anticipated. Books and articles have to be located, and the temptation to read just one more book is always strong. At some stage a decision has to be made to stop reading, no matter how inadequate the coverage of the topic is. Forcing yourself to move on is a discipline that has to be learnt.

Activity 23.4: List two things that could delay your producing an essay on time.

23.4 Language

The basic requirement for writing an essay is the ability to use language in a clear and coherent manner. Remember you are at a distance so good language use will save you the problem of being asked to repeat the work particularly when the language is so bad that your lecturer is unable to read and understand it. An early start helps much, because if you start on time you will have the opportunity to revise and clarify awkward sentences. The language should be creative, clear and concise. Use of simple language and short, coherent sentences should be used. Slangs should be avoided. Sexist expressions such as using men to refer to humankind should be avoided e.g. Man is capable of controlling events that worry him. Human kind is capable ...

23.5 Body of the Essay and Referencing

The body of the essay should be arranged under subheadings or paragraphs. As mentioned earlier an issue that forms a subheading should be exhaustively discussed under that heading. The format style for the essay should be as follows:

Title
Abstract
Introduction
Content
Conclusion and
References

Abstract: this should be a summary of the entire essay. It should be written at the end of the essay. SOMeone who has no time to read your essay, should get a picture of what the essay is all about by reading your abstract.

Title: the title should not be another essay of its own though for this particular assignment the essay topic will be supplied to you.

Conclusion: the conclusion should be able to provide some of the highlights of the essay. Where a debatable issue has been treated, the writer should be able to take a stand at this point. A typical point example is as follows:

Title: A Classroom Practice for Enhancing Scientific Sense Making.

Name

Address

Abstract

Introduction

After introduction the body of the essay is broken into the following subheadings.

Scientific sense making

Affective constructs

Description of persons concerned

--------------------------------------- --------

Conclusion and finally References

Subheadings should not be numbered or underlined.

Referencing: The American Psychological Association format is adopted for this course. Three examples are shown below, one for a journal, one for a book, and the other for an edited material.

JOURNAL

Minstrel', J. (1982). Explaining the inertial condition of an object. *The Physics Teacher,* 20, 10-14. In this citation, 20 is the volume and 10-14 pages.

TEXTBOOK

Kuhn, T. S. (1970). *The structure of scientific revolutions.* Chicago. The university press, 81- 98.

EDITED WORK

Voorde, H. H. (1990) "On teaching and learning about atoms". In P.L. Licht & A. J. Waarlo (eds), *A central problem in science education.* 81- 103, lbadan: UPL. Plc.

You have now been given enough information for the essay which you are to write. You should choose one of these two topics.

(1) Equity in Science Education in Nigeria.
(2) A National Policy for Science Education in the Twenty First Century.

For the first topic: Equity in Science Education in Nigeria

You were told in Unit 7 of this course which dealt with equity and science learning in Nigeria that there are many inequalities in Nigeria. Such inequalities:

- Unequal access to education.
- Unequal access to wealth.
- Unequal access to accommodation.
- Unequal access to basic needs food, shelter and water. Even safety of life among other.

In Unit 7 the topic was limited to Gender only. In this essay you are to choose at least three of these variables and discuss how they affect science education -teaching and learning as well as performance. You may like to read Unit 7 again as a guide.

On *A National Policy for Science Education in the Twenty First Century;* you are expected to consider all you have learnt in this course so far and use them to formulate a national policy for science education. You should consider such issues: Goals and objectives, primary science education, secondary Science Education and teachers education. Admission policy, examination policy, provision of facilities among others. These topics are mentioned in the course guide and they will be sent to you clearly spelt out later .

23.6 Conclusion

In this unit you have learnt about how to choose an essay topic, how to develop the topic, how to categorize your library findings, how to time your work and how to write the entire essay from title to references. You have also been provided two topics out of which you are to choose one to write on.

23.7 Summary

You have studied how to write an academic essay in this unit. You will now plan how you will write on one of the two topics provided. I congratulate you once more for completing this course.

23.8 Tutor Marked Assignments

- Now that you have completed this course titled Foundations of Science. In not more than 6 A4 pages. Formulate a National Policy in Science Education.

23.9 References

Bell,!. (1983). During your Research Project: A Guide for First-time Researchers in Education and Social Science. Buckingham: Open University Press 15-24.

Uduigwomen, A. F. (1996). *A Textbook of History and Philosophy of Science*. Aba: AAU Industries. 147—157.