MANGALORE UNIVERSITY

CENTRE FOR DISTANCE EDUCATION
MANGALAGANGOTHRI - 574 199,
DAKSHINA KANNADA DISTRICT, KARNATAKA STATE

COURSE 8
Pedagogy of School Subject - II (c)

BIOLOGICAL SCIENCE
(Curriculum and Pedagogic Studies)
BLOCKS 1 & 2
(PART - 1)

B.Ed. DEGREE PROGRAMME
(OPEN AND DISTANCE LEARNING)

SECOND YEAR B.Ed.

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Contents

Overview of the Course

The basic concerns of education-to enable children to make sense of life and develop their potential, to define and pursue a purpose and recognise the right of others to do the same-stand uncontested and valid even today (NCF 2005). With this context, it becomes very important that student-teachers should get acquainted with the pedagogical bases of their method-subject/school subject. Pedagogy is considered a fertile ground for the integration of knowledge about the learner, the subject, and the social context.

Biological Science as Course 8 Paper under ODL of B.Ed. Programme is constituted by three major areas, namely, The nature, scope, history, and importance of biological sciences, The aims and pedagogical approaches for teaching-learning of biological sciences at different stages of school, and Theoretical aspects regarding how children understand and construct the knowledge of biological concepts in their diverse social contexts (NCTE 2009). Learning Resources of Biology and Assessment Practices are the other two integral parts of this course-8 paper.

The framework of the pedagogy of Biological Science is designed using Four Blocks with Six Units each. All the four blocks head towards the objectives of the paper Course-8 in which developing scientific temper, scientific attitude, appreciation towards the dynamic and expanding body of knowledge, nurturing curiosity, bringing the relationship with every day's experience and concepts of biological sciences, constructing appropriate and meaningful inquiry episodes, problem-solving situations and investigatory projects based on biology curriculum, bringing/developing linkage of different concepts of biological sciences with life skills are the thrust areas.

In the First Block, the nature and objectives of teaching biological science, its scope, history of biological sciences, the significance of inquiry, observation, and experiments in biological science, its inter-disciplinary linkages, and social concerns are discussed. The Second Block focuses on the Approaches and strategies of learning biology. Observation, inquiry, experimentation, experiential learning, expository approach, investigation, project, and collaborations are discussed with a special reference on teaching-learning in Biology. The Third Block deals with Learning Resources in Biology. Use of ICT tools and online resources at various stages of school education, ICT based virtual experiments and simulations as learning resources in biology are introduced with examples and illustrations. Planning for teaching-learning of Biology and Assessment parts are focused in the Fourth Block. It explains the need, importance, and different avenues for the professional development of Biology Teachers.

Finally, it all depends upon the other end of the communication i.e., the Receiving End. Hence the way how you receive, perceive, and practice this academic pursuit is the most significant aspect. These course materials may not be all-in-all but it gives you a path with a clear destination. Further, it will become more functional by your inquisitiveness and enthusiasm. Wishing you all the very best for your academic journey for great success and positive professional transformation.

Block 1 : Nature and Objective of Teaching Biological Science

Unit 1 : Nature of Biological Science

Unit Structure

1.1.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Recall the derivation of the term "Biology";
- Explain the meaning and nature of the subject Biology;
- Justify the importance of Biological Science;
- Trace out the historical stages of development of the subject Biology; and
- Describe the nature of modern biological science.

1.1.2. Introduction

Take a moment and observe the surrounding life patiently, surprisingly you will come to know that life is full of Biology! At one time you may feel that in life everything is made up of Biology, maybe it is our food, clothes, shelter, and what not? Biology as a discipline and subject in our curriculum took a late entry and for this, there are so many reasons. Experts in this field have seen the gradual but systematic evolution of the subject of Biology and now it is everywhere, influencing all walks of human life. Now the Science in general and Biology/life-science in specific have become an integral part of our school curriculum. In this unit, you will come to know about the meaning, nature, and importance of Biological Science, the history of the development of biological science, and also the modern biology, and its social context.

1.1.3. Learning Points and Learning Activities

1.1.3.1. Meaning, Nature and Importance of Biological Science

Activity 1: List out important uses of knowledge of Biological Sciences to the student in his day to day activities

Activity 2: Search information on interdisciplinary branch of biology - Bioinformatics

Greeks have very meaningfully defined Biology as the Science of Life. The term is derived from Greek words, like "Bios" which means life, and "logos" which means to study. According to Greeks' definition biology is the study of the structure and function of life i.e.,

living organisms. Apart from this biology studies the origin, evolution, and distribution of all living organisms. It also studies the growth, development, life-processes, and genetics of living beings. Here organisms means, it includes plants, animals, and micro-organisms.

Biology is the natural science that studies life and living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development, and evolution. It encompasses all the divisions of natural sciences namely, anatomy, physiology, cellbiology, cytology, biochemistry, and biophysics, etc. In recent years, a tendency of cross-disciplinary research and discoveries from different fields have merged to give a new horizon altogether. Because of this, the subject has also changed its features, and now it is integrated with other fields, like, chemistry, physics as biochemistry, biomedicine, biophysics, and biotechnology. However, the courses such as Botany-study of plants, Zoology-study of animals, and microbiology-study of microorganisms are ever occurring as usual. Biology mainly deals with the study of the structure of organisms-morphology and study of functions in organisms-physiology and the common phenomenon like propagation in organisms, genetics, evolution, and cellbiology. A cell is considered a fundamental unit of life. Hence biology is often approached based on levels that deal with fundamental units of life. All living organisms, regardless of their uniqueness, have certain biological, chemical, and physical characteristics in common. All, for example, are composed of basic units known as cells and of the same chemical substances, which, when analysed, exhibit noteworthy similarities, even in such disparate organisms as bacteria and human beings. Furthermore, since the action of any organism is determined by how its cells interact and since all cells interact in much the same way, the basic or the fundamental functioning of all organisms is also similar.

Biology has been understood on a certain framework in which all the branches of biology are unified under the canopy of a framework. This framework is designed with five fundamental basic understandings of living beings. The framework gives strong support and nourishment for the innumerable continuation of studies in the field of life science. The five major ideas under the framework are as follows:

- **Cell Theory:** The Cell Theory involves three parts, namely, (i) The cell is the basic unit of life, (ii) All living things are composed of cells, and (iii) All cells arise from pre-existing cells.
- **Energy:** According to The Theory of Energy, all living things require energy, and energy flows between organisms, as well as between organisms and the environment.
- **Heredity:** The theory of Heredity deals with the propagation of organisms. It states that all living things have DNA or some genetic information codes which determine the structure and function of all cells.
- **Equilibrium:** The theory of Equilibrium expresses that all living things must maintain homeostasis, a state of balanced equilibrium between the organism and its environment.
- **Evolution:** This theory is said to be the overall unifying concept of biology. Evolution is the change over time that is the engine of biological diversity.

The subject of Biology has its nature and characteristic features that are very important for the study purpose. So we shall look into this in detail in the following discussion:

1. Biological Science is a Rapidly Expanding Body of Knowledge

Newer disciplines are being discovered and established every day. This may be because of knowledge explosion, researches, science, and technological intervention. More and more subtle things are elaborated and have become different branches of science itself. Biology being one of such fertile branches of science is growing so rapidly and its body of knowledge is expanding at a supersonic speed. One should keep this in mind, otherwise, very soon people will become out-dated, and especially teachers must get abreast with the new knowledge without fail.

2. Biological Science is an Interdisciplinary Area of Learning

As it is told earlier, knowledge of science as a whole started growing and became too large. Though philosophy is considered the mother of all knowledge, each discipline has its depth and breadth. Knowledge being eternal has no water-tight compartments but it is humans who made the divisions just for the sake of convenience to study them. Therefore, there will be no one subject having a pure boundary of its own. Everything will be interdisciplinary only. In fact, at present, the trend is towards studying more than one discipline, or interdisciplinary subjects. For example, biotechnology, molecular biology, and biochemistry have emerged in recent times that necessitate the study of biology along with physics, mathematics, and chemistry. Can you imagine the disease diagnostic tools of today being developed without the experts from the fields of physics, chemistry, biology, mathematics, computer science, and others, pooling their expertise and cooperating? The equipment that measures the Blood Pressure, Body Temperature and so many machines that are used to diagnose the diseases, are the product of interdisciplinary contributions. In the case of biotechnology, you can very well see the combination of Biology and Technology. Biotechnology deals with the techniques of using live organisms or enzymes from organisms to produce products and processes useful to man. The name Biotechnology was given by the Hungarian engineer. The principles of Biotechnology are Genetic engineering and maintenance of sterile ambiance which works based on the chemical engineering process.

3. Biological Science is Always Tentative

Biological science like any other branch of science is empirical and testable. And it is tentative also. All theories, even the seemingly well-founded ones, can be revised or improved upon, or abandoned altogether whenever new evidence emerges, either as new experimental observations or as new theoretical developments. Whatever the view we take of the development of scientific theories, the fact remains that scientific theories are tentative and are always subject to change. Example-Lamarck's theory of use and disuse was later modified as Neo-Lamarckism and other theories like Darwin's theory of the origin of life by natural selection, mutation theory, etc.

4. Biological Science Demands Perseverance from Its Practitioners

Science demands tenacity and perseverance. A scientist, getting an inspirational idea or a creative thought on making a chance observation, or otherwise, has to persist with the idea to take it to its logical conclusion. Sometimes, the scientist works alone to the discovery or invention, while at other times the scientist can make only a beginning and then others join him/her in developing the idea further. This holds good for biological science also.

5. Biological Science as an Approach to Investigation and as a Process of Constructing Knowledge

Most investigations in science involve some form of the scientific method. It shows the creativity of humankind in seeking a solution to its problems. The approach used by the scientists in the study of astronomy and ecology is observation and prediction. In microbiology, they rely on laboratory experiments focused on cause and effect relationships. This is a glimpse of the process by which science works. Adding to the complexity it is the overlapping nature of different branches of biology. It is impossible to study zoology without knowing a great deal about evolution, physiology, and ecology. You can't study cellular biology without knowing biochemistry and molecular biology as well.

The importance of biology could be highlighted in the following manner:

- Biology helps us to know about the diversity in the living world and the ways by which it can be preserved.
- Biology helps us to know more about ourselves.
- Biology is such a vast field that it encompasses the study of various aspects of living organisms as well as their interactions with the non-living components. Hence, the studies of these different aspects form different branches of biology.
- Interdisciplinary branches indicate the relationship of Biology with other branches of science. Some common interdisciplinary branches, like, Biophysics, Biochemistry, Biometry and Bioinformatics, Psychology, and Socio-biology these have brought welfare to society and individual human beings.
- Applied branches enable us to apply the knowledge gained from different areas to be used for the welfare of man, animals, and plants. These include branches like Agriculture, Animal husbandry, Dairy, Poultry, Entomology, Aquaculture, Food Technology, and Biotechnology.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. The theory which was got neglected by the majority of the people in the beginning
    a. Theory of Inheritance by Gregor Mendel
    b. Lamarck's Theory of Use and Disuse
    c. Darwin's Theory of Organic Evolution
    d. Aristotle's Theory of Classification

2. The framework which helps us to understand the whole of Biology
    a. Cell, Tissue, Organ, Organ System and Organism
    b. Structure, Function, and Evolution
    c. Cell theory, Energy, Heredity, Equilibrium, and Evolution
    d. Plants, Animals, and Microorganisms

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. As a branch of science biology does not give scope for perseverance rather it demands then and there the results
    b. Biology as a branch of science has many applied disciplines
    c. Tentativeness is one of the major features of the subject of Biology
    d. The history of Biology could be traced back to the stone-age of man
    e. Charles Darwin proposed the theory of use and disuse
    f. Homeostasis is one of the mechanisms in which a natural equilibrium established

1.1.3.2. History and Evolution of Modern Biological Science

Activity 3: Ask the students to collect information regarding the History of Biological Science

Activity 4: Ask the students to collect information regarding Modern Biological Science and its Advantages.

Though it was not termed as biology, the subject has a long history. However it is not known when the study of biology originated, early humans must have had some knowledge of the animals and plants around them. Human survival depended upon the accurate recognition of non-poisonous food plants and an understanding of the habits of dangerous predators. Archaeological records indicate that even before the development of civilization, humans had domesticated virtually all the amenable animals available to them and had developed an agricultural system sufficiently stable and efficient to satisfy the needs of large numbers of people living together in communities. It is clear, therefore, that much of the history of biology predates the time at which humankind began to write and to keep records.

Ancient men of the Stone Age or even earlier to that had to study the animals they hunted and know where to find the plants they gathered for food. We know that the invention of agriculture was the first great advance of human civilization. In classical times, Aristotle is often considered to be the first to practice scientific zoology. He is known to have performed extensive studies of marine life and plants.

If we take the evidence, one of the first illustrated biology books is a botanical text written by German botanist Leonhard Fuchs in 1542. The binomial classification was inaugurated by Carl Linnaeusin 1735, using Latin Names to group species according to their respective characteristics features. The major credit should go to the invention of the microscope. Microscopes opened up new worlds for scientists. In 1665, Robert Hooke used a simple compound microscope to examine a thin sliver of cork. He observed that the plant tissue consisted of rectangular units that reminded him of the tiny rooms used by monks. He called these units “cells”. In 1676, Anton von Leeuwenhoek published the first drawings of living single-celled organisms. Theodore Schwann added the information that animal tissue is also composed of cells in 1839.

On Nov. 24, 1859, Charles Darwin published “On the Origin of Species”, the text that forever changed the world by showing that all living things are interrelated and that species were not separately created but arise from ancestral forms that are changed and shaped by adaptation to their environment. Gregor Mendel now known as the father of genetics was almost did not get any recognition at his time. But his work was re-discovered and the Theory of Inheritance came to the surface during 1900. Watson and Crick brought outstanding work with the structure and function of DNA the genetic material. From there on all the fields of biology have expanded exponentially and touched every aspect of our lives. Hence the 20th and 21st centuries may be considered as the “Time of Biological Revolution”. Medicine will be changed by the development of therapies tailored to a patient's genetic blueprint or by combining biology and technology with brain-controlled prosthetics. Economies hinge on the proper management of ecological resources, balancing human needs with conservation. We may discover ways to save our oceans while using them to produce enough food to feed the nations. We may develop batteries from bacteria or light buildings with bioluminescent fungi. The possibilities are endless; biology is just coming into its own.

Moreover, as a result of the relatively recent development of extremely sophisticated instruments, such as the electron microscope, the ultracentrifuge, and automated DNA sequencing machines, biology has moved from being a largely descriptive science-one concerned with entire cells and organisms to a discipline that increasingly emphasizes the sub cellular and molecular aspects of organisms and attempts to equate structure with function at all levels of biological organization.

In the 1970s the development of recombinant DNA technology opened the way to genetic engineering, which enabled researchers to recombine nucleic acids and thereby modify organisms' genetic codes, giving the organisms new abilities or eliminating undesirable traits. Those developments were followed by advances in cloning technologies, which led to the generation in 1996 of Dolly the sheep, the first clone of an adult mammal. Together, recombinant DNA technology and reproductive cloning (the method used to produce a living animal clone) facilitated great progress in the development of genetically modified organisms (GMOs). Such organisms became crucial components of biomedical research, where genetically modified (GM) mice and other animals were developed to model certain human diseases, thereby facilitating the investigation of new therapies and the factors that cause disease. Recombinant DNA technology played a crucial role in the generation of GM crops, including pest-resistant forms of cotton and herbicide-resistant forms of maize (corn) and soybeans.

Advances in tissue culture have enabled countless discoveries in biology. For example, many experiments have been directed toward achieving a deeper understanding of biological differentiation, particularly of the factors that control differentiation. Crucial to those studies was the development in the late 20th century of tissue culture methods that allowed for the growth of mammalian embryonic stem cells—and ultimately human embryonic stem cells on culture plates. Just as the 19th century can be considered the age of cellular biology, the 20th and 21st centuries were characterized primarily by developments in molecular biology.

The 20th and 21st centuries also saw major advances in areas of biology dealing with ecosystems, the environment, and conservation. In the 20th century, scientists realized that humans are as dependent upon Earth's natural resources as are other animals. However, humans were contributing to the progressive destruction of the environment, maybe because of an increase in population pressure and certain technological advances. Lifesaving advances in medicine, for example, had allowed people to live longer and resulted in a dramatic drop in death rates (primarily in developed countries), contributing to an explosive increase in the human population. Chemical contaminants introduced into the environment by manufacturing processes, pesticides, automobile emissions, and other means seriously endangered all forms of life. Hence, biologists began to pay much greater attention to the relationships of living things to each other as well as to their biotic and abiotic environments.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. "The Origin of Species" by Charles Darwin was published in the year
    a. 1859
    b. 1857
    c. 1888
    d. 1890

2. The Dolly Sheep was produced in
    a. 1990
    b. 1996
    c. 1995
    d. 1998

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Genetic engineering enabled researchers to recombine nucleic acids and modify organisms' genetic codes
    b. Individual's fingerprints are known as DNA-Finger Print
    c. Stem cells are nothing but the cells from the stem part of a plant body
    d. DNA technology and reproductive cloning facilitated great progress in the development of genetically modified organisms
    e. The binomial classification was inaugurated by Carl Linnaeus
    f. The present 21st century is noted for the developments in Molecular Biology

1.1.4 Let us Summarise

Biology is the natural science that studies life and living organisms, including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development, and evolution. The term 'Biology' is derived from Greek words, like "Bios" which means life, and "logos" which means to study. According to Greeks' definition biology is the study of the structure and function of life i.e., living organisms. Biology mainly deals with the study of the structure of organisms-morphology and study of functions in organisms-physiology and the common phenomenon like propagation in organisms, genetics, evolution, and cell biology.

Biology has been understood on a certain framework in which all the branches of biology are unified under the canopy of a framework. This framework is designed with five fundamental basic understandings of living beings. Those five fundamental frameworks are cell theory, heredity, energy, equilibrium, and evolution. If we look at the nature of the subject biology, it appears as a descriptive discipline with, rapidly expanding body of knowledge. It is an Interdisciplinary Area of Learning and always tentative. Biological Science Demands Perseverance from Its Practitioners and it is an approach to Investigation and as a Process of Constructing Knowledge. The advantages of learning biology will be like, it helps us to know about the diversity in the living world and the ways by which it can be preserved. It helps to understand ourselves clearly. Biology is such a vast field that it encompasses the study of various aspects of living organisms as well as their interactions with the non-living components. Hence, the studies of these different aspects form different branches of biology.

Interdisciplinary branches indicate the relationship of Biology with other branches of science. Some common interdisciplinary branches, like, Biophysics, Biochemistry, Biometry and Bioinformatics, Psychology, and Socio-biology these have brought welfare to society and individual human beings. Applied branches enable us to apply the knowledge gained from different areas to be used for the welfare of man, animals, and plants. These include branches like Agriculture, Animal husbandry, Dairy, Poultry, Entomology, Aquaculture, Food Technology, and Biotechnology.

The invention of microscopes made drastic developments in the subject as a whole. Just as the 19th century is considered the age of cellular biology, the 20th and 21st centuries were are characterized primarily by developments in molecular biology.The 20th and 21st centuries also saw major advances in areas of biology dealing with ecosystems, the environment, and conservation.

1.1.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1
1.a 2.c 3.a- X b- √ c- √ d- √ e- X f- √

Check Your Progress - 2
1.a 2.b 3.a- √ b- X c- X d- √ e- √ f- √

1.1.6. Unit end Exercises

1. What is Biology? Explain the origin of the term Biology.
2. Why Biology is called a descriptive subject? Justify your answer.
3. Explain the meaning and nature of biological science.
4. Is biology important to our life? Express your answer with a strong rationale.
5. Trace out the historical stages of development of the subject Biology
6. Describe the nature of modern biological science
7. Elucidate that biological science demands perseverance from its practitioners.

1.1.7. References

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Block 1: Nature and Objective of Teaching Biological Science

Unit 2: Scope of Biological Science for understanding the diversity of the living world, the origin of life and its evolution, environment, health, sustenance of the ecosystem vis-à-vis values and ethics

Unit Structure

1.2.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Identify the scope of biology in terms of diversity of the living world;
- Recall the theories of the origin of life;
- Explain the theories of organic evolution;
- Exhibit the relationship between the scope of biology, environment, and health;
- Describe the values and ethics of sustenance of the ecosystem; and
- Recognise the vast scope of the subject biology and its relevance to life.

1.2.2. Introduction

You might have observed that 'scope of the subject' or 'choice of the optional subjects' is a very much-discussed topic among the 10^{th} standard or 12^{th} standard students. Because it is high time for them to decide to which line their further academic journey will be or where/what will be their destiny. Here scope means what are the chances of getting benefits, like, job, earning, facilities and uses of studying a particular subject. However, the term scope has more meaning which goes beyond the above-said parlance. In this unit, you will come to know about the scope of biology in general and understanding the origin of life, diversity in life, organic evolution, our environment and its sustainable development, values, and ethics that are needed for this in particular. Knowing biology will enable an individual to lead a healthy and hygienic life. By studying Biology one may get a job that satisfies his vocational desire. In this way, biological studies have certain impregnated values, like, pragmatic or utilitarian value, vocational value, aesthetic value, and intellectual value. In this unit, all these information are explained with suitable illustration.

1.2.3. Learning Points and Learning Activities

1.2.3.1. Scope of Biological Science

Activity 1: Search for different connecting links in animals and plants and discuss them in the classroom.

Usually, the scope of biology is discussed with the vast number of branches it has. Because more the number of branches and applied branches more will be the scope of the subject. To illustrate some of such branches could be, like, Botany, Zoology, Applied Botany, Microbiology, Biotechnology, Bio-Engineering, Food Technology, Genetic Engineering, medicine, and Environmental Science. Bio-Engineering deals with the production of artificial body parts, like, limbs, stunts, pace-makers, and other machines that help in impaired body functions. Biotechnology is a combination of biology with technological as well as the industrial field. Genetic engineering is the field in which the hereditary features are taken into consideration for the needful modification, including artificial gene production. Such synthesized genes are used to cure certain hereditary diseases. Food-technology is the science of processing and preservation of healthy foods. The application of science for the manufacture of milk products is called Dairy technology.

Branches, like, Apiculture (honey bees rearing), Pisciculture (Fishery), Mushroom Culture, Sericulture, Flora-Culture, growing Orchids for commercial purpose, Tissue culture and maintaining plant nurseries-all these have vocational value and knowledge in such branches help individuals to gain their bread and butter. Apart from these, innumerable branches are emerging in the current situation, and right now the most demanded branches are virology and bacteriology.

Diversity of the Living World, Origin of Life and Evolution

The scope of Biology is well understood by knowing its diversity. If a particular geographical place is having a large variety of organisms, then it is said to be a rich biome and fertile area. Biologically speaking such areas are said to be a good sign of life on earth. Now we shall look into the meaning and nature of the term Diversity of the Living World.

How wonderful is the living world! Just observe it mindfully! The wide range of living types is amazing. The extraordinary habitats in which we find living organisms, be it cold mountains, deciduous forests, oceans, freshwater lakes, deserts, or hot springs, leave us speechless. The fascinating world of birds, butterflies, flowers, molluscan shells, and starfishes- no one is a Xerox Copy of the other. If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets, or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. If you were to increase the area that you make observations in, the range and variety of organisms that you see would increase. If you were to visit a dense forest, you would probably see a much greater number and kinds of living organisms in it. Each different kind of plant, animal, or organism that you see, represents a species. This is called biodiversity meaning the number and types of organisms present on earth. ‘Biological diversity’ means the variability among living organisms from all sources including, terrestrial, marine, and other aquatic systems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

The science of Biology is very broad in its scope, this is because there is a tremendous diversity of life on Earth. The source of this diversity is evolution, the process of gradual change during which new species arise from older species. Biodiversity may be defined as the variety and variability of living organisms and the ecological complexes in which they exist. Biodiversity includes the genetic variability (for which different varieties of spices have appeared in the course of evolution) and the diversity of life forms such as plants, animal microbes, etc. living in a wide range of ecosystems. The diversity may be inter-specific (within species) and inter-specific (in between the species) but these are well supported by the ecosystem. It is seen that the diverse living forms of the ecosystem are modulated with global environmental changes.

Types of Biodiversity

For the study purpose, the diversity has been grouped into three interrelated but hierarchical levels, namely, Genetic Diversity, Species Diversity, and Community/Ecosystem Diversity.

1. Genetic Diversity

It describes the variation in the number and types of genes as well as chromosomes present in different species. The magnitude of variation in genes of a species increases with an increase in size and environmental parameters of the habitat. The genetic variation arises by gene and chromosome mutation in individuals especially in sexually reproducing organisms and it is spread in the population by recombination of genetic materials during cell division after sexual reproduction. Genetic diversity mainly helps in knowing the speciation or evolution of new species. The study gives an extension to know about the adaptation to the environment by the organisms. The credit of revolutionary advancement in the field of agriculture must go to the branch, Genetic Diversity.

2. Species Diversity

It describes the variation in the number and richness of the spices within a region. The species richness may be defined as the number of species per unit area. The richness of a species tells about the extent of biodiversity of a site and provides a means for comparing different sites.

The species richness depends largely on climatic conditions. The number of individuals of different species within a region represents species evenness or species equitability. The product species richness and species evenness give species diversity of a region. When a species is confined entirely to a particular area, it is termed as endemic species.

3. Ecosystem Diversity

It describes the assemblage and Interaction of species living together and the physical environment in a given area. It relates varieties of habitats, biotic communities' ecological processes in the biosphere. It also tells about the diversity within the ecosystem. It is referred to as Land-scape diversity because it includes the placement and size of various ecosystems.

For example, landscapes like grasslands, deserts, mountains, etc. show ecosystem diversity. The ecosystem diversity is due to the diversity of niches, trophic levels, and ecological processes like nutrient cycling, food webs, energy flow, the role of dominant species, and various related biotic interactions. Such type of diversity can generate more

productive and stable ecosystems or communities capable of tolerating various types of stresses e.g. drought, flood, etc.

The knowledge of Diversity among living beings later lead to the classification and Binomial Nomenclature by the scientists. This made the study of biological sciences more rigorous and systematic. Taxonomy thus became a very significant and prominent part of the biological studies. The taxonomic studies of various species of plants and animals are useful in agriculture, forestry, industry, and in general for knowing our bio-resources and their diversity. The basics of taxonomy like identification, naming, and classification of organisms are universally evolved under international codes. Based on the resemblances and distinct differences, each organism is identified and assigned a correct scientific/biological name comprising two words as per the binomial system of nomenclature.

The living organisms on earth are of great diversity, living in diverse habitats, and possessing diverse qualities and are vital to human existence providing food, shelter, clothing, medicines.

Biodiversity has the following uses for the development of humanity:

- It provides food of all types.
- It provides fibers, sources for the preparation of clothes.
- It provides different types of oil seeds for the preparation of oils.
- It provides new varieties of rice, potato, etc. through the process of hybridization.
- It provides different drugs and medicines which are based on different plant products.
- It is very essential for natural pest control, maintenance of the population of various species, pollination by insects and birds, nutrient cycling, conservation and purification of water, the formation of soil, etc. All these services together are valued at 16.54 trillion dollars per year.

Understanding the Scope of Biology by knowing the Origin of Life and Evolution

If a species can develop only from a pre-existing species, then how did life originate? If "Life begets Life" what is the origin of life? This is how the tricky question has tackled the biologists in the earlier days. So to answer this question several theories were also generated. Greeks believed that flies and other small animals arose from the mud at the bottom of streams and ponds by spontaneous generation. According to the Theory of Special Creations, God created all the life on earth. The theory of spontaneous generation or abiogenesis assumes that non-living material in a spontaneous manner gives rise to life.

The Italian physician and poet Francesco Redi was one of the first to question the spontaneous origin of living things. The theory of spontaneous generation was criticized by Lazzaro Spallanzani, Francisco Redi, and Louis Pasteur. These great scientists performed well designed scientific experiments to disprove the theory of spontaneous generations. Pasteur later showed that parent microorganisms generate only their kind, he thereby established the study of microbiology. Moreover, he not only succeeded in convincing the scientific world that microbes are living creatures, which come from pre-existing forms but also showed them to be an immense and varied component of the organic world, a concept that was to have important implications for the science of ecology. Further, by isolating various species of bacteria and yeasts in different chemical media, Pasteur was able to demonstrate that they brought about chemical change characteristically and predictably, thus making a unique contribution to the study of fermentation and biochemistry.

The theory which was put forward by Richter and strongly supported by Arrhenius, namely, The Theory of Cosmozoic assumes that life was present in the form of resistant spores and appeared on earth from another planet. Since the condition of the earth was supporting life, these spores grew and evolved into different organisms. The theory initially got support from the fact that fossils of microorganisms were found in meteorites in 1961. But no mechanism is known about the transfer of spores from other planets or whether these spores could survive the journey in space. The absence of life forms on any planet except earth and no details about the spores, their origin, and mechanism of crossing interplanetary space and reaching the earth. Also, this theory doesn't add much to the fundamental details about the origin of life. No scientific experiments were given to support the theory. As a result, the hypothesis didn't receive much attention.

In the 1920s the Russian biochemist Alexander Oparin and other scientists suggested that life may have come from non-living matter under conditions that existed on the primitive Earth when the atmosphere consisted of the gases methane, ammonia, water vapour, and hydrogen. According to that concept, energy supplied by electrical storms and ultraviolet light may have broken down the atmospheric gases into their constituent elements, and organic molecules may have been formed when the elements recombined.

Some of those ideas have been verified by advances in geochemistry and molecular genetics; experimental efforts have succeeded in producing amino acids and proteinoids (primitive protein compounds) from gases that may have been present on Earth at its inception, and amino acids have been detected in rocks that are more than three billion years old. With improved techniques, it may be possible to produce precursors of or actual self-replicating living matter from non-living substances. But whether it is possible to create the actual living heterotrophic forms from which auto trophs supposedly developed remains to be seen.

Modern Theory/Chemical Theory was put forward by A.I. Oparin and J.B.S Haldane. It was based on the hypothesis of abiogenesis with a condition that the non-living materials can give rise to life in the condition of the primitive earth. They proposed that,

1. Spontaneous generation of life under the present environment is not possible.
2. Earth's atmosphere ~1 billion years is very different from the current conditions.
3. Primitive earth's atmosphere was reducing in nature.
4. Under these conditions, the chemical molecules (inorganic molecules) react with each other through a series of reactions to form organic substances and other complex biomolecules.
5. The solar energy and UV radiation provided the energy for the chemical reactions.

Organic Evolution

Today life diversity on earth is the result of evolution. On Earth life began at least 4 billion years ago and it has been evolving every year. In the beginning, all living things on earth were a single-celled organism, after several years multi cellular organism evolved after that diversity in life on earth increased day by day. The evolutionary history of life on Earth traces the processes by which both living organisms and fossil organisms evolved since life emerged on the planet, until the present. The similarities among all present-day organisms indicate the presence of a common ancestor from which all known species have diverged through the process of evolution.

The formation of complex organisms through 'gradual change' from simple ancestral types throughout geological time is termed Evolution of Organic Evolution. According to the Theory of Organic Evolution the various present-day organisms were not created in the same form in which they exist today, but have gradually evolved from much simple ancestral forms from a common ancestor. The characteristics of organisms had been changing in the past, they are changing even today, and will continue to do so in the future as well.

Why do organisms undergo change as a constant phenomenon? The answer to this question is associated with the environment or the habitat in which the organisms live and propagate. The environment in which organisms live undergoes changes and organisms need to adapt to this changing environment to survive. It is their survival inevitability. You know that several living organisms of the past have become extinct. The origin of the various forms (species) found on earth has been a gradual and extremely slow process, requiring hundreds or even thousands of years. However, the evolution of black peppered moths or polyploid varieties of some crops or pesticide-resistant mosquitoes happened in much shorter periods. This process of slow and gradual change is called Organic Evolution. Therefore, the theory of organic evolution states that "All living things on earth are here as a result of descent, with modifications from a common ancestor".

A scientific inquiry regarding the evidence of organic evolution involved different branches of Biology. That is how when you try to learn about the origin and evolution of life on earth, it becomes to know about the scope of the subject Biology also! For example, if you want to acquire the knowledge of organic evolution, then Morphology, Embryology Molecular Biology and Palaeontology, and much more than this will be sourced. Because all these branches of biology will provide evidence of organic evolution.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. The concept **'**parent microorganisms generate only their own kind' is proposed by
    a. Francesco Redi
    b. A.I. Oparin
    c. Louis Pasteur
    d. J.B.S Haldane

2. life was present in the form of resistant spores and appeared on earth from other planet-was proposed by
    a. Cosmozoic Theory
    b. Theory of Spontaneous Generation of Life
    c. Modern Theory of Chemical Theory
    d. Theory of Special Creations

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Italian physician and poet Francesco Redi strongly supported the spontaneous origin of living things.
    b. Taxonomy only helps in scientific naming nothing more than this.
    c. Alexander Oparin suggested that the origin of life is from non-living matter.
    d. Proteinoids are primitive protein compounds.
    e. Greeks believed in spontaneous generation of life
    f. Too many varieties of organisms in a given area will not survive longer.

1.2.3.2. Understanding the Scope of Biology by knowing Environment and Health

Activity 2: Ask the students to make a small survey about how mankind is getting all its life support and benefits from the environment

Activity 3: Motivate the students to prepare a report based on observation of their surrounding area regarding medicinal plants

Activity 4: Encourage the students to grow small medicinal plants in pots or any empty container. For example, Ginger, Beetle leaf, Pepper, Aloe Vera, Lucas Aspera (Tumbe), and turmeric. And ask them to work on their medicinal value.

The place which we see in our surroundings is the environment. This is made up of plants, animals, and microbes in general. These living entities are the integral and inseparable parts of Biology. So there is a strong link between biology and the environment which looks almost the same. Hence the scope of biology could be understood by learning about the environment. Here the term 'environment' is more than mere biology which encompasses the interaction of all living species, climate, weather, and natural resources that affect human survival and economic activity. Studying biology not only enables students to learn a great deal of environment-related basic knowledge but also can foster a feeling towards the environment and develop skills needed to protect the environment. And the study of the environment is synonym with 'Ecology'. Describing the scope of ecology, Odum wrote in 1963: "This small book aims to outline those basic principles of environmental biology that are of interest, as well as of vital concern, to all of us". He further mentioned the special term for the environmental biology field of interest in ecology, a word derived from the Greek root "oikos" meaning "house". Thus literally, ecology is the study of "houses" or more broadly, "environments". Because ecology is concerned especially with the biology of groups of organisms and with functional processes on the lands, in the oceans, and freshwaters, it is more in keeping with the modem emphasis to define ecology as the study of the structure and function of nature. It should be thoroughly understood that mankind is a part of nature since we are using the word nature to include the living world."

Ecological studies focus on how individual organisms interact with their environment, or how ecological populations or communities interact with their environment. The study of how organisms are adapted to respond to temperature or other factors of their physical environment is an example of such a focus. This approach is called eco-physiology or physiological ecology. Organisms of the same species living in the same place and time constitute an ecological population. All the populations of natural habitat are linked to one another by several types of interactions including feeding relationships. These interacting populations form ecological communities and their study is called community ecology.A community plus its environment forms an interacting entity called an ecosystem, which is considered as a unit in the study of ecology. Although ecology has shown tremendous progress during the past 50-60 years, its main focus has been on various types of ecosystems – terrestrial, freshwater, marine and on how human activity has influenced these ecosystems.

However, ecology is deeply rooted in biology and in classical ecology often the focus is mainly on the "ecosystem studies" (energy flow and productivity) but in environmental biology, the focus is on the "biological organisms of the environment" and their eco-

physiological adaptations and interactions. For example, if we use the phrase "environmental biology of fish" it will mean how the fish species of a particular environment (pond, lake, river, estuary, and ocean) are interacting with the environmental factors, both biotic and abiotic; which of these factors govern their distribution and abundance, and how these factors have influenced their adaptations and life history strategies.

Basic ecology is an important topic in elementary and middle school biology and is also needed to learn and understand basic ecology, thus this kind of information will help students to understand environmental issues, develop the value system and attitude, and be proactively involved in environmental problem-solving. Moreover, biology plays a vital role in developing a student's positive feelings about nature. Finally, it helps students develop environmental skills such as the ability to identify and define environmental problems, the ability to analyse environmental problems, and the ability to solve the environmental problems. Here it will take the pattern as Education of Environment, Education for Environment, and Education by Environment.

Biology and Health

Biology provides the knowledge to maintain good health by following proper food, exercises, good habits, etc. The scope of biology is revealed in the field as follows:

- All the personnel who work in the field of health like, doctors, nurses, health assistants, and dentists need knowledge of the biological background.
- Different vaccines are developed only after successful experiments upon wild animals.
- Different medicines are prepared from plants and animal products. For example, erythromycins from fungi, herbal products in Ayurveda medicine, and a variety of medicines as plant and animal products.
- Different diseases such as malaria, black fever, yellow fever, etc. can be controlled only after the destruction of vector hosts like the mosquito, sand fly, etc. which can be done only with the biological knowledge by the biologists.
- Different medicines are prepared after the successful test on wild animals.
- Being a multidisciplinary subject, the term 'Biology' is often replaced by– ***Biological*** **Sciences** or **Life Sciences** showing the immense scope in multiple fields.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Community Ecology means
    a. The study of interacting populations in an ecological community
    b. Study of the human community
    c. Study of environment and people
    d. Study of the human population

2. Eco-physiology means
    a. Study of an ecosystem
    b. Study of adaptations of organisms to their environment
    c. Growing plants in artificial conditions
    d. Study of biodiversity

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:

a. Biology and Environment are synonymous terms.
b. Biology is a multi-disciplinary subject
c. Ecology is deeply rooted in Biology
d. Environmental education help students to acquire environmental skills
e. Ecology includes only terrestrial ecosystem
f. Organisms of the same species living in the same place and time constitute an ecological population.

1.2.3.3. Sustenance of the Eco-System vis-à-vis Values and Ethics

Activity 3: Discuss how the usage of chemical pesticides disturbs the ecological balance.

Sustainability is the most focused concept nowadays. Sustainability is commonly understood in terms of ecological health, social equity, and economic welfare. It reflects not only the present situation but also the coming days. Hence it is grounded on the ethical commitment to the well-being not only of contemporary populations but also the wellbeing and enhanced opportunities of future generations. Invariably it emphasizes more thrust on science and technology. Because, the scientific and technical professions have a special responsibility as the knowledge and technologies they develop and employ have immense impacts on natural environments, economies, and the empowerment of citizens and societies. Moreover, their efforts and achievements can continue to produce effects, maybe good or repercussions will be on future generations.

Ethical Approaches to the Environment

This chapter will introduce multiple ethical approaches and world views taken to biodiversity and nature. Through focusing on theory and the conceptual framework of ethics and biodiversity, it may hopefully provide support when considering the examples contained in later sections. This chapter will take into account philosophical contemplations, as well as offer some descriptive analysis of the approaches contained within. Common critiques and ethical dilemmas associated with approaches to biodiversity are also taken into account to better understand the challenges of forming accepted theories for environmental ethics. This report will approach the ethical issues of biodiversity from primarily a descriptive angle, through analysis, case studies, and real-world policy, while offering several prescriptive elements. It will also introduce how ethics and biodiversity are interconnected and how the implications of decision manifest themselves based on the categorical differences between the approaches that are discuss

Survival of all organisms is actualized due to ecological balance. Various species survive because favourable ecosystems were created. A favourable ecosystem ensures that each organism thrives and multiply as expected. They get enough food to keep them alive. Ecological balance is also important because it leads to the continued existence of the organisms. It ensures that no particular species is exploited or overused. For example, human activities such as farming and resource exploitation are checked to prevent excessive destruction of the forests. If this care is not done, deforestation leads to drought. Drought reduces food production and thereby reducing the existence of some species. Some species will get the endangered situation and some will become completely extinct. This will affect the food-chain and Eco balance. Therefore we, as human beings follow certain ‘do’ and

'don't'. Such social norms will be recognised as Values and Ethics. In this context, it could be termed as "Value and Ethics of Biodiversity".

Biodiversity is the most precious gift of nature mankind is blessed with. As all the organisms in an ecosystem are interlinked and interdependent, the value of biodiversity in the life of all the organisms including humans is enormous. Ethics arrives at the forefront of biodiversity, as concerns for conservation and preservation. Often the dynamic actions of human beings stem from ethical or moral values aimed at combating the destruction of this planet's resources. Science teaching relies on the presentation of scientific facts, even though some of these may be open to heated debate. However, in the case of biodiversity, the presence of scientific fact alone has not been enough to change actions or approaches to avoid the acidification of the oceans, reduce the accumulation of carbon dioxide in the atmosphere, or curtail the current human-caused species extinction rates. Hence the need has arisen for the formation of Values and Ethics for the conservation of Biodiversity. United Nations Environmental Programmes Committee has framed six major values and is presented below:

1. Primary Value (PV)
2. Total Economic Value (TEV)
3. Use Value (UV)
4. Direct Use Value (DUV)
5. Indirect Use Value (IUV) and
6. Ethical and Aesthetic Values.
7. Total Environmental Value (TEnV)

1. Primary Value (PV):

This is defined as the value of the system characteristics upon which all ecosystem functions depend (UNEP, 1995). It is called the primary value because the structured ecosystem produces functions that have secondary value. The secondary value will exist as long as the ecosystem retains its health, existence, homeostasis, operation, and maintenance.

2. Total Economic Value (TEV):

Also called Total Value (TV) or simply Value (V). TEV denotes the sum of all kinds of values attached to biodiversity minus the primary value. It is the function of use and non-use values. Total economic value by itself will underestimate the true value of ecosystems. It has to be considered along with the primary value.

3. Use Value (UV):

This represents the value arising from an actual use made of a given component of biodiversity. It is often a function of Direct and Indirect Use Values.

4. Direct Use Value (DUV):

This is also known as direct value. It is defined as actual uses, especially in consumption. It represents the economic values derived from direct use or interaction with a biological resource or resource system, DUV is relatively easily measured by assigning market prices.

5. Indirect Use Value (IUV):

It is defined as benefits arising from an ecosystem function. It represents the economic value derived from the role of resources and systems in supporting or protecting activities whose outputs have direct value in production on consumption (UNEP, 1995). Indirect contributions of biodiversity to human welfare are said to have this value.

Biogeochemical cycles, photosynthesis, climate regulation, prevention of soil erosion, pollutant degradation are the phenomena that contribute indirectly to biodiversity.

6. Ethical and Aesthetic Values:

People with good cultural background have a deep concern for biodiversity. They derive an ethical benefit from biodiversity. Biodiversity is considered to have a great value on cultural and religious grounds especially in India and East Asian countries. Ethical values differ from place to place, culture to culture, time to time and differ between different components of biodiversity. For example, the ethical value attached to sacred basil is not accorded to cactus in India. Most people value certain species more than others subconsciously.

The aesthetic value of biodiversity is very well known. Most people react more aesthetically towards plants that are appealing, visually, or otherwise. Most cultured societies have attached great value to the effect that plant and animal beauty has on the human mind and emotions. Poets, writers, and artists from various cultures have given expression to the aesthetic appeal of plants and animals. Roses, for instance, kindle the aesthetic sense much more than cacti and carnivorous plants, although the latter have their admirers. Such relative aesthetic judgments could compel greater concern for certain biodiversity elements than for others.

1. Total Environmental Value (T En. V):

UNEP (1995) defined this as a function of primary value and total economic value.

Check Your Progress - 3

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Survival of all organisms is actualized by
    a. Favourable ecosystem
    b. Ecological balance
    c. No competitions from other organisms
    d. Pests and insects control

2. Sustainability means
    a. Ecological health, social equity, and economic welfare
    b. Longevity of life
    c. Continuation of the existing quality of life
    d. Human welfare activities

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. TEV denotes the total of all kinds of values attached to biodiversity excluding the primary value
    b. All the organisms in an ecosystem are interlinked, interdependent, and integrated
    c. Ethics and aesthetic values of the environment help in the conservation of biodiversity
    d. Extinct organisms affect the foodchain in an ecosystem
    e. Industrialization has resulted in enhancing the environmental quality
    f. Use value is nothing but the value arising from an actual use made of a given component of biodiversity.

1.2.4. Let us Summarise

The scope of Biology is understood by its number of branches with the economic support they give, job opportunities they secure, and standard of life in common parlance. Generally, the subject of biology is considered as a Descriptive subject with multi-disciplinary dimensions. The study of biology mainly includes structure, function, and the evolution of organisms. Hence, the origin of life, organic evolution are the first and foremost concepts to be discussed for understanding the scope of biology. A scientific inquiry regarding the evidence of organic evolution involved different branches of Biology. That is how when you try to learn about the origin and evolution of life on earth, it becomes to know about the scope of the subject Biology also!

There is a strong link between biology and the environment which looks almost the same. Hence the scope of biology could be understood by learning about the environment. Here the term 'environment' is more than mere biology which encompasses the interaction of all living species, climate, weather, and natural resources that affect human survival and economic activity. Studying biology not only enables students to learn a great deal of environment-related basic knowledge but also can foster a feeling towards the environment and develop skills needed to protect the environment. And the study of the environment is synonym with 'Ecology'. Ecological studies focus on how individual organisms interact with their environment, or how ecological populations or communities interact with their environment. The study of how organisms are adapted to respond to temperature or other factors of their physical environment is an example of such a focus. This approach is called eco-physiology or physiological ecology. And coming to the field of Health, you know that, all the personnel who work in the field of health like, doctors, nurses, health assistants, and dentists need the knowledge of the biological background. Different vaccines are developed only after successful experiments upon wild animals. Different medicines are prepared from plants and animal products. For example, erythromycins from fungi, herbal products in Ayurveda medicine, and a variety of medicines as plant and animal products.

Sustainability is commonly understood in terms of ecological health, social equity, and economic welfare. It reflects not only the present situation but also the coming days. Hence it is grounded on the ethical commitment to the well-being not only of contemporary populations but also the wellbeing and enhanced opportunities of future generations. Biodiversity is the most precious gift of nature mankind is blessed with. As all the organisms in an ecosystem are interlinked and interdependent, the value of biodiversity in the life of all the organisms including humans is enormous. Ethics arrives at the forefront of biodiversity, as concerns for conservation and preservation. Often the dynamic actions of human beings stem from ethical or moral values aimed at combating the destruction of this planet's resources. Hence the need has arisen for the formation of Values and Ethics for the conservation of Biodiversity. Hence the need has arisen for the formation of Values and Ethics for the conservation of Biodiversity. United Nations Environmental Programmes Committee has framed six major values are Primary Value (PV), Total Economic Value (TEV), Use Value (UV), Direct Use Value (DUV), Indirect Use Value (IUV), and Ethical and Aesthetic Values. And cumulatively Total Environmental Value (TEnV).

1.2.5. Answers to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1
1.c 2.a 3.a- X b- X c- √ d- √ e- √ f- X

Check Your Progress - 2
1.a 2.b 3.a- X b- √ c- √ d- √ e- X f- √

Check Your Progress - 3
1.a 2.a 3.a- √ b- √ c- √ d- √ e- X f- √

1.2.6. Unit end Exercises

1. Explain the scope of biology in terms of diversity of the living world
2. What are the theories of the origin of life? Explain the Modern theory of the origin of life.
3. Explain the theories of organic evolution
4. Exhibit the relationship between the scope of biology, environment, and health
5. Describe the values and ethics aboutthe sustenance of the ecosystem
6. Bring out the vast scope of the subject biology and its relevance to life
7. Discuss the role of biological science in understanding the diversity of the living world.
8. How the study of biological science help in the understanding of human health?

1.2.7. References

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Block 1 : Nature and Objective of Teaching Biological Science

Unit 3 : Significance of Inquiry, Observation and Experiments in Biological Science, its Inter-disciplinary linkages and Societal Concerns

Unit Structure

1.3.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Identify inquiry as one of the science process skills;
- Explain observation as a significant component in the scientific study;
- Describe the significant role of experiments in biological studies;
- Recognise the inter-disciplinary linkages of Biological Science;
- Cite examples for contributions from Biological Science with Societal Concern; and
- Recall the inter-relationship between Biological Science and Social Concerns.

1.3.2. Introduction

You know that science is empirical and needs everything should be tested. The inventions or discoveries are accepted by society only with soundproof and evidence. For this, there is an enormous thrust on science process skills, namely, observation, identification, classification, hypothecation, inquiries, explorations, experimentation, and collection of scientific information. Biology being one of the profound branches of science, it also depends upon the above-said science process skills. Though collectively these are called 'Science Process Skills' each one of them has its own nature and salient features. The richness in the subject of Biology is mainly because of the adaptation of these skills in the process of Biological Science Development as a whole. In this unit, you will come to know about the nature and salient features of inquiry, observation, experimentation, and their significant role in the subject of Biology. The present unit also deals with concepts, like, inter-disciplinary linkages of Biological Sciences and the role of Biological Science in Societal Concerns.

1.3.3. Learning Points and Learning Activities

1.3.3.1. Significance of inquiry, observation and experiments in Biological Science

Activity 1: Once in a classroom the teacher gave a challenge to students. The challenge was

(i) Growing plants without making use of soil, and the other challenge was
(ii) Growing plants without using seeds.

For the first activity, students started inquiring, collecting information regarding, like, which are the plants that could be grown without soil, then they collected the real specimens. They developed some hydrophytes in their lab by making use of some small containers, water, and the plant species, for example, money-plant.

For the second activity again students inquired about the plants that could be grown using their cuttings (Somatic Propagation) and did the experiment and got the results. (Banana plant, Rose, Chrysanthemum, Cucumber, and some other creepers).

The activity was extended to grow some medicinal plants, like, Beetle leaf, Onion, Ginger and Turmeric, etc. And the challenge was further raised to the level so that students were asked to do a comparative study in which condition all these plants showed faster growth and development (use of chemical and organic manure).

Significance of Inquiry in Biological Science:

Nobel Prize-winning chemist Sir Cyril Norman Hinshelwood described science as "an imaginative adventure of the mind seeking truth in a world of mystery." The different ways that scientists explore or seek truth in the world can be collectively described as scientific inquiry. The most traditional model for conducting scientific inquiry is known as the scientific method.

The scientific method is a series of processes that people can use to gather knowledge about the world around them, improve that knowledge, and, through gaining knowledge, attempt to explain why and/or how things occur. This method involves making observations, forming questions, making hypotheses, doing an experiment, analysing the data, and forming a conclusion. Every scientific experiment performed is an example of the scientific method in action, but it is also used by non-scientists in everyday situations. An inquiry is a methodical process that has sequential steps. Following are the steps of the scientific method:

Making an Observation

The first step of the scientific method is to observe the world around you. Before hypotheses can be made or experiments can be done, one must first notice and think about some sort of phenomena occurring. The scientific method is used when one does not know why/how something is occurring and wants to uncover the answer, but before one can even question an occurrence, they must notice something puzzling in the first place.

Asking a Question

Next, one must ask a question based on their observations, such as why/how is this thing occurring? Why/how does it happen this way? Sometimes this step is listed first in the scientific method, with making an observation (and researching the phenomena in question) listed as second. In reality, both making observations and asking questions tend to happen

around the same time, as one can see a confusing occurrence and immediately think, "Why is it occurring?" When observations are being made and questions are being formed, it is important to research to see if others have already answered the question or uncovered information that may help you shape your question. For example, if you find an answer to *why* something is occurring, you may want to go a step further and figure out *how* it occurs.

Forming a Hypothesis

A hypothesis is an intellectual guess to explain the phenomena occurring based on prior observations. It answers the question posed in the previous step. Hypotheses can be specific or more general depending on the question being asked, but all hypotheses must be testable by gathering evidence that can be measured. If a hypothesis is not testable, then it is impossible to experiment to determine whether the hypothesis is supported by evidence.

Performing an Experiment

After forming a hypothesis, an experiment must be set up and performed to test the hypothesis. An experiment must have an independent variable, which is something that is manipulated by the person experimenting, and a dependent variable, which is the thing being measured (and which may be affected by the independent variable). All other variables must be controlled so that they do not affect the outcome. During an experiment, data is collected. Data is a set of values; it may be quantitative (e.g. measured in numbers) or qualitative (a description or yes/no answer).

For example, if you were to test the effect of sunlight on plant growth, the amount of light would be the independent variable (the thing you manipulate) and the height of the plants would be the dependent variable (the thing affected by the independent variable). Other factors such as air, temperature, amount of water in the soil, and species of plant would have to be kept the same between all of the plants used in the experiment so that you could truly collect data on whether sunlight affects plant growth. The data that you would collect would be quantitative since you would measure the height of the plant in numbers.

Analysing Data

After performing an experiment and collecting data, one must analyse the data. Research experiments are usually analysed with statistical software to determine relationships among the data. In the case of a simpler experiment, one would look at the data and see how they correlate with the change in the independent variable.

Forming a Conclusion

The last step of the scientific method is to form a conclusion. If the data support the hypothesis, then the hypothesis may be the explanation for the phenomena. However, multiple trials must be done to confirm the results, and it is also important to make sure that the sample size the number of observations made is big enough so that the data is not skewed by just a few observations. If the data do not support the hypothesis, then more observations must be made, a new hypothesis is formed, and the scientific method is used all over again. When a conclusion is drawn, the research can be presented to others to inform them of the findings and receive input about the validity of the conclusion drawn from the research.

Thus inquiry forms one of the fundamental activities in biological sciences. Social problems, like, epidemic or pandemic are solved so far by the application of inquiry approach in biological fields only. Vaccinations, antibiotics, and even gene therapy all such contributions in modern life are because of one strong element that is inquiry.

Significance of Observation in Biological Science:

The scientific method consists of a series of steps while conducting the experiments. The word "observation" has two meanings in the scientific method. First, there is the observation of the world as it leads to hypothetical theory. This is the first step of the scientific method and can be presented in two ways, either as a natural observation or a staged one. Second, in the collection of data in an experiment using the scientific method, there are two types of observations, qualitative and quantitative.

Observation is an integral part of scientific study. Without this, we cannot call it science at all. Observation is an intellectual activity having rigorous steps and framed by certain criteria to be referred to while observing. It is a purposeful activity. Sometimes it happens naturally also. For example, suddenly we may see a difference in the routine processes. Then naturally we tend to observe the same process with a more attentive mind. Isn't it? Usually in-home while preparing "Dosa", we start one day earlier. And before doing dosa, we check whether the dough is fermented properly, because, that is the main reason for dosa becoming tastier! So if it is not so, then we start analysing and find the real cause for it. This is an example of **"Natural Observation"**

In biology, there is **"Staged Observation"** also. Gregor Mendel's Experiment on pea-plant is an example here. He grew several generations of pea-plant to find out how the characteristic features or the traits, like, smooth-surfaced or rough-surfaced seeds are transformed from one generation to another. He called this "Segregation" meaning one character will not interfere with other (surface of the seed and the height of the plant) features during reproduction.

Once the experiment is underway, it must be observed. The obtained results are checked for their consistency. Hence it goes for more number of repeated experiments and collection of data. One form of data collection during the method is quantitative. "**Quantitative observation"** is common in biology and the natural sciences.

Qualitative Observation

While conducting experiments, sometimes, the effectiveness of the experiments is described in qualitative terms. Like, how best is the remedy, or how good is the product obtained, etc., observations concerning the quality of what has happened in an experiment is considered a "**Qualitative Observation"**. And the data obtained in this manner will be subjected to qualitative analysis.

The Importance of Observation

Observation is a very important and basic part of science. Based on observation all the other part of science is designed. It lets us see the results of an experiment, even if they are not the results we expect. It lets us see unexpected things around us that might stimulate our curiosity, leading to new experiments. Since it is one of the science process skills, plays the role of mother of all other activities in a scientific method.

Significance of Experiments in Biological Sciences

The term *'Experiment'* has come from the Latin word *'Experimentum'* meaning *'to try'* or *'put into act'*. In common parlance, an experiment is nothing but certain procedural aspects applied to test a phenomenon. It is a procedure in which a hypothesis is framed based on previous findings and is tested by systematically adapting independent variables and their effect on dependent variables. It is further explained as a process of observing to find the causal relationship between two or more phenomena by keeping all other conditions constant (approximately). It involves objective observation and rigorous measurement which will result in drawing certain conclusions. Experiments are always empirical and subjected to repetition, verification, rectification, and getting consistent results. An experiment should satisfy the criteria of validity, reliability, objectivity, feasibility, and flexibility.

Biology is a practical science. Experiments in Biology enable students to apply and extend their knowledge and understanding of biology in novel investigative situations, which can aid learning and memory, and stimulate interest.

Experiments and other types of hands-on activities are very important to student learning in the science classroom. Experiments can raise test scores and help a student become more engaged and interested in the material they are learning, especially when used over time. Experiments can vary from personal and informal natural comparisons to highly controlled and vast scope. Experiments typically include controls, which are designed to minimize the effects of variables other than the single independent variable. This increases the reliability of the results, often through a comparison between control measurements and the other measurements. Scientific controls are a part of the scientific method. Ideally, all variables in an experiment are controlled (accounted for by the control measurements) and none are uncontrolled. In such an experiment, if all controls work as expected, it is possible to conclude that the experiment works as intended, and that results are due to the effect of the tested variable.

Biological experiments are full of interest, curiosity, and enthusiasm. Students feel like doing experiments and involve themselves. It may be a very small activity, like counting the number of leaves arising in a seedling, measuring the length of a growing plant, observing and finding in how many days the newborn puppies will open their eyes, and what is the insect that builds its mud-nest and what all it keeps inside the nest. Finding the rate of respiration in plants, presence or absence of carbon-di-oxide in photosynthesis, is oxygen liberated during plants' respiration or do plants respire at all?! - are some of the examples for experiments in Biology.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. A hypothesis is
    a. An intellectual guess
    b. Proven solution
    c. A Document
    d. Statistical technique

2. Inquiry means
    a. Data collection
    b. Testing
    c. Solving Problems
    d. Scientific method

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. An inquiry is a procedure following steps of a scientific method
    b. Since Biology is a descriptive subject, there will be no scope for experiments
    c. Looking at an object casually is also an observation
    d. Experiments with glaring success only are accepted
    e. Observation forms an integral part of the inquiry as well as in experiments
    f. The observation could be quantitative and qualitative

1.3.3.2. Biological Science and its Inter-disciplinary Linkages

Activity 2: Ask the students to collect the information regarding inter-disciplinary links of Biology with history, and social studies, and also ask them to collect the same concerning Biology and other science branches. Use this information for the discussion and debate in the class.

Science is a systematic study and it deals with understanding the nature and mechanism of the world. According to modern science, Nature is a continuum of the physical world to the chemical world and the biological world. In the present scenario of our education system, a concept in physics has no relationship with biology. For example, all of Newton's Laws of Motion are taught in Physics and Life-Processes in Biology. This makes the students assume that Newtonian mechanics does not apply to biological systems or there is nothing to take from Physics/Chemistry/Mathematics to learn/research in Biology.

It is said that no subject is independent and every subject is dependent on the other. This dependency is more apparent among the three major branches of science, namely, Physics, Chemistry, and Biology. It is because they have more number of facts and principles which are common to all the different branches. The biological sciences have long benefited from the intellectual and pragmatic input of ideas and techniques from other disciplines, including medicine, chemistry, engineering, and mathematics. The reach of biology extends well beyond the sciences and technology into interdisciplinary interactions within the social sciences, arts, and humanities.

Every branch of science relates to all other branches of science in certain ways. Presently, biology has expanded our knowledge base about living beings to a molecular level. Researches in biology confirm that living organisms are made of molecules, atoms, and organic macromolecules. Also, it justifies that the life processes within the body of a living thing take place due to interactions of particles. Thus it has brought linkages between biology, chemistry, and physics. All living organisms have organic and inorganic substances or compounds that dissolve in water. These inorganic substances or mixtures exist in the bodies of living things in the form of ions. These ions influence the life processes and the internal environment of these living organisms. The capillarity and surface tension that is formed by water due to adhesion and cohesion force is helpful in specific life processes of living things. For a living organism to survive in various environments due to their different biochemical reactions, a particular pH is maintained by the acid base-equilibrium. The

processes of osmosis and diffusion enable the movement of molecules and atoms in and out of cells in living organisms. Thus the subject of Biology is full of interlinks of other branches of science. Now we shall take some examples and illustrations to see how biology is interlinked with other subjects:

Biology and Physics (Biophysics):

It is quite common to see that the principles of physics are applied in biology. The topics in which physics gets exposed in biology are, (i) human eye structure and function, lens and image formation on the retina- which act as a camera, (ii) instruments that work on the principles of physics such microscopes and X-Rays. Biology uses physics techniques such as fractionation, X-rays, and Chromatography which has helped in understanding the cellular and semi-cellular components. Bio-Physics is the branch of science that explains the application of the methods and principles of physics to biological phenomena. Certain instruments are the product of physics used in the study of the physical arrangement of the functioning of biological materials at the molecular level. Apart from this, we know that several physical principles are essential for the life of living organisms. Plants require, water, they absorb water from the soil by osmosis (Root Pressure). The basis of osmosis is the density which is a concept in physics. Living organisms show movement, for all such living activities, like, stand, walk run - gravity and friction are responsible. For circulation, respiration, and other metabolic activities, pressure plays an important role. So biology and physics are very well interrelated and integrated.

Biology and Physics (Biochemistry):

Chemistry is the study of matter and its composition. It helps us understand the reactions that happen in different processes in our human body. Chemistry has helped biologists describe metabolic processes that occur in our body such as digestion, breathing, and also photosynthesis in plants. Biology is more closely related to Chemistry than Physics. The substances we use daily in our food are chemical substances in one way or the other.

Biochemistry deals with the structure and function of various elements in the world. Mainly it deals with the chemical substances and chemical changes that are found in the living organisms. The food molecules are combinations of carbon, hydrogen, oxygen, and nitrogen. These are chemical substances. We consume chemical substances in the form of food. Digestion which is one of the life-process is nothing but burning and liberation of energy. So, digestion, absorption, and assimilation all are biochemical activities only.

Biology and Mathematics (Biomathematics):

Biology uses mathematical rules to process, analyse, and present experimental research of various phenomena in living organisms. The knowledge of mathematics is important for the understanding of science, especially, Biology. The number of plants and animals in a particular place, the ratio of one organism to the other, the proportion of substances present in a cell, and simple calculations in genetics and physiology invariably make use of mathematics.

Biology and History (Bio - History):

As the structure and Functions are the basic approaches in Biology, Evolution is also one of the components which has contributed to the development of biological sciences. Biology uses the knowledge of history to date the evolutionary process of the species. Fossils and remnants have a greater value in biological sciences. Likewise, the subject of History also is used by biologists to carry out the invention of specific species based on seasons and

historical eras. Apart from this Bio-history has helped us to know about ancient scientists and their contributions.

Biology and Geography (Bio – Geography):

Geography explains to us about the vegetation and animal's habitat on earth with geographical conditions. Biology uses the knowledge obtained in Geography to explain the earth's elements which are vital when studying the evolution, structure, and origin of our planet. It also strives to explain why different biological processes occur under certain conditions geography studies the distribution of different species of organisms in their latitudes. Using Geography, we come to know about the landforms, climatic conditions, rainfall, and sunlight with other physical factors in a particular place. A particular type of plant is seen in a particular place because of its adaptations to that place. Hence geographical conditions are closely related to living organisms.

Biology and Sociology (Bio – Sociology):

Sociology studies the social relationships, antisocial relationships, and human behaviour that need biological science. For example, police departments use the knowledge of hormones, glands, pedigree analysis, Norco-analysis, and the principle of inheritance to get hold of criminals and terrorists.

Biology and Environment:

Any environment will have two types of facts. They are physical factors and biotic factors. Physical factors are also known as Abiotic Factors, namely, light, atmospheric pressure, temperature, availability of water, rainfall, nature of the soil, PH value of water, and soil. The Biotic factors are living plants, animals, and microbes as well as viruses. The nature of organisms is controlled by physical as well as biotic factors. All organisms must and should get adapted to their environment which is inevitable for their survival. The study of the environment depends upon much on Biology and thus a great relationship is established between the subjects, Biology and the Environment.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. The branch which deals with correcting eye-problems with lenses is
    a. Physics
    b. Biology
    c. Engineering
    d. Biophysics

2. The subject which helps to know more about Bio-diversity is
    a. Geography
    b. Sociology
    c. History
    d. Botany

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. To get the interdisciplinary connection between History and Biology is almost impossible
    b. All organisms should get adapted to their environment for their survival
    c. Bio-sociology is used by the Police Department while doing case studies
    d. Mathematical operations are seldom used in Biology

e. All the medical instruments are the expressions of the interdisciplinary nature of science
f. It is wrong to say that digestion is a chemical reaction

1.3.3.3. Biological Science and Societal Concerns

Activity 3: Ask the students to collect information regarding Stem Cell Therapy and support their investigation with illustrations, like celebrities who have adopted this technique or the companies which have established their contributions in this field.

Biological science with its ever-increasing growth and development is showing a very promising response to social problems and societal needs. By all the way the societal concerns shown by biological science is outstanding. Maybe it is the food, health or environment - for everything that is concerned with plants and animals life including human beings, it is Biological Science which has an answer for every question or solution for every problem.

In the United States of America the committee by the name "A New Biology Approach" has laid down several measures and activities to combat the burning problems and issues not only in America but all over the world. During its deliberations, the committee concluded that the best way for the United States to capitalize on the new capabilities emerging in the life sciences would be a multi-agency initiative to marshal the necessary resources and provide the coordination to enable the academic, public, and private sectors to address major societal challenges. Some of the suggested provisions and measures are noteworthy to ponder over. So let us have a look at it:

A New Biology Approach:

Food Challenge:

Growing enough food worldwide is facing a shortfall and to address this shortfall, as well as providing the higher quality food that will be expected by people living in countries where standards of living are improving, is an enormous challenge. For this, a better fundamental understanding of plant growth and productivity, as well as of how plants can be conditioned or bred to tolerate extreme conditions and adapt to climate change, will be key components in increasing food production and nutrition. A New Biology Approach is going to help by addressing this problem suitably.

Genetically Informed Breeding

As a result of plant genome sequencing, plant genome analysis, and advances in bioinformatics, it is now possible to recast the principles of highly successful traditional plant breeding into a new and accelerated type of plant breeding termed "genetically informed breeding."Additional advanced genetic and molecular methods, including those in place and others now being explored, are leading to improvement in the nutritional value of crops, for example by changing the composition of soybean oil to reduce trans fat concentrations (Fehr, 2007).

Crops as Ecosystems

All crops grow in a complex environment, characterized by physical parameters like temperature, moisture, and light, and biological parameters including the viruses, bacteria, fungi, insects, birds, and others that interact with the crop plants. Therefore, a greater

understanding of insect-plant interactions, both beneficial and harmful, offers another route toward increasing crop productivity. Furthermore, complex microbial communities in the soil, previously difficult to study, play critical roles in providing nutrients and protecting plants from pests and diseases. Understanding these microbial communities in predictive detail will also point to new ways to increase plant productivity. Genetic engineering (as well as plant breeding) has been of great importance in improving crop resistance to plant diseases caused by viruses, bacteria, and fungi, and in resistance to herbivores such as insects.

Humans do not exist independently of the rest of the living world. From the most basic requirements of oxygen, clean water, and food, to raw materials like fuel, building material, fibre for clothing, and shelter that have allowed human societies to flourish around the globe, to intangible benefits that enrich the quality of life such as the shade of a tree on a hot day or the inspiration of an eagle in flight, humans are dependent on other organisms. Together, the resources and benefits that are provided by the living world are considered "ecosystem services" (Millennium Ecosystem Assessment, 2005). The amount of services that ecosystems can provide depends, at the base, on their productivity: that is, their ability to use energy from the sun to make complex carbon-containing molecules like sugars and starches. Sustaining ecosystems so that their productivity remains high even in the face of rapid climate change is essential to sustaining and enhancing the quality of life of a growing human population.

Health Challenge:

Large-scale studies that associate genotype to phenotype are rapidly identifying many, many genetic variations (both human and microbial) and environmental factors that are associated with specific diseases. The keyword in that sentence is "associated." While some of these variations may have a direct role in causing disease, there is currently a substantial gap between discovering an association and uncovering a causal mechanism. But ultimately, if health care is to move from treatment based on statistical likelihood to treatment based on each individual's specific circumstances—in other words, truly personalized medicine—the chasm between genotype and phenotype will have to be bridged. Indeed, it is a challenge that will demand a New Biology-driven research community empowered by scientific and technical resources from across the federal government, the broad community of scientists, and the private sector. Unraveling the genotype-phenotype connection will require combining increasingly sophisticated genotype-phenotype associations with experimentation, modeling, systems analyses, and comparative biology.

Between the starting point of an individual's gene sequences and the endpoint of that individual's health is a web of interacting networks of staggering complexity. Recent advances are enabling biomedical researchers to begin to study humans more comprehensively, as individuals whose health is determined by the interactions between these complex structural and metabolic networks. On the path from genotype to phenotype, each network is interlocked with many others through intricate interfaces. Study of the complex networks that monitor, report, and react to changes in human health is an area of biology that is poised for exponential development. These networks consist of circuits of interacting genes, gene products, metabolites, and signals that function together much like electronic integrated circuits. Tools and methodologies are being developed that can detect, synthesize, and process complex biological information at a network level, image cellular events in real-time, delineate how proteins interact, and access single sites within the DNA library of the cell. Computational and modeling approaches are beginning to allow an analysis of these

complex systems, with the ultimate goal of predicting how variations in individual components affect the function of the overall system.

Living donations of the kidney, part of the liver, the lobe of the lung, part of the intestine, and a portion of the pancreas can be made. Due to more demand for such transplantation, a new strategy, like, using animal-to-human transplants (xenotransplantation) is also a trend. Apart from this more modern and technology-based Gene Therapy in which a faulty gene is replaced with a normal and healthy one is advancing like anything. The HGP (Human Genome Project) identified up to 25000 genes in human DNA making this possible. This is going to address problems like cancer, genetic diseases, genetic disorders, and viral infections.

Reproductive Technologies (AI and IVF)

AI (Artificial insemination) – A technique that involves collecting sperm from a male and placing it in the reproductive system of a female. Human sperms are collected and preserved scientifically in "Sperm Banks" and this technique has solved problems for individuals who cannot get their offspring due to one or the other reasons. This is very much used in cattle production.

IVF (In vitro fertilization) – sperm and eggs are collected and placed in a test tube or petri dish for fertilization to take place in a controlled environment. The developing embryo is implanted in the female's uterus. Many are implanted since the chance of survival is less than 50%. Both AI and IVF have become a boon to many childless-couples.

Sex Selection Technologies

This technique involves choosing the sex of a baby through methods such as sperm separation and staining, and PGD (Pre-implantation genetic diagnosis). However, sex-detection or knowing the child's gender before its birth is considered an offense in India. This is due to unscientific female foeticide and biased treatment for the female child. PGD is completed by choosing male or female embryos after the IVF process. PGD's original use was to detect genetic mutations linked to genetic diseases.

Stem Cell research

Stem cells are unspecialized cells having the potential of growing into any type of tissue and organs. They have an enormous capacity for cell division. Stem cells are found in animals. In human beings, the umbilical cord in an embryo is made up of stem cells. Nowadays so much research is going on about stem cells. Scientists believe they can treat injury and disease using stem cells. The availability of stem cells will be in the form of embryonic stem cells – from an embryo, can still differentiate, Adult stem cells – from an adult's brain, bone marrow, limited ability to become any type of cell and Cord blood – small amounts can be harvested.

Cloning Technique: Creation of a genetically identical organism that is an exact copy of a gene, cell, tissue, and organism.

Cloning in Plants:

(a) **Vegetative propagation. This involves** cutting a piece from a plant and allowing it to produce and another plant.

(b) Grafting- this is a technique in which roots of one plant are attached to shoots of another to produce a more desirable type of plant (for example, a more desirable quality of fruit, more juicy, seedless variety).
(c) Hybridization: Here also different species are genetically combined to produce new varieties having features of both the plants. For example, Pomato Plant – a combination of Potato and Tomato plants.

Cloning in Animals:

(a) Reproductive cloning – transferring a nucleus from a donor body into an egg that has no nucleus. The egg is then transferred into the uterus of the mother
(b) Gene cloning – transferring an egg into bacteria so that it reproduces multiple times. Useful in scientific research
(c) Therapeutic cloning – same as reproductive cloning, but the purpose is to harvest embryonic stem cells from a developing embryo

Transgenic Techniques

Transgenic organisms contain genes from other species. These are produced to study the effects of disease and for xenotransplantation.

A major issue is the one that encompasses a group of specific problems which if solved would provide a major effect on the survival or quality of life of organisms or the entire living world. Some of the issues are, Beginning of Life, End of Life, Stem Cell Research and Therapy, Patents on medical protocols- these are posing Ethical Issues in the field of Synthetic Biology. Endangered Species, Global Warming, Ocean Acidification, Pollution, and deforestation are also viewed as burning problems and challenges. No doubt biology is showing its concerns regarding these issues. The future is imposing challenges for humankind with sensitive areas like, efficiently improving the sustainable productivity of diverse food crops, producing sustainable substitutes for fossil fuels, monitoring and restoring ecosystem services, and understanding and promoting human health. So subject Biology with its interdisciplinary approach must enhance its horizon to reach every problem and issue.

Check Your Progress - 3

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Reproduction in plants without the role of gametes is called
    a. Sexual reproduction
    b. Somatic propagation
    c. Grafting
    d. Layering

2. Therapeutic cloning is used
    a. To harvest embryonic cells
    b. To reproduce identical organism from mother
    c. To produce multiple organisms
    d. To save endangered organisms

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Crops resistant to diseases are the contribution of Genetic Engineering
    b. Cloning is against social ethics, hence it should be banned
    c. Transplanting the liver and pancreas is impossible

d. Stem cells are the cells from the stem of a plant
e. So far 25000 genes are identified in human DNA
f. Any new species found is said to Genetically Informed Breeding

1.3.4. Let us Summarise

Compared to other subjects science has its own characteristic features. It is constantly subjected to verifications and testing. Biological science is also bound by these features and principles. Added to this, as a subject with multi-disciplinary dimensions it is dominated by science process skills, namely, observation, identification, classification, inquiries, scientific method, scientific attitudes, experimentation, and inferences. Inquiry, observation, and experimentations are the major component of biological sciences. Hence they are very significant.

The different ways that scientists explore or seek truth in the world can be collectively described as scientific inquiry. The most traditional model for conducting scientific inquiry is known as the scientific method. This method involves making observations, forming questions, making hypotheses, doing an experiment, analysing the data, and forming a conclusion. Observation is an integral part of scientific study. Without this, we cannot call it science at all. Observation is an intellectual activity having rigorous steps and framed by certain criteria to be referred to while observing. It is a purposeful activity. It could be qualitative, quantitative, natural, and staged observation by nature. Observation is a very important and basic part of science. Based on observation all the other part of science is designed. It lets us see the results of an experiment, even if they are not the results we expect. It lets us see unexpected things around us that might stimulate our curiosity, leading to new experiments. Since it is one of the science process skills, plays the role of mother of all other activities in a scientific method. Biology is a practical science. Experiments in Biology enable students to apply and extend their knowledge and understanding of biology in novel investigative situations, which can aid learning and memory, and stimulate interest.

It is said that no subject is independent and every subject is dependent on the other. This dependency is more apparent among the three major branches of science, namely, Physics, Chemistry, and Biology. Hence the interdisciplinary linkages, like, Bio-Physics, Biochemistry, Bio-mathematics, Bio-Engineering, Bio-Technology, and Bio-sociology, as well as Bio-history have entered into the new millennium. Biological science with its ever-increasing growth and development is showing a very promising response to social problems and societal needs. By all the way the societal concerns shown by biological science is outstanding. Maybe it is the food, health or environment - for everything that is concerned with plants and animals life including human beings, it is Biological Science which has an answer for every question or solution for every problem.

1.3.5. Answers to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1

1.a 2.d 3.a- √ b- X c- X d- X e- √ f- √

Check Your Progress - 2

1.d 2.a 3.a- X b- √ c- √ d- X e- √ f- √

Check Your Progress - 3

1.b 2.a 3.a- √ b- X c- X d- X e- √ f- X

1.3.6. Unit end Exercises

1. Prove that inquiry as one of the science process skills.
2. Explain observation as a significant component in scientific study.
3. Describe the significant role of experiments in biological studies.
4. Show that there is an inter-disciplinary linkage between Biological Science and other subjects.
5. Cite examples for contributions from Biological Science with Societal Concern.
6. Illustrate the Social Concerns and the respective solutions expressed by Biological Science.

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Block 1 : Nature and Objective of Teaching Biological Science

Unit 4 : History of Biological Sciences

Unit Structure

1.4.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Recall the ancient background of Biology to the prehistoric period of man;
- Trace out the outstanding contributions of Ancient Indian great personalities who have contributed in the field of medicine;
- Explain the historical development of the subject biology with respect to plants and animals;
- Recognise the ancient foreign contributors for the subject Biology;
- Describe the postulates provided by Lamarck and Darwin;
- Reason out why Greg or Mendel is called the father of genetics; and
- Explain the significance of Crick and Watson's contribution to DNA structure.

1.4.2. Introduction

In this unit, we will be knowing about the historical background of the subject Biology. You know that in high school curriculum also the clear appearance of the subject biology was a little bit late though it was there as a latent part. Similarly, though the term "Biology" was not there, the history of biology will take us to the Vedic period. And in the case of abroad, we have to look into the contributions of Hippocrates and Aristotle. Starting from the invention of the microscope, and the discovery of "Cell", the subject started growing in multi-directional ways. For our convenience, the history of biology is divided into History of Indian Biological Science and History of Biological Science in Abroad. In both cases, the influence of science and technology is very obvious.

1.4.3. Learning Points and Learning Activities

1.4.3.1. History of Biological Science in India

Activity 1: List out any 3 names of the scientist with their contribution to the field of medicine from the period of ancient India

There is one logic that says that human knowledge of biology began with a prehistoric man. His experiences with plants and animals and also through the instincts and efforts to explore nature made him accumulate knowledge about biology. Of course, the term 'Biology' might not be there in the beginning. This accumulated knowledge was verbally passed on from one generation to another. The history of science therefore can be said to have begun with the history of human existence. During the early period, people knew about medicinal and poisonous plants and knew that a heartbeat meant that someone or some animal was alive. Records of advances made in the field of medicine as well as some other branches were biological sciences during the early civilization are available.

One of the oldest organised systems of medicine is known from the Indian subcontinent in the form of Ayurveda. It was originated around 1500 BCE from Atharvaveda (one of the four most ancient books of Indian knowledge, wisdom, and culture).In the field of botany, there were considerable efforts in the past. Classification of organisms in India comes from Vedas and Upanishads (1500 B.C to 600 B.C). In these books, many technical terms were used to describe plants and their parts both morphologically as well as anatomically.

Rotation of crops was practiced and medicinal plants were also collected and studied. Two eminent ancient Indian scholars and Ayurvedic physicians named Charaka and Susruta contributed to our knowledge of the diversity and utility of plants. The ancient Indian scholars compiled 'Vrikshayurveda' before the beginning of the Christian era and this deals with the scientific study of plants and animal life. One of the earliest Ayurvedic treatises was the Sushruta Samhita, attributed to Sushruta in the 6th century BCE. It was also an early materiamedica, describing 700 medicinal plants, 64 preparations from mineral sources, and 57 preparations based on animal sources. This ancient work was further developed in the middle Ages by Muslim physicians and scholars such as Avicenna.

Technical literature on medicinal plants with complete detail of morphology and pharmacology is described in the works like the Charaka-Samhita and Susruta Samhita and exclusive plants related work under the title of Vrksayurveda. Parasara's Vrksayurveda is supposed to be the most ancient work in actual botany; it was composed during the first century BC and the first century AD. From the literary evidence, it is clear that even in the First Millennium BC, botany was fully systematized and taxonomy was well developed in India.

The Charaka Samhita: The Charaka-Samhita or (Compendium of Maharishi Charaka)is an early text on Ayurveda (Indian traditional medicine). This was long before the birth of Hippocrates. Charaka was the first physician to present the concept of digestion, metabolism, and immunity in his book. Hence he was referred to as the Father of Indian Medicine. His ancient manual on preventive medicine remained a standard work on the subject for two millennia and was translated into many foreign languages, including Arabic and Latin.

The Sushruta Samhita: The Sushruta Samhita is an important Classical Sanskrit text on medicine. Written by Maharishi Sushruta, it is dated to the period of 600 BC. It is one of the foundational texts of Ayurveda (Indian traditional medicine), alongside the Charaka Samhita, Bhela Samhita, and the medical portions of the 'Bower Manuscript'. The Sushruta Samhita, in its extant form, in 184 chapters contains descriptions of 1,120 illnesses, 700 medicinal plants, 64 preparations from mineral sources, and 57 reparations based on animal sources.

The text discusses surgical techniques of making incisions, probing, extraction of foreign bodies, alkali and thermal cauterization, tooth extraction, excisions, and trocars for draining the abscess, draining hydrocele and ascetic fluid, the removal of the prostate gland, urethral stricture dilatation, vesicular- lithotomy, hernia surgery, cesarean section, management of hemorrhoids, fistulae, laparotomy and management of intestinal obstruction, perforated intestines, and accidental perforation of the abdomen with protrusion of omentum and the principles of fracture management, namely, traction, manipulation, appositions, and stabilization including some measures of rehabilitation and fitting of prosthetics. It enumerates six types of dislocations, twelve varieties of fractures, and classification of the bones and their reaction to the injuries, and gives a classification of eye diseases including cataract surgery.

The first cataract surgery is said to have been performed by the ancient Indian physician Sushruta, way back in the 6th century BCE. To remove the cataract from the eyes, he used a curved needle, *Jabamukhi Salaka*, to loosen the lens and push the cataract out of the field of vision. The eye would then be bandaged for a few days till it healed completely. Sushruta's surgical works were later translated into Arabic language and through the Arabs, his works were introduced to the West.

Sushruta Samhita of 6th Century BC is considered to be one of the most comprehensive textbooks on ancient surgery. The text mentions various illnesses, plants, preparations, and cures along with complex techniques of plastic surgery. The *Sushruta Samhita's* most well-known contribution to plastic surgery is the reconstruction of the nose, which is also known as rhinoplasty.

All the above information regarding the historical periods of documentation in India reveal one thing that the knowledge about plants (maybe taxonomy and study of medicinal plants) is very ancient so that it runs back to the Vedic period – 2500 BC to 600BC. At that time itself, the well-known personalities had a vast knowledge of plants with their scientific features and medicinal value. Certain botanical names of some plants are derivations of Sanskrit. For example, Amala (Phyllanthus Emblica), Vasaka (Adhatoda vasica), etc., based on this historical evidence and ethnobotanical studies, we can conclude that the subject of biology in terms of knowledge of plants and animals was present much earlier than what we think.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Father of Indian Medicine
    a. Charaka
    b. Sushruta
    c. Parashara
    d. Arybhata

2. Plastic surgery was in practice in
    a. 4^{th}Century BC
    b. 6^{th}Century BC
    c. 3^{rd} Century BC
    d. 5^{th} Century BC

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:

a. 'Vrikshayurveda' was contributed after the Christian era
b. During the 6th Century BC, a curved needle was used to remove the cataract from the eyes
c. Sushruta compiled 'Charaka Samhita'
d. Parashara prepared 'Sushruta Samhita'
e. Amala is Phyllanthus Emblica.
f. Adhatoda vasica is Vasaka

1.4.3.2. History of Biological Science in Abroad

Activity 2: Search information about the evolution of organisms in the Galapagos Islands studied by Darwin

The etymology of Biological Science

The word biology is formed by combining the Greek bios, meaning "life", and -logy', meaning "science of", "knowledge of", "study of", "about of", the term biology in its modern sense appears to have been introduced independently by Thomas Beddoes (in 1799).

Before biology, there were several terms used for the study of animals and plants. Natural history referred to the descriptive aspects of biology, though it also included mineralogy and other non-biological fields; from the Middle Ages through the Renaissance, the unifying framework of natural history, conceptual and metaphysical basis of plant and animal life, dealing with problems of why organisms exist and behave the way they do, though these subjects also included what is now geology, physics, chemistry, and astronomy. Physiology and (botanical) pharmacology were the province of medicine. Botany, zoology, and geology replaced natural history and natural philosophy in the 18th and 19th centuries before biology was widely adapted. To this day, "botany" and "zoology" are widely used, although they have been joined by other sub-disciplines of biology.

Hippocrates (460-377 B.C) and Aristotle (384-322 B.C)the two great Greek philosophers, studied and classified various living organisms, but their classifications were not based on scientific method and reasoning. **Theophrastus (370-285 B .C),** a disciple of Aristotle classified the plants based on form and texture and is known as the 'father of botany', and his book 'Historia Plantarum' deals with 480 plants. One of the things for which Hippocrates remembered is his theory that the human body was composed of the four elements (earth, air, fire, water) plus four fluids or humors- sanguis or blood, produced by the heart; choler or yellow bile, produced by the liver; melancholia or black bile, produced by the spleen; and phlegma or phlegm, produced by the brain.

Aristotle, one of **Plato's** most famous pupils, lived from 343 to 322 BC and contributed much to what we now consider to be in the realm of biology. His refinement of the systems of animal and plant classification has profoundly influenced the course of biological thought ever since. His classification system included what he called the Scala Naturae, the "scale of nature." He said that all organisms are arranged in a hierarchy from simplest to most complex, like rungs on a ladder with no vacancies, no mobility, and no change possible since all the spots were full.

With the decline of the Greek and Roman civilization, there was no significant botanical advancement for more than fourteen centuries. However, there was again awakening of botanical learning in the sixteenth century when several herbals, especially those of Brunfels (1530), Bock (1539), Fuchs (1542), Turner (1551), Cordus (1561), Lobelius (1581), and Gerar (1597) were published. Otto Brunfels was one of the first among the group of renowned herbalists, who described and illustrated the plants known to that period. They were more interested in the purported medical values and domestic uses of plants. Braunfels produced one of the first illustrated herbals and recognized the perfect and imperfect groups of plants characterized by the presence and absence of flowers respectively. These herbalists as a group are considered as important for their contribution to the descriptive phases of systematic botany. During the European Renaissance and early modern period, biological thought was revolutionized in Europe by a renewed interest in empiricism and the discovery of many novel organisms. Prominent in this movement were Vesalius and Harvey, who used experimentation and careful observation in physiology, and naturalists such as Linnaeus and Buffon who began to life and the fossil record, as well as the development and behaviour of organisms.

By the late 1600s, observations were being made with the first, primitive instruments called microscopes. In 1665, **Robert Hooke** was the first person to see and name cells. He examined (dead) cork bark with a primitive microscope and saw little cubicles which he called cells. Even now the term is not changed, the unit of life is "Cell".

Anton van Leeuwenhoek was the first person to observe sperm cells with his very primitive microscope. He thought he saw tiny body parts in the sperm. He used this as "proof" of the idea that the homunculus was in the sperm and the mother's body just served as a place for the planted seed to grow. Additionally, Leeuwenhoek proposed that fertilization occurs when the sperm enters the egg, but this could not be observed for another 100 years.

John Ray (1627-1706) and **Francis Willoughby** (1635-1672) the two European scientists in the 17th century collected many plants and animals and classified them. Ray described 18,000 plants and published between 1686 and 1704 a book 'Historia Generalis Plantarum' in three volumes.

Carl Linnaeus (1707-1778), a Swedish naturalist, who is also called the 'Father of Taxonomy', classified the organisms according to his system of classification, which is called the binomial system of nomenclature. This system is based on the principle of naming organisms by two words: genus and species. According to him, existing species of plants and animals were the descendants of the previously created species. His 'Sistema Naturae' appeared in 1735. This was followed by 'Genera Plantarum' and 'Classes Plantarum' appeared in 1737 and 1738 respectively. Linnaeus 'Philosophia Botanica' appeared in 1751, which was a revised version of his system, published in 'Classes Plantarum'. His 'Species Plantarum' was published in 1757, a work in which 1700 species were described and arranged based on the sexual system of classification. His system is considered an artificial system.

Jean Baptiste Lamarck in the year 1809, published his 'Theory of Evolution'. He explained his theory by the following major points:

- Evolution or change within a species is driven by an innate, inner striving toward greater perfection,
- Use or disuse of various organs made them larger or smaller, accordingly, and

- These acquired traits could be inherited or passed on to offspring (inheritance of acquired traits).

Karl von Baer in 1828, published the developmental stages in mammalian eggs. He was able to show that an undifferentiated, single-celled egg grows into a many-celled embryo in which all the cells have different functions. This disproved the preformation theory (which said that the preformed homunculus just gets bigger).

Charles Darwin in 1859, published The "Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life", more commonly known as The Origin of Species. In this landmark book, he made four main points:

- Individuals, even siblings, in a population vary (there is a variation),
- These variations can be passed on to offspring (are inherited remember- he, too, thought this happened via pangenesis),
- More offspring are produced than the environment can support, so there is competition for resources, and
- Those individuals whose characteristics make them best suited to the environment live and reproduce and have more offspring (survival of the fittest).

Thus in any population, there is descent with modification (changes occur over the generations) due to natural selection the "pressure" the environment puts on the various genetic varieties in terms of their ability to cope and/or survive.

John Needham, a Scottish clergyman, and naturalist in 1745-1748 showed that microorganisms flourished in various soups that had been exposed to the air. He claimed that there was a "life force" present in the molecules of all inorganic matter, including air and the oxygen in it that could cause spontaneous generation to occur, thus accounting for the presence of bacteria in his soups.

Gregor Mendel, an Austrian monk in 1865, published a paper on genetics that earned him the nickname "Father of Modern Genetics". One of Mendel's jobs at the monastery was to care for the garden. As he went about his chores, he noticed that some of his pea plants were tall while others were short, some had purple flowers while others had white, some had yellow seeds while others had green, and some had wrinkled seeds while others had smooth seeds. As Mendel raised peas, he made specific crosses between certain plants and did something very unusual for biology in those days- he counted the results. From this, he developed a theory of genetics that refuted the pangene/homunculus idea and enabled people to predict the outcome of a genetic cross if the genes of the parents were known. When Mendel first published his paper, the idea of the pangenesis was still so deeply held that people ignored his work or dismissed it as false. It wasn't until 1900 that a couple of botanists working on other research rediscovered his work.

In 1870 the process of mitosis, regular cell division by which one cell divides to make two cells, was observed, and researchers noticed that chromosomes, whose function was not understood, were moving around in the cell during mitosis so that each daughter cell got an exact set of them. In 1890 the process of meiosis, a special cell division involved in producing eggs or sperm, was observed. Again, researchers did not yet understand what chromosomes were, but they did note that as a result of meiosis, each egg or sperm cell formed had half as many chromosomes as the original cell.

Thus, after Mendel's work was rediscovered in 1900, researchers started seeing parallels between his theory of genetics and what the chromosomes were doing in mitosis and meiosis. From this, people figured out that Mendel's genes were on the chromosomes. In the 1940s, people finally started fitting the two together. People began to think that the DNA in the chromosomes was the genetic material, but because its chemical structure was unknown, a lot of biologists were skeptical about this idea. In 1953, James Watson, an American, and Francis Crick, an Englishman, published a paper in which they proposed a hypothetical structure for DNA, which also showed how DNA could be the genetic code material and suggested a means whereby it could replicate itself. Subsequent chemical analyses of DNA have upheld their prediction. Until about 100-150 years ago, science/biology and "religion" were intervened in human thought and culture. After the publication of Watson and Crick's paper on DNA, our biological knowledge has increased exponentially, especially in the field of genetics.

Hugo de Vries (1848–1935) was a Dutch botanist who worked in genetics after rediscovering Mendel's laws and produced De Vries' Mutation Theory (1903). De Vries disagreed with the mechanism of natural selection and offered, instead, a theory of rapid changes, which he called mutations. According to this, theory,

- New elementary species arise suddenly, without transitional forms.
- New elementary species are constant from the moment they arise
- The mutations, to which the origin of new species is due to appear to be indefinite, that is to say, the changes may affect all organs and seem to take place in any direction
- These mutations are different from our modern concept of mutation, which only occurs in the genetic material.

Bateson(1861–1926) was a Cambridge natural scientist and zoologist, who founded the department of genetics. Bateson supported evolution as a biological fact, but he did not accept the mechanism of natural selection. He argued, instead, that species are created by hybridization or drastic mutations. Bateson and his colleagues discovered semidominance, showed that there are Mendelian traits in animals as well and that some genes are linked. However, both Darwinists and Mendelians were opposed. They supported and opined different ideas, like gradual vs. sudden change, continuous vs. discrete traits. Even they had different methods, like, observation vs. experimentation and they represented different research traditions.

Mendeliancontributions came to the limelight during the beginning of the 20th century. A noteworthy point here is experiments with Drosophila Melanogaster, the Common Fruit Fly**.**

The fruit fly has had a long career in science; due to their ubiquitous and breed easily and quickly character, they were used by many scientists for experiments. The fruit fly first came into genetic labs in 1901 as a control for other experiments. Gradually, however, researchers noticed that they show a large number of easily observable mutations that display Mendelian traits. The fruit fly was made most famous by the Fly Lab at Columbia and remains an essential tool for genetic research.

In the 1930s-40s, there was a revival of the theory of evolution through the mechanism of natural selection. The modern synthesis brought together many different branches of the biological sciences such as field studies, paleontology, embryology, genetics,

population genetics, etc., and interpreted their findings through the adaptive mechanism. As a result, there was a renewed interest in the evolution of the human race and in thinking about the implications of evolution through natural selection as a basis for understanding our social and moral place in the world.

Based on these kinds of ideas, physicists and chemists began to become interested in biology and began a process of colonization of the biological sciences with physical and chemical methods and ways of thinking. Using techniques such as x-ray crystallography, physicists and chemists began to study the minute structure of biological molecules. Biochemists, such as Erwin Chargaff (1905–2002), began to use chemical techniques to analyse biological molecules into their components. Linus Pauling (1901–1994), who had worked extensively on the nature of the chemical bond using quantum theory, showed that a polypeptide chain of proteins is a single helix, the alpha-helix.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Hippocrates belonged to
    a. 460-377 B.C
    b. 384-322 B.C
    c. 370-285 B .C
    d. 343-322 BC

2. The unit of life 'Cell' was discovered by
    a. Anton van Leeuwenhoek
    b. Robert Hooke
    c. Carl Linnaeus
    d. Karl von Baer

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. John Ray published 'Historia Generalis Plantarum' in three volumes
    b. De Vries opined that new elementary species arise suddenly, without transitional forms
    c. RNA was considered as the factor responsible for the mutation
    d. Gametes are produced by mitotic cell division
    e. Gregor Mendel got recognition for his discoveries in his lifetime
    f. John Needham showed that microorganisms flourished in various soups that had been exposed to the air

1.4.4. Let us Summarise

The history of Biology logically goes back to the prehistoric era of man. For the convenience of study, it could be divided into the ancient history of biology in India and Abroad separately. One of the oldest organised systems of medicine is known from the Indian subcontinent in the form of Ayurveda which was originated around 1500 BCE from Atharvaveda (one of the four most ancient books of Indian knowledge, wisdom, and culture). Technical literature on medicinal plants with complete detail of morphology and pharmacology is described in the works like the Charaka-Samhita and Susruta Samhita and exclusive plants related work under the title of Vrksayurveda. Parasara's Vrksayurveda is supposed to bethe most ancient work in actual botany; it was composed during the first

century BC and the first century A.D. From the literary evidence, it is clear that even in the First Millennium BC, botany was fully systematized and taxonomy was well developed in India.

Charaka was the first physician to present the concept of digestion, metabolism, and immunity in his book. Hence he was referred to as the Father of Indian Medicine. His ancient manual on preventive medicine remained a standard work on the subject for two millennia and was translated into many foreign languages, including Arabic and Latin. *Sushruta Samhita* of 6th Century BC is considered to be one of the most comprehensive textbooks on ancient surgery. The text mentions various illnesses, plants, preparations, and cures along with complex techniques of plastic surgery. The *Sushruta Samhita's* most well-known contribution to plastic surgery is the reconstruction of the nose, which is also known as rhinoplasty.

Hippocrates (460-377 B.C) and Aristotle (384-322 B.C) the two great Greek philosophers, studied and classified various living organisms, but their classifications were not based on scientific method and reasoning. Theophrastus (370-285 B .C), a disciple of Aristotle classified the plants based on form and texture and is known as the 'father of botany', and his book 'Historia Plantarum' deals with 480 plants. By the late 1600s, observations were being made with the first, primitive instruments called microscopes. In 1665, Robert Hooke was the first person to see and name cells. He examined (dead) cork bark with a primitive microscope and saw little cubicles which he called cells. Even now the term is not changed, the unit of life is "Cell".

Leeuwenhoek, Carl Linnaeus, Lamarck, Darwin, Gregor Mendel, Hugo de Vries, and Bateson are some of the famous eminent personalities who have contributed significantly to the development of the subject as a discipline. In the 1930s-40s, there was a revival of the theory of evolution through the mechanism of natural selection. The modern synthesis brought together many different branches of the biological sciences such as field studies, paleontology, embryology, genetics, population genetics, etc., and interpreted their findings through the adaptive mechanism. As a result, there was a renewed interest in the evolution of the human race and in thinking about the implications of evolution through natural selection as a basis for understanding our social and moral place in the world. Based on these kinds of ideas, physicists and chemists began to become interested in biology and began a process of colonization of the biological sciences with physical and chemical methods and ways of thinking. Biochemists, such as Erwin Chargaff and Linus Pauling (1901–1994), who worked extensively on the nature of the chemical bond using quantum theory, showed that a polypeptide chain of proteins is a single helix, the alpha-helix.

1.4.5. Answers to 'Check Your Progress - 1and 2'

Check Your Progress - 1
1.a 2.b 3.a- **X** b- √ c- **X** d- **X** e- √ f- √

Check Your Progress - 2
1.a 2.b 3.a- √ b- √ c- **X** d- **X** e- **X** f- √

1.4.6. Unit end Exercises

1. Give an account of Ancient Indian Contributors in the field of medicine
2. Explain the historical development of the subject biology in India
3. Describe the contributions of any two ancient foreign personalities in Biology
4. What are the postulates provided by Lamarck and Darwin?
5. Why Gregor Mendel is called the father of genetics?
6. Why DNA is called genetic material?

1.4.7. References

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Block 1 : Nature and Objective of Teaching Biological Science

Unit 5 : Aims and Objectives of Teaching Biological Sciences

Unit Structure

1.5.1 Learning Objectives

After completing this Unit, the student teachers will be able to

- Define Aims of Teaching of Biological Science;
- Recall the goals of teaching-learning of Biological Science;
- Recognise the objectives of Biological Science;
- Apply the knowledge of Objectives of the teaching of Biological science classroom; and
- Justify the importance of Aims of Teaching of Biological Science.

1.5.2. Introduction

Before telling anything about achieving after studying a subject, first, we should look at it as studying a subject should make a person happy and be joyful while learning. Is it not? Take, for example, Biology, it is both fascinating and fun for students. It is because the subject is having a direct connection to our daily life. It maybe dirty water, but observing it under a microscope and recognising the microbes will be a thrilling experience for students. Similarly, elementary students enjoy studying tadpoles. The subject Biology nurtures intellectual curiosity, increases the awareness of the fragile ecosystem, and also stimulates critical thinking. These are the potential power in the subject. So the aims and objectives of studying biology should focus on the importance of appreciating the natural world and protecting Mother Earth. In this unit, you will come to know about the aims and objectives of teaching biological science. Objectives bring a firm basis for classroom teaching and Aims will take an individual to the path of transformation of one's personality.

1.5.3. Learning Points and Learning Activities

1.5.3.1. Meaning, Nature and Importance of Aims of Teaching Biological Science

Activity 1: Discuss with an example of how learning biological science helps in developing logical thinking.

Activity 2: Find out some superstitious practices prevailing in society and suggest how you would tackle such issues with your students in the classroom.

Aims act as basic directions while carrying out teaching Biological science. It can be divided into various objectives which help in reaching the aim easily. It has a long-range perspective that reflects the aspirations and ambition of the entity. Aims are general statements concerning the overall goals, ends, or intentions of teaching. Objectives are the individual stages that learners must achieve on the way to reach these goals. Aims are general, objectives are specific. There are more objectives than aims. Aims are like strategy, objectives are like tactics. Aims and objectives can form hierarchical structures so that in complex curricula aims at one level might be seen as objectives at another.

All the National Policies of Education, as well as National Education Commissions in India, have advocated certain aims of teaching science include the following:

- To develop the scientific temper, attitude and outlook
- Training in the scientific method and to develop the science process skills
- To develop open-mindedness, objectivity, honesty, national integration, international and international understanding
- To develop concern for the environment and democratic, socialistic and secularist values.
- To respect others view and opinion
- To develop gender equity.
- To promote research in the field of science and technology.

The aims of learning biological science like knowledge, understanding of science, nurturance of process skills, development of scientific attitude, scientific temper, nurturance of curiosity, creativity and aesthetic sense, imbibing values, developing problem-solving and relating biological science education with nature, social environment, technology and society are common at all educational processes. It is also emphasized that achieving the aims of biological science should be a continuous effort of a teacher.

Time and again the Aims and Objectives get changed to reciprocate the societal changes. The aims and objectives of teaching biological science retain the same status-quo as science in general but maintain its specificity also. So the following aspects will help us understand the Aims of teaching biological science:

Aim of Teaching Biological Sciences

- Develop minds with inquiry and curiosity about science and the natural world
- Acquire knowledge, conceptual understanding, and skills to solve problems and make informed decisions in scientific and other contexts
- Develop skills of scientific inquiry to design and carry out scientific investigations and evaluate scientific evidence to draw conclusions
- Communicate scientific ideas, arguments and practical experiences accurately in a variety of ways
- Think analytically, critically and creatively to solve problems, judge arguments and make decisions in scientific and other contexts
- Appreciate the benefits and limitations of science and its application in technological developments
- Understand the international nature of science and the interdependence of science, technology and society, including the benefits, limitations and implications imposed by social, economic, political, environmental, cultural and ethical factors
- Demonstrate attitudes and develop values of honesty and respect for themselves, others, and their shared environment.

The above-said aims to insist on a transformation in the teacher's role also. It becomes obvious for the teacher to teach/help students to become responsible democratic citizens of our country. Making the students understand and appreciate the contributions of science and technology in benefiting society. Teachers have to assist students in developing models of inquiry and discovery. They have to provide a rich variety of experiences to students, encourage students to ask questions, browse reading materials, and express their ideas without hesitation. Teachers must encourage students to construct hypotheses, testing of hypotheses, and conducting experiments.

National Curriculum Framework 2005 has emphasized that "teaching of science should be recast so that it enables children to examine and analyse everyday experiences. Concerns and issues about the environment should be emphasized in every subject and through a wide range of activities involving outdoor project work. Some of the information and understanding flowing from such projects could contribute to the elaboration of a publicly accessible, transparent database on India's environment, which would in turn become a most valuable educational resource. If well planned, many of these learner projects could lead to knowledge generation." It means, science teaching should be organized around learners' experiences and opportunities should be provided to learners to explore the science around them. This marks a clear shift from classroom and laboratory centred science pedagogy. Integration in science teaching-learning is very important and scientific knowledge should not be compartmentalized in subject domains like physics, chemistry, biology, environmental science up to the secondary level.

NCF-2005 and Position Paper of National Focus Group on Teaching of Science (2006)-NCERT have proposed 6 criteria for the validity of a science curriculum i.e. cognitive, content, process, historical, environmental and ethical. On this basis, the following general aims of science education have been conceptualized:

Science education should enable the learner to:

- Know the facts and principles of science and its applications, consistent with the stage of cognitive development
- Acquire the skills and understand the methods and processes that lead to the generation and validation of scientific knowledge
- Develop a historical and developmental perspective of science and to enable her to view science as a social enterprise
- Relate to the environment (natural environment, artifacts and people), local as well as global, and appreciate the issues at the interface of science, technology and society
- Acquire the requisite theoretical knowledge and practical technical skills to enter the world of work
- Nurture the natural curiosity, aesthetic sense and creativity in science and Science Teaching-Learning technology
- Imbibe the values of honesty, integrity, cooperation, concern for life and preservation of the environment, and
- Cultivate scientific temper, objectivity, critical thinking and freedom from fear and prejudice.

  Major aims of teaching Biological Science are:

1. Acquiring Knowledge and Understanding through Biological Science

Children should be given various opportunities to develop process skills of biological science. Action provides a practical basis for thinking. Opportunities for discussion in small or large groups and the whole class maybe provided. These allow children to listen to others, explain, argue, express, and share their ideas, thus involving them in thinking about what they have done, relating to the evidence, and considering multiple ways of approaching a problem.

To help children develop process skills, the teacher needs to know how children are using those skills. The teacher can observe their work and listen to their discussions to pick up information on how children have collected and used the evidence.

2. Developing Scientific Attitude and Scientific Temper

Science learning and the development of scientific attitudes and temper are complementary to one another. We can say that development of attributes such as respect for evidence, open-mindedness, truthfulness, critical and logical thinking, skepticism, objectivity, perseverance, curiosity, creativity and inventiveness, sensitivity to living and non-living, and cooperation with others through exploration of the world around leads to the inculcation of scientific attitude and scientific temper. These qualities affect the willingness of pupils to take part in the activities, respond to persons, objects, situations, or events in a rational manner. Their development is not spontaneous.

While developing skills of collecting evidence for verifying and testing ideas, the students must be trained to confront ideas with evidence. If ideas conflict with evidence, students should be encouraged to check again and collect more evidence for concluding. They should be flexible and willing to change their ideas where there is convincing evidence to the contrary.

For true learning in biological science, it is important not to have a set mind with preconceived notions. An open-minded person is one who can modify plans or discard hypotheses, if necessary, and accepts a new explanation, model, or changes because it explains the evidence better. An open-minded person evaluates all reasonable inferences, remains open to alternative interpretations, accepts new priorities in response to a re-evaluation of the evidence or re-assessment of the existing ideas, and does not reject unpopular views out rightly. The teachers can help students acquire this through activities and experiments, frequent collaborative work, and discussions in which each child must be allowed to express her viewpoint. Others can reflect on it in a socially acceptable manner.

3. Developing Truthfulness in Reporting Observations

It is very required to report the correct observations in the experiments to conclude. In the scientific procedure, observations in an experiment are repeated and verified before concluding. Teachers should encourage honesty in reporting the result of the experiments among students. They should create a fear-free environment in which students do not feel scared if the results deviate markedly. If the need arises, teachers should work with the students to help them find out the reasons for the discrepancies and guide them, so that they don’t manipulate the results.

4. Developing Critical Thinking

In science, critical thinking increases science learning potentials. It requires a deliberate review of how activities are carried out, the ideas emerge and the way these can be improved. It is the ability to analyse information and experiences objectively.

Reflecting on the processes of thinking does not come readily to young children as it involves abstract thinking as well. Teachers can facilitate this by engaging the children in discussions through activities.

Following actions should be emphasized for the development of this attribute.

- Willingness to review the work done for its further improvement.
- Considering alternative ways.
- Identifying the aspects that are for and against the way adapted.
- Reflecting on the previous work to identify the mistakes and avoid those in the next.
- Focusing on relevant scientific facts.

5. Developing Logical Thinking

Thinking with reasoning is known as logical thinking. Children should be helped to reason out consistently before concluding. Scientific temper is refined logical thinking. The refinement in logical thinking can be brought in by making an observation, quantifying the observation to increase the resolution of our observation, and organizing the information gathered from observation. Organizing includes a recording of the important information, classifying and looking for a pattern. Based ona pattern or no pattern hypothesis is made (why and how) and verified to know whether an explanation holdswellinother situations.

6. Developing Scepticism

Skepticism is questioning the accepted beliefs, ideas, or facts in a society based on scientific investigations. For instance, a lot of superstitions still prevail in society and even some educated people continue to follow them, sometimes out of fear of the unknown. Of throwing away all food items after a solar or lunar eclipse. There are various other examples of superstitious beliefs that have no scientific basis like sneezing at the time of stepping out of your house or a cat crossing your way are bad omens, etc. Before believing in such things and falling prey to such unscrupulous practices, children need to be taught to weigh properly the scientific evidence in favour or against such beliefs.

Myths and superstitions should be discarded by making and evaluating judgments based on evidence. The teachers need to organize planned debates on such issues and encourage children to participate in the discussions, thus, sensitizing them gradually against the causes by promoting rational and critical thinking.

7. Developing Objectivity

Objectivity is looking at things without any preconceived notions, biases, prejudices or discrimination. It can be developed by understanding the importance and use of evidence. This would also help in developing respect for evidence. Learners should be open to others' ideas and should respect others' point of view, but they should accept the ideas only after testing and verification or with sufficient evidence. This also requires a change in our traditional authoritarian attitude.

While developing skills of collecting evidence, verifying and testing their ideas, the following points should be emphasized.

- Respect others' ideas or point of view, based on sound logic.
- Confront your ideas with evidence.
- If ideas conflict with evidence, Collect more evidence before concluding.
- Treat all ideas and statements as provisional.
- Be flexible and willing to change your ideas if they are not consistent with the evidence.

Children can be made open towards this quality by eliciting examples of how other people's ideas and those of the great scientists changed due to new findings.

8. Developing Perseverance

It is expected that the students are given opportunities to work repeatedly to arrive at a scientifically valid conclusion. The teachers may elaborate on this aspect through the narration of the efforts of different scientists. Qualities of critical and logical thinking, open-mindedness, hard work, perseverance, and love for the search for knowledge should be highlighted. A science teacher needs to provide children experiences of several scientific activities as a base for a thorough understanding of science and developing scientific attitude and temper.

9.Nurturing the natural curiosity, creativity and aesthetic sense

Curiosity helps to learn a particular concept. Curiosity gets aroused as a result of doubt, perplexity, contradiction, cognitive conflict, ambiguity, lack of clarity, etc. A teacher needs to create suitable learning situations for this.

Creative thinking is a novel or innovative way of seeing or doing things. It is also referred to as thinking 'out of the box'. Creative thinking enables a learner to explore available alternatives and consequences of actions or non-actions and contributes to decision-making and problem-solving.The teacher plays an important role in nurturing creativity in learners. From the pedagogical perspective of Biological science, inquiry and activity-oriented, process-based teaching-learning can facilitate nurturing creativity. Teachers should be respectful to unusual questions and imaginative unusual ideas of learners. Occasionally, provide opportunities for them to do tasks without any fear of evaluation. Let the learners evaluate the task on their own without pointing it as right or wrong. Do not tell the results of an experiment in advance. Help them to conclude.

Aesthetics deals with the creation and appreciation of beauty that gives us happiness. Harmony, order, and pattern are some of the criteria which define beauty. A scientist, like an artist, is in search of harmony. The harmony of nature and its experience, direct or indirect, is believed to be expressible in different ways. In science, the harmonious character of nature is visible in laws and theories in their proclaimed scope of universality.

10. Relating Biological Science Educations to Social, Environment, Technology and Society

Relating science education with the environment of a child has been the prime concern of educationists. The environment of a child includes natural and social environments, artifacts and people. In biological science, we learn about the environmental phenomena of both natural and man-made interventions affecting the environment. We can say that science education is mainly of the environment and for the environment. Therefore, every effort should be made to integrate science with learning the environment. The science curriculum should address issues and concerns related to the environment such as climate change, acid rain, growth of water eutrophication and various types of pollution, etc. through

teaching-learning of science at all stages. Students will be attracted to science when they realize its significance to society and relevance to their lives. Science teacher should aim to enlighten the young minds with the wonders of biological science.

Science and technology are linked to each other. Discoveries in science have paved the way for the evolution of new technologies. At the same time technology has been instrumental in the development of science. Applications of biological science in different fields like medicine have a remarkable improvement in the quality of human life. It has provided humankind with comfort and leisure on the one hand and equipped it with the skills needed for problem-solving and decision-making on the other hand. It has changed the outlook of the individual, the group, or the society on different beliefs, myths, taboos and superstitions. People have started working with logical thinking, objectivity and open-mindedness. Modern society recognizes the diversity in social and political thinking and believes in coexistence. It has started thinking about the welfare of our future generations and talks about sustainable development. The society also shows its concerns for use of scientific knowledge for peace.

11. Imbibing the Values through Science Teaching

Education for human values is an important area that needs to be promoted at all stages of education. Values are abstract and multi-dimensional and present an idea for the members of the society to shape their personalities. Biological Science offers many opportunities for value inculcation. These cannot be imposed, but need to be part and parcel of the teaching-learning process. There is no need to have a separate period for value education. Teachers can integrate values during the teaching-learning of different subjects like science, language, social studies, mathematics, arts, crafts, etc. For example, during the teaching-learning of the concepts such as the symbiotic association between organisms, the teacher can discuss the values of coordination, unity and stay together based on how two organisms of distant taxonomical groups stay together. The teaching of biological science can help in developing certain values, namely, Patience, Perseverance, Cooperation, Honesty, Integrity, and Concern for life.

12. Developing Problem Solving Skills

Problem-solving means that an individual has learned the skills and acquired relevant information necessary to solve problems that are not only curricular but also related to everyday life. Various skills required for problem-solving can be enhanced by providing opportunities to students, like, to ask questions, think aloud, look for alternative explanations and procedures, isolate and control variables, keep a record, apply reasoning and analogy, make models, and apply process skills in teaching-learning of science. Students can explore such potentiality while working on the problem. They feel a sense of achievement in getting success and develop self-confidence.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Aims of teaching science are formed based on
    a. Public suggestions
    b. Experts' opinions
    c. National Policies and National Curriculum Frame Work
    d. Students' Interest

2. Problem-solving Skill means
    a. Ability to solve a mathematical problem
    b. Ability in solving school-based problems
    c. Ability to solve the financial problems
    d. Ability to solve the problems of life in general

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. There will be no scope for developing human values in teaching biological science
    b. Scientific temper is the refined logical thinking
    c. For true learning in biological science, it is important not to have a set mind with preconceived notions.
    d. Conservation of the environment cannot be done through biology teaching
    e. The teaching of biological science can help in developing certain values
    f. Science learning and development of scientific temper are complementary to each another.

1.5.3.2. Meaning, Nature and Importance Objectives of Teaching Biological Science

Activity 3: It is better to look at the recommendation of NCF 2005 about the Aims and Objectives of Science Education, because, based on these guidelines all the other academic and curricular patterns are formed. So the discussion on these areas will put some light on the topic 'Objectives of Teaching Biological Science'.

"Science education should enable the learner to know the facts and principles of science and its applications, consistent with the stage of cognitive development"- and the main objective of science education is to make the learners "Scientifically Literate", as Science is a compulsory subject of the curriculum up to secondary level. Here the focus should be on 'Developing awareness among the learners about the interface of science, technology, and society, sensitizing them, especially to the issues of environment and health and enabling them to acquire particular knowledge and skills to enter the world of work'- NCF 2005.

Usually, Educational Aims in general and Aims of Science Education, in particular, will be very vast encompassing broad areas of knowledge and experience. But contrary to these objectives will give us the proper track to move on so that the goal or the aim is achieved. In the real sense, learning objectives guide the teachers to take the required actions to bring the transformations in students' personalities so that their learning will become more meaningful. Apart from this, objectives will help a teacher to decide the teaching strategies, techniques, tactics and teaching approaches, methods to adapt while teaching. Objectives are the common support system for both teacher and the taught. Objectives will give a strong reference for the evaluation of the teaching-learning process also. In a way objectives of teaching biological science help the teachers and learners as well in self-assessment and will facilitate to plan, perform and workout systematically.

Goals or Aims are the ultimate destinations to reach (Achieve) and Objectives are the means to reach that (Ways, Means and Strategies). Therefore an objective is called the part of an aim. Objectives are very practical, attainable and will be specific. Because of their specificity objectives vary from subject to subject. As a rule, objectives are written in behavioural terms by making use of action verbs. They indicate the transformation or the behavioural changes among the students which are considered as learning outcomes.

According to Good C.V. objective is an end towards which a school-sponsored activity is directed (1959). The objectives of science teaching in general and biology teaching, in particular, are formulated on philosophical, sociological and psychological bases. Objectives are formulated by giving due importance to, abilities of the students, requirements and demands of the society, the nature of the subject, general aims of the educational system and constraints in implementing the subject.

The objectives of teaching biological science must be consistent with the aims of biological sciences. These have to be aligned with the three major components of the teaching-learning process, namely, the purpose of teaching (Objectives), teaching-learning activities (Curricular transaction), and Assessment (Evaluation). The well-balanced scheme of evaluation will help in knowing whether the pre-determined objectives are realized or not. Hence it is said that if these three components are congruent, teaching-learning is meaningful.

In all the educational policies it is observed that more emphasis is on acquiring skills so that learners can deal with the ever-changing and expanding world of science. At the primary level, the emphasis is on engaging the learners in joyfully exploring the world around them and harmonizing with it. Hence the objectives at this stage are,

- To nurture the curiosity of the child about the world (natural environment, artifacts and people)
- To have the child engage in exploratory and hands-on activities to acquire basic cognitive and psychomotor skills through observation, classification, inference, etc.
- To emphasize design and fabrication, estimation and measurement as a prelude to the development of technological and quantitative skills of later stages; and
- To develop basic language skills: speaking, reading, and writing not only for science but also through science. At this level, Science and social science have been integrated as 'Environmental Studies'.

At the upper primary level, the emphasis is on engaging the learner in learning principles of science through familiar experiences, working with hands to design simple technological units and modules, and continuing to learn more about the environment and health through activities and surveys.

At the secondary school level, learners are supposed to be engaged in learning science as a composite discipline. Concepts, principles, and laws of science should be introduced at this level with an emphasis on comprehension and not on mere formal definitions. At this stage, those concepts, which are beyond direct experience, should also be introduced and learners should make understand that all scientific phenomena are not directly observable; science also relies on inference and interpretation. Experiments must be used as an important tool to discover/verify theoretical principles at this stage. At this level, emphasis also should be to organize co-curricular activities like some small group projects on local issues and use the problem-solving approach.

The taxonomy of educational objectives, known as Bloom's Taxonomy is one of the most recognized learning theories in the field of education. Educators often use Bloom's Taxonomy to create learning outcomes that target not only subject matter but also the depth of learning they want students to achieve and then to create an assessment that accurately reports on students' progress towards these outcomes (Anderson & Krathwohl)-2001.

In 2001, a new taxonomy of instructional objectives has emerged which was proposed by Anderson and Krathwohl in their book "A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives."In Bloom's taxonomy, there were 6 categories under the cognitive domain i.e. Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Except for Application, all other 5 main categories were further divided into subcategories. It was a hierarchical structure where categories were arranged from simple to complex and concrete to abstract. It was assumed that attainment of one category is a prerequisite for the next category.

In Bloom's Taxonomy of Cognitive Domain, the objective statements will find that be having two major components, like, a) Some subject matter content (A Noun or Noun phrase) b) A description of what is to be done with or to that content (A verb or verb phrase). For example, "a learner will be able to define **Photosynthesis**". In this objective statement, the noun phrase is "**Photosynthesis"** and the verb is "**define**." In the revised taxonomy, the first change is that the noun and verb dimensions are separate. The noun is providing the basis for the Knowledge dimension and the verb is forming the basis for the Cognitive Process dimension. The new knowledge dimension contains four categories i.e. factual, conceptual, procedural and metacognitive. Metacognitive Knowledge involves knowledge about cognition in general as well as awareness of and knowledge about one's cognition.

Factual Knowledge: The basic elements that learners must be acquainted with a discipline or solve problems in it, namely,

- Knowledge of terminology
- Knowledge of specific details and elements

Conceptual Knowledge: The interrelationships among the basic elements within a larger structure that enable them to function together as

- Knowledge of classifications and categories
- Knowledge of principles and generalizations
- Knowledge of theories, models, and structures

Procedural Knowledge: How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. For this the following are essential:

- Knowledge of subject-specific skills and algorithms
- Knowledge of subject-specific techniques and methods
- Knowledge of criteria for determining when to use appropriate procedures

Metacognitive Knowledge: Knowledge of cognition in general as well as awareness and knowledge of one's cognition.

- Strategic knowledge
- Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
- Self-knowledge

The "Most Important" objectives for secondary school biology teaching are expressed in terms of students behaviour, like, pupils will be able to Present major facts, principles, or fundamentals (from **Cognitive Domain**), Expresses scientific attitudes and appreciation, Identifies the nature of science and scientists, and Identifies scientific interest and career development (from **Affective Domain**) and conducts observations, survey,

experiments, preservative activities and drawing scientific diagrams (from **Psychomotor Domain).**

Now we shall have a look into the objectives confining to Cognitive Domain in general:

Remembering

Learner recalls and recognizes the facts, definitions, laws, principles and other bits of knowledge from memory. It helps the learner in understanding biological science. For helping learners to recall and recognize the names of compounds learned in biology, the teacher can provide in the class the simple root, prefixes, suffixes that can provide clues to numerous other words which will help them to learn new vocabulary.

Example:

- Identifying the missing link in organisms
- Recalling the definition of life processes
- Recognising common features of species of genera

Understanding

Learner constructs meaning in various teaching-learning situations and understands by correlating and connecting different concepts and bits of knowledge. Understanding supports logical and abstract thinking.

Example:

- Describing the digestion process
- Summarizing various steps involved in the digestion of food
- Distinguishing between mechanical and chemical digestion
- Illustrating digestion by taking an example.
- Correlate digestion and energy liberation
- Connects digestion and respiration

Applying

The learner uses facts, concepts, principles, theories and solves problems in new situations.

Example:

- Demonstrating at least one chemical test of biomolecules like glucose
- Predicting the presence of glucose in a given sample
- Application of knowledge of pest control for mosquito control at home.

Analysing

Learners see patterns, recognize the inherent meaning and identify components. At the level of analysing, the learner is in a position to compare, attribute, organize, and breaking down the content into its constituent parts.

Example:

- Comparing the structure and function of the human eye to a camera
- Comparison of good and bad cholesterol and heart diseases
- Industrialization and Environmental Pollution

Evaluating

Learners evaluate, generate, critique, judge, formulate a hypothesis of scientific concepts and plan experiments. They can justify a decision or course of action. Critical thinking is a process of analysing and evaluating information to determine its validity in a given situation. Learners should be allowed to solve problems and follow various steps in the process like gathering related data, formulating hypotheses, finding an alternate solution and choosing the best solution in the light of the given situation. These strategies of teaching-learning help teachers to achieve the learning objective of evaluating categories.

Example:

- Judging the quality of a hybrid variety of a chosen vegetable
- Developing a rationale for stem-cell therapy
- Justifying the need for technology for the benefit of society

Creating

Creating implies designing, planning, and writing, constructing, and producing through one's imagination. This has to be communicated to others. The communication may be done either through a write-up or through verbal communication in the form of a debate, discussion, etc. This can be made possible by organizing activities like presenting a poster or seminar in the class. Learners can be encouraged to present their understanding by presenting findings in the form of a Venn diagram or a flow chart.

Key Differences between Aims and Objectives
The following points are vital, so far as the difference between aim and objective is concerned:
1. The term aim is described as the ultimate goal, which an individual or the entity strives to achieve. The objective is something a person seeks to achieve.
2. The aim reflects its long-term outcomes while objectives indicate the short term targets.
3. Aim refers to the general direction or intent of an individual. On the other hand, the objective is the specific goal of an individual.
4. Aim answers the question, what is to be achieved? Unlike objective which answers, how it is to be achieved?
5. Aims are not time-bound, i.e. there is no time frame within which it must be achieved as it is hard to say accurately, how much time it will take to achieve. On the other hand, objectives are always accompanied by a time frame, within which it must be achieved.
6. Last but not least difference between these two is on measurability, i.e. objectives are measurable while aims lack measurability.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Quantifying is possible with
    a. Objectives of teaching Biology
    b. Aims of teaching Biology
    c. Students attendance in the Biology Classroom
    d. Number of students in the Biology Classroom

2. Aims of teaching Biology is achieved through
    a. Students, promotion
    b. Objectives of teaching biology
    c. Examinations
    d. Assessment of teaching-learning process

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Aim answers the question, how is to be achieved, and objective answers, what is to be achieved
    b. Objectives are available in the cognitive, affective and psychomotor domain
    c. Objectives are expressed in behavioural terms
    d. Aims are time-bound whereas objectives are not
    e. Learners also can evaluate their achievement
    f. Now people are using revised Bloom's Taxonomy of Educational Objective

1.5.4. Let us Summarise

The aims and objectives of studying biology should focus on the importance of appreciating the natural world and protecting Mother Earth. Objectives bring a firm basis for classroom teaching and Aims will take an individual to the path of transformation of one's personality. Aims are general statements concerning the overall goals, ends or intentions of teaching. Objectives are the individual stages that learners must achieve on the way to reach these goals. Aims are general, objectives are specific. There are more objectives than aims. Aims are like strategy, objectives are like tactics. Aims and objectives can form hierarchical structures so that in complex curricula aims at one level might be seen as objectives at another.

Acquisition of knowledge, understanding the scientific facts, concepts, principles and generalizations, adapting and practicing these in real-life situations, developing a scientific attitude and scientific method- appear to be the major goals and objectives of teaching biological science. Developing Truthfulness in Reporting Observations, Developing Critical Thinking, Logical Thinking, Scepticism, Creativity, Objectivity and Perseverance are also the part and parcel of aims of teaching biology. Nurturing the natural curiosity, creativity and aesthetic sense, Relating Biological Science Education to Social, Environment, Technology and Society, making students Imbibing the Values and inculcating Problem-solving skills are the other predominant aims of teaching biology.

The objectives of teaching biological science must be consistent with the aims of biological sciences. These have to be aligned with the three major components of the teaching-learning process, namely, the purpose of teaching (Objectives), teaching-learning activities (Curricular transaction), and Assessment (Evaluation). The well-balanced scheme of evaluation will help in knowing whether the pre-determined objectives are realized or not. Hence it is said that if these three components are congruent, teaching-learning is meaningful.

At the secondary school level, learners are supposed to be engaged in learning science as a composite discipline. At this stage, those concepts, which are beyond direct experience, should also be introduced and learners should make understand that all scientific phenomena are not directly observable; science also relies on inference and interpretation. Experiments must be used as an important tool to discover/verify theoretical principles at this stage. At this level, emphasis also should be to organize co-curricular activities like some small group projects on local issues and use the problem-solving approach.

1.5.5. Answers to 'Check Your Progress - 1and 2'

Check Your Progress - 1
1.c 2.d 3. a- X b- √ c- √ d- X e- √f- √

Check Your Progress - 2
1.a 2.b 3. a- X b- √c- √ d- X e- √ f- √

1.5.6. Unit end Exercises

1. What are the Aims of Teaching of Biological Science?
2. Explain the nature of the aims of teaching Biological Science.
3. What are the objectives of Teaching Biological Science?
4. Explain the salient features of the Objectives of the teaching of Biology.
5. Bring out the differences between the Aims and objectives of Teaching of Biology
6. Illustrate your answer for the Aims and objectives of Teaching of Biology.

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Block 1 : Nature and Objective of Teaching Biological Science

Unit 6 : Instructional Objectives in Biological Science

Unit Structure

1.6.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Define Instructional Objectives of teaching biological science;
- Explain the nature and importance of instructional objectives;
- Identify the instructional objectives in different domains;
- Recall the instructional objectives recommended by NCF-2005;
- Recognise the difference between Bloom's taxonomy and revised Anderson and Krathwhol's taxonomy; and
- Illustrate the instructional objectives with action verbs.

1.6.2. Introduction

Education is the greatest device in bringing out the transformation in any country. Any education is run by a well-designed curriculum and in turn, any curriculum is flourished based on its pre-determined aims and objectives. In a very simple statement, we can say that education is a process of bringing desirable changes in individuals. For this to happen most of the time classroom is the flat form. That is why it is said that classroom activities and teaching-learning processes are the gateways in achieving the aims and objectives of an educational system. Objectives are more systematic, specific, and confine to each class differently. These are constructed by the teacher for one teaching-learning period of 45 to 60 minutes of duration. Cumulatively many such lessons aggregate to form a broader unit and in turn achievement of all such instructional objectives will make the broader goal or aim as achievable. Instructional objectives cater to the cognitive domain, affective domain and psychomotor domain as well. In this unit, you will come to know about the instructional objectives catering to a different domain, Bloom's taxonomy of instructional objectives and revised version of instructional objectives also.

1.6.3. Learning Points and Learning Activities

1.6.3.1. Meaning, Nature and Importance of Instructional Objectives in Biological Science

Activity 1:

- **Ask the students to write what they see on the road while coming to school.**
- **Next day ask them to observe a few particular things and write their experience**
- **Let the students find the difference between the two experiences.**
- **Activities done with a purpose are very close to the actions/experience with objectives or purpose**

Instructional objectives are exclusively meant for students and their learning outcomes. They speak about the purpose of every activity in the classroom. They are specific, measurable, observable, short-term and modifiable learner's behaviour. Each lesson will have its instructional objective, therefore it is highly specific. Often the instructional objective is considered as a statement that will describe what the learner will be able to do after completing the instruction (Kibler, Kegla, Barker and Miles-1974).

According to Dick and Carey (1990), a performance objective is a detailed description of what students will be able to do when they complete a unit of instruction. It is also referred to as a behavioural objective or an instructional objective.

Robert Mager (1984), in his book '**Preparing Instructional Objectives',** describes an objective as "a collection of words and/or pictures and diagrams intended to let others know what you intend for your students to achieve" An objective does *not* describe what the instructor will be doing, but instead the skills, knowledge, and attitudes that the instructor will be attempting to produce in learners.

As we know that instructional objectives are constructed by teachers for their day to day lessons, they become the first and foremost elements of a lesson plan. Other than this instructional objectives are governed by certain rules. Now let us see what those rules are:

- Instructional objectives are statements expressed in the written form.
- Instructional objectives are written in simple, meaningful sentences.
- Instructional objectives are the means of achieving the Goals or Aims of Education.
- Instructional Objectives must be consistent with the Goals of Education.
- Instructional Objectives are constructed by making use of action verbs.
- Instructional Objectives must represent the learning of students in terms of behavioural changes.
- They must be unambiguous and precise without any uncertainty.
- They must provide the scope to observe, measure and modify the performs of the students.

Instructional objectives are the answers to several questions about a specific teaching-learning activity. For example, one can get answers to the following questions through instructional objectives:

- **What to Teach:** This deals with the chosen topic/subject for a class.
- **Whom to Teach:** This gives the details about the particularities of students, like, which standard, their, age, level of their maturity and their background.

- **When to Teach:** Certain topics are well suited with the seasons, (For example, Inflorescences), it could also be with the level of difficulty (For example, all the lessons are taught hierarchically-simple, easy to complex and difficult).
- **Where to Teach:** Teaching can occur even outside the classroom, isn't it? So this will explain about classroom activities, outside the classroom activities and laboratory experiments.
- **How to Teach:** This is with respect to the methodology of teaching. A teacher can adapt either lecture-cum-demonstration method, experiments, or observations of some natural phenomena or even through the problem-solving method.
- **Why Teach:** This is more significant as a teacher will have multi-dimensional answers to this question. For example, to impart knowledge, to train certain skills, to develop the personality, to develop vocational competence, to enable the students to earn their bread and butter, to impart life-skills, to make the students independent and autonomous learner, etc.

Well defined instructional objectives help in evaluation, feedback and self-assessment for both the teacher and the students also. They keep the teaching-learning process on track. These will always guard the teacher and students against going aimlessly in academic activities. How far one has achieved the pre-determined objectives, will always be an expression of their achievement, could be both qualitatively and quantitatively. Instructional objectives give clarity, precise and goal-oriented nature to the teaching-learning process. Instructional objectives must be written to communicate realistic, measurable, and learner-centered outcomes. Objective statements contain three parts, namely, **behaviour, conditions, and criteria.**

Characteristics of a Well-Written Objective

Usually, objectives began with the phrase: "Upon completion of this lesson, the student will be able to…." This phrase focused on the outcome of learning rather than on the learning process. One of the criteria for a well-written objective is that it describes the outcome of learning, that is, what the learners can do after learning has occurred that they might not have been able to do before the teaching and learning process began. A well-written objective should meet the following criteria: (1) describe a learning outcome, (2) be student-oriented, (3) be observable (or describe an observable product).The key to writing observable objectives is to use verbs/action-verbs that are observable and lead to a well-defined product of the action implied by that verb. Verbs such as "to know," "to understand," "to enjoy," "to appreciate," "to realize," and "to value" are vague and not observable. Verbs such as "to identify," "to list," "to select," "to compute," "to predict," and "to analyse" are explicit and describe observable actions or actions that lead to observable products.

Many skills cannot be directly observed. The thinking processes of studentswhile learning Mendel's di-hybrid ratio cannot be easily observed. However, one can look at the answers they come up with and determine if they are correct. It is also possible to look at the steps a student takes to arrive at an answer if they are written down (thus displaying his thinking process). Many end products also can be observed (e.g., scientific diagrams, experiments and findings, a 3-dimensional working model).

Criteria for Useful Instructional Objectives

We know that objectives are the guidelines for a teacher in executing the process of teaching-learning. Very particularly these objectives have to (i) sequentially appropriate (ii)

practically attainable with a reasonable time limit and (iii) appropriate to the developmental stages of the learners.

Sequentially appropriate: This means the objective should be per the content to be taught. And also, all the earlier objectives must have already been achieved. Guarantee of this aspect is very important because nothing will thwart the learners in the process of learning. This could be checked by the systematic, continuous and comprehensive evaluation.

Practically attainable with a reasonable time limit: Objectives show time-bound nature. Therefore, if an instructional objective takes students an inordinately long time to achieve, then, it is either sequentially inappropriate or it is too broad, having a dependency of the accomplishment of several outcomes linked together. An objective should set the learning situations for a single learning outcome and not a cluster or cumulative outcome.

Appropriate to the developmental stages of the learners: This criterion is about the developmental stages and the respective developmental tasks of the students. Hence instructional objectives must be well within the corresponding level of intellectual, social, language and moral development. The contributions from Jean Piaget, Bruner (Cognitive Development) Erick Erickson (Social Development), Lev Vygotsky (Language Development and Lawrence Kohlberg (Moral Development) are very significant in this direction. Therefore teachers should acquire knowledge by studying these great works. For the construction of instructional objectives, such academic background becomes very essential.

Check Your Progress - 1

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. 'Preparing Instructional Objectives' the book was written by
    a. Robert Gagne
    b. Robert Hook
    c. Robert Mager
    d. Robert Krathwhol

2. Objective statements contain three parts, namely,
    a. Behaviour, conditions, and criteria.
    b. Teaching, learning and assessment
    c. Cognitive domain, affective domain and psychomotor domain
    d. Teacher, student and the subject

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Instructional objectives must be sequentially appropriate
    b. 'understand' term could be very well used in writing instructional objectives
    c. Only observable and measurable behavioural terms have to be used in instructional objectives
    d. Instructional objectives give the idea about how to teach
    e. Instructional objectives are written by teachers for the sake of students
    f. Instructional objectives form a strong basis for evaluation

1.6.3.2. Instructional objectives in different Domains

Activity 2: Ask the students to list the objectives under a cognitive, affective and psychomotor domain. Take these as the basis for the explanation of the present teaching-learning activity.

All-round development being the whole aim of the educational system, the three domains of a personality, namely, cognitive domain, affective domain and psychomotor domain occupy the pivotal position in the teaching-learning process. Hence each domain is designed with specific instructional objectives. In turn, instructional objectives are classified. There are numerous taxonomies of instructional objectives; the most common taxonomy was developed by Benjamin Bloom and his colleagues. The first level of the taxonomy divides objectives into three categories: cognitive, affective, and psychomotor. The instructional objectives confining to the use of intellectual power grouped under a cognitive domain. For example, Recall, Recognise, memorise, analysis, synthesis, comparing, problem-solving and evaluation are the learning outcome coming under a cognitive domain.

Affective objectives focus on emotions. Development of attitude, values, interest and commitment, accepting responsibilities, being duty conscious are the behavioural changes as learning outcome under the affective domain. Likewise, Psychomotor objectives focus on the performances, maybe, control or manipulation of the muscular-skeletal system. For example, drawing, sketching the scientific figures, writing, setting up the apparatus for experiments and conducting experiments, handling the equipment and taking the reading – all such skills requiring fine or gross motor coordination fall into the psychomotor category. To learn a motor skill requires some cognition. After the mastery learning skills are performed automatically and there again and again cognition may not be needed for the same type of task.

Blooms Taxonomy of Educational Objectives

The word taxonomy is derived from the Greek word ‘taxis’ which means systematic classification. Benjamin S Bloom and his associate, the University of Chicago developed and classified the domains of educational objectives. Bloom (1956) presented his taxonomy related to the cognitive domain emphasizing the hierarchy of cognitive process in attaining knowledge and development of thinking. Later Krathwhol (1964) introduced the affective domain and Simpson (1966) developed psychomotor domain. They described the hierarchical development of the three domains of the learner through instruction. This classification objective is known as Bloom's taxonomy of educational objectives. According to Bloom and et al, the cognitive domain includes the knowledge field, the affective domain includes the feeling field and the psychomotor domain includes the doing field. Every educational activity should be planned to develop all this domain of the learner. Hence these three domains are mutually interrelated and interdependent also.

Instructional Objectives in Cognitive Domain

The cognitive domain deals with the intellectual aspect of cognition. It is concerned with sensation, perception and application of knowledge. The hierarchical development of the cognitive domain is discussed below.

Knowledge

Acquisition of knowledge is the lowest level in the cognitive domain. It includes the ability of students to recall and remember the information learned in the classrooms. Recall and recognition are the specifications of this instructional objective.

Comprehension

It is the second level of the cognitive domain. It is the meaningful recall and recognition of the learned content. Here the learner could understand and explain what he learned in the classroom as his language. Identifying relations, classification of objects, explanations, comparisons, translation, etc. are the specification of this level.

Application

In the third level, the learners can apply or use the knowledge which is acquired and comprehended during the first two levels. It is the ability to apply the acquired knowledge through instruction in real-life situations. Establishing new relationships, formulating a hypothesis, predictions are some specifications of this level.

Analysis

An analysis is the meaningful breakdown of the materials into their various components and to identify the interrelationship between the elements and find out how they are organized and related. Specification of this level includes the analysis of elements, analysis of the relationship, analysis of organizational principles.

Synthesis

Synthesis is the mental ability of the learner to integrate the acquired, comprehended, applied and analysed knowledge into a comprehensive whole. It involves the ability to give a new shape or structure to statements or procedures.

Evaluation

This is the highest level of the cognitive domain. Students could evaluate an object, person, a theory or a principle if only he is par with all other lower hierarchy in the cognitive domain. It is the ability to judge the value of a material, aspects, methods, principles, theory, philosophy and so forth for a given purpose. At this level, learners could perform personal viewpoints about the information they have synthesized.

Instructional Objectives in Affective Domain

The affective domain is related to the development of the heart and mind of the child. It includes the areas of emotions, feelings, interest, attitude, appreciation and values. The teacher should be emphasized to correlate the development of the cognitive domain with the affective domain. A person who studied the Gandhian principles, civic rights and duties without developing his affective domain are worthless for the country as well as society. Hence the teacher should ensure the development of the affective domain in his instructional objectives of the classroom instruction. Bloom and Krathwohl (1964) introduced the following hierarchy for the affective domain. “Live and let Live” principle is the best example in the subject biology, wherein the ability in the affective domain makes one’s life more meaningful and grateful.

Receiving

At the basic level, the learner is sensitized to the existence of a certain phenomenon and stimuli. S/he is willing to receive the information wholeheartedly by exhibiting awareness

of the stimuli and become conscious of a particular person, principle, philosophy, incidents, etc. For example, students are interestingly participating in preservative activities in a Botany Class.

Responding

Effective reception prepares the learner to respond seriously. As a result of receiving some good messages from the first hierarchy, the learner tries to respond to the situation positively. For example, students show a keen interest in growing Orchids, succulent plants or some show plants in their school garden, etc.

Valuing

By responding in good ways, the students set guidelines for their behaviour. Accepting values, preference for values, commitment to values are the important behavioural changes at this level. For example, students develop a positive attitude towards the environment and commitment to several conservative activities concerning natural resources.

Organization

Student builds a system of value at this level. Value conflict and value crisis are resolved. Through organizing different values students can develop their code of conduct and standard of public life in society. For example, Pupil identifies the difference between "Need" and "Want". The use of plastics, pesticides, and organic treatment for plants are expressed according to the wise rationale.

Characterization

This is the highest level of the internalization process. Values are imbibed and form part of the lifestyle of the individual. For example, students will not be ready to compromise with the quality of the environment for the sake of some short-term benefits.

Instructional Objective for Psychomotor Domain

Psychomotor domain deals with the action or performance level. This domain includes muscular action and neuromuscular coordination. Educational objectives of this domain aim to develop proficiency in performing certain acts. Simpson (1966) presented the psychomotor domain as follows.

Perception

Perception is the first level in the psychomotor domain. It consists of the process of becoming aware of objects, qualities or relations through sense organs.

Set

In this second hierarchy, students make preparatory adjustment of readiness for a particular kind of action or experience. The mental, as well as the physical setting for action, is performed here.

Guided response

It is the overt behavioural act of a student under the guidance of the teacher. Students initially perform an act that is perceived and set through earlier levels. It includes imitation of teachers, elders, parents, and trial and error activities in attaining writing, reading skills etc. For example; the Student imitates the drawing style of his teacher to draw the Transverse Section of the stem.

Mechanism

At this level, students show progress in performing the act through imitation, trial and error. The student learns to mount a temporary slide of T.S. of Stem to observe it under a compound microscope imitating his teacher and through trial and error activity. Here learned response has become habitual. It is a microanalysis in which each step in the mechanism is properly examined and drilled.

Complex Overt Response

At this level, the student can perform a complex motor act that required a complex movement pattern. In this hierarchy, students attain a high degree of skill and the act can be carried out smoothly and efficiently. At this level, students could perform the act without any hesitation. Fine muscular coordination and a great deal of ease in performing acts are the peculiarities of this level. Here students can write many diagrams and words easily and simply within a short time. The ability to run, walk, jump and talk easily also comes under this category.

Adaptation and Originating

This is the highest level. Here the student is adapted with the ability to do an act which is acquired through the above steps. Now spontaneously learners can perform the act with accuracy. Moreover, learners can originate a new pattern of action or style in doing the activity.

Dave Classification-Psychomotor Domain

Dave (1969), from NCERT also contributed taxonomy for the psychomotor domain which is discussed below.

Imitation

It is simply an imitation act of a student who is energized through cognitive as well as affective domain development. It means that the student who learned how to write (cognitive domain), willing to write (affective domain) may imitate to write to get the ability to write (psychomotor domain).

Manipulation

This level student tries to do the imitated activity in various ways through repetition. Here students try many ways and styles to perform the activity and select an appropriate one that is suitable and convenient for them.

Precision

In this level, students attain speed, accuracy, proportion, exactness, neatness in performing the act which is acquired through the above two levels.

Articulation

Here the student able to handle many actions in unison. This includes coordination, sequence and harmony among acts.

Naturalization

This is the highest level in the psychomotor domain. Here student attains proficiency in performing a particular task. The action becomes automatic with the least physical as well as mental energy.

Check Your Progress - 2

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. The instructional objective at Valuing comes under
    a. Psychomotor domain
    b. Affective domain
    c. Cognitive domain
    d. Psycho-social domain

2. Bloom presented his taxonomy related to the cognitive domain in
    a. 1964
    b. 1956
    c. 1969
    d. 1959

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Articulation includes coordination, sequence and harmony among acts.
    b. Acquisition of knowledge is the lowest level in the cognitive domain
    c. NCERT has prescribed the instructional objectives as proposed by Bloom
    d. Dave (1969) contributed taxonomy for the psychomotor domain
    e. Precision is the highest level of instructional objective in the psychomotor domain
    f. Manipulation means altering the obtained data

1.6.3.3. Application of Instructional Objectives in the Teaching of Biological Science

Activity 3: Allow the students to choose the topic of their choice in Biology and construct the instructional objective according to NCERT guidelines

Instructional objectives are constructed by the teachers while planning their lesson plans. Robert Gagne believes that effective teachers first learn to categorize their instructional objectives and then develop the teaching-learning activities that will help students do the kind of thinking required for that kind of learning.

As discussed earlier, classroom instruction needs an effective instructional plan to achieve fruitful results. Classroom coursework is wholly dependent on the instructional objectives of the lesson plan. A lesson plan is a meticulous intellectual plan with ideas aiming at the cognitive, affective and psychomotor development of the child through teaching the concerned subject. Each domain has its objective and each objective has its specific objectives. Specific objectives are written generally in the form of an action verb. To understand the writing of instructional objectives and specific objectives see the following example.

As a biology teacher, you have to formulate learning objectives in statement forms and also keep in mind that they should be achievable. Robert Mager (1997) has identified three important characteristics of an instructional objective as, specific learning outcome (performance), circumstances under which learning occurs (condition), and an element that specifies a level of proficiency (criterion).To understand the writing of instructional objectives and specific objectives see the following example.

Objective: Learners will be able to understand the phenomenon of Respiration

In the above objective the term "understand" lacks clarity and also it does not give any idea about how learners will tell you what they know. Terms that are not clearly stating "action" should be avoided. Many such terms as "understand, know, appreciate, comprehend, learn, recognize" should be avoided while stating an instructional objective.

Objective (Modified):
Learners will be able to define Respiration
Learners will be able to explain the process of Respiration
Learners will be able to describe Respiration in animals

Instructional objectives are the specific or immediate outcome as a result of an instruction. Hence it should be designed in such a manner that it shows what the students will be able to recall or perform after the completion of classroom coursework. It describes the progressive changes in the cognitive, affective and psychomotor domain in terms of Knowledge, comprehension, applications, skills, appreciation and so forth. But the problem that arises, in this case, is that, how could a teacher understand whether the student gains any knowledge, able to apply the information he has received from the classroom interaction. It requires the presence of specification or specific objectives. Specifications are the observable and measurable changes in the behaviour of the learner. It tells us what the pupil will do or how they behave if they realize an objective. Hence it is the behavioural changes showed by the students which can be observable and measurable by the teacher is called Instructional/behavioural objectives.

NCERT has worked and adapted the blooms' taxonomy with some modifications to suit with Indian situation. It has mentioned the cognitive, affective and psychomotor domains with their instructional objectives as well as specification.In the cognitive domain, NCERT listed the Knowledge, Comprehension and application. But it merged the analysis, synthesis and evaluation into application objectives. Development of psychomotor domain intended by the development of skills related to the concerned subject. It may be drawing, locating, observing, experimentation, drama, and so on. Affective domain indicates the student appreciation of personalities, events, culture, tradition and good deeds of individuals, etc. it also indicates the development of interest among the student to learn more related to subject by further reading, conducting interviews, preparation of the album, bulletin boards, projects, etc. NCERT also gave an important place to develop a positive attitude among students towards constructive persons, events, and programmes which may bring world peace, Social welfare, economic as well as national development and vice versa.

Following are the Action verbs at the knowledge level:

At the knowledge level, State, define, explain, identify, relate, list, recall, recognise, name, mention, give examples, illustrate, etc. are Action Verbs that are useful to formulate instructional objectives. Now let us take a few topics and see how instructional objectives are constructed:

Topic: Ecology
Instructional Objectives:

- The student will be able to identify the different component of an ecosystem
- The student will be able to explain the interrelationship between biotic and abiotic components of an ecosystem

- The student will be able to evaluate the quality of the environment by the richness of biodiversity

Topic: Cell
Instructional Objectives:
The student will be able to

- Define cell
- Explain the functions of the cell membrane
- Identify the cell organelles
- Differentiate membranous and non-membranous cell organelles

Action Verbs at Comprehension/Understanding Level:

Comprehension is the ability to grasp or construct meaning from material. Comprehension could be overtly seen through the following action verbs and these are the representation of the internalized knowledge.

Define (in own words), locate, report, recognise, recall, express, discuss, review, infer, conclude, illustrate, interpret, draw, represent differentiate, distinguish, compare and contrast, etc. Apart from this comprehension as a whole is made up of the following process with the behavioral expression:

- **Translation:** which involves the ability to understand literal messages across communication forms, changing what is known from one form of communication to another e.g. from words to numbers, graphs, maps, charts, cartoons, pictures, formulas, symbols, models, equations etc.
  For example, the number of stomata on the upper and lower epidermis are expressed and compared in a diagram.

- **Interpretation:** which goes beyond mere literal translation to the identification of interrelationships among parts and components of communication and interpreting and relating these to the main components
  For example, the number of stomata in hydrophytes and xerophytes and interpreting the type of plants

- **Extrapolation**: which involves the ability to draw implications and ability to identify and continue a trend, isolate or detect consequences, suggest possible meaning and estimate the possible effect.
  For example, constructing more number of Bore wells, Stay-home and Resorts in Kodagu (Coorg) and the natural disaster occurring is explained.

Action Verbs at Application Level:

At this level, the students are supposed to apply the knowledge that they have already learned in new or novel situations. It may include some modifications in what they have learned already and apply also. Hence here the action verbs are intellectually at a higher level. Apply, relate, develop, utilize, operate, organise, translate and restructure, interpret, infer, demonstrate, illustrate, exhibit and problem-solving are some of the action verbs at this hierarchical level.

Action Verbs at Analysis Level:

An analysis is the breaking down of the whole into its constituent parts or elements to establish the relationship or make the relations between ideas expressed to be clear or explicit. Analyse, compare and contrast, inquire, distinguish and differentiate, examine, classify, detect, deduce, experiment, inspect, dissect, discriminate, separate, scrutinize and discover are some of the action verbs at this hierarchical level. An analysis is made up of the following components:

- **Analysis of Elements:** It deals with the identification of the internal components of a whole, for example, Environment, is made up of biotic and abiotic components. In biotic factors-there are plants, animals and microbes. Likewise, in abiotic factors, there are soil, water, atmospheric pressure, sunlight, humidity, temperature, etc.

- **Analysis of Relationship:** It deals with the behaviour which will try to determine how the elements identified are related to each other? For instance, knowing about how biotic and abiotic factors interact with each other in the environment. How they get influenced by each other etc.

- **Analysis of Organizational Principles:** It deals with the behaviour which will try to determine the principles or system of organization which holds the different elements and parts together? It involves finding the pattern, the structure, systematic arrangements, point of view, etc.

Action Verbs at Synthesis Level:

Contrary to analysis which involves breaking down of a whole, synthesisis building up or putting together elements is processed. Synthesis is concerned with the ability to put parts of knowledge together to form new knowledge. Parts, pieces and components are clubbed together to form a unique whole or to constitute a new form, plan, pattern, or structure. It involves designing a whole, creative output, solving a problem, developing new material, etc. Synthesis is the ability to put the different parts together to form or integrate into a coherent or unique new whole. Plan, compose, produce, design, assemble, invent, collect, summarise, arrange, construct, formulate, prepare, modify, rectify, generalize, organise and derive are some of the action verbs of this hierarchical level.

Synthesis can be subdivided into the following categories:

- **Production of unique communication:** which is concerned with the ability to put together in a unique organizational form a piece of written or oral communication to convey a novel idea, feeling or experience

- **Production of a plan or proposed set of operations:** This is concerned with the ability to develop a plan or propose a course of action, procedures for solving a problem or negotiating with others.

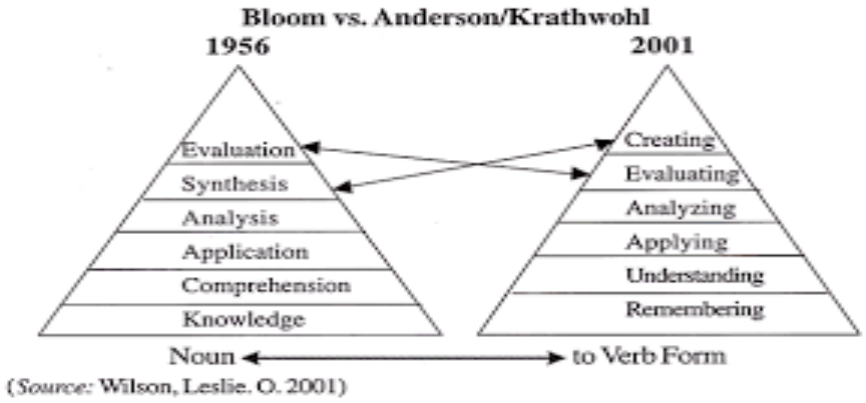
- **Derivation of a set of Abstract Relation:** This is an action based on the result of analysis of experimental data, observation. It deals with generalizations, deductions, predictions or relationships based on the classification of experiences or observations.

Action Verbs at Evaluation Level:

It is the topmost level in the hierarchy in the cognitive domain. It includes the learners' ability to organize his thought and knowledge to reach a logical and rational decision that is defendable. It deals with making a quantitative or qualitative judgment about a piece of communication, a procedure, a method, a proposal, a plan etc. Based on certain internal or external criteria alternatives abound, choice depends on the result of judgment which we make consciously or unconsciously based on values we held. Evaluation is the most complex of human cognitive behaviour. It embodies elements of the other five categories, namely, knowledge, comprehension, analysis and synthesis. Evaluation is the ability to judge, check, and even critique the value of material for a given purpose. Judge, assess, evaluate, compare, measure, deduce, argue, decide, choose, select, estimate, validate, appraise, criticize, infer, rate and conclude are some of the action verbs at this hierarchical level. Evaluation is made up of (i) Judgement in terms of Internal Criteria and (ii) Judgement in terms of External Criteria.

Revised B.S. Bloom Taxonomy of Instructional objectives

Anderson and Krathwohl in the year 1995-2000 revised the taxonomy of instructional objectives previously propounded by Bloom. In the following figure, a visual comparison of instructional objectives provided by Bloom and Anderson & Krathwohl is displayed. You just observe and try to analyse. The one on the left, entitled Bloom's, is based on the original work of Benjamin Bloom and et al., as they attempted in 1956 to define the functions of thought, coming to know, or cognition.



(*Source:* Wilson, Leslie. O. 2001)

Visual comparison of the two taxonomies

The primary differences are not just in the listings or rewordings from nouns to verbs, or in the renaming of some of the components, or even in the repositioning of the last two categories. The major differences in the updated version are in the more useful and comprehensive additions of how the taxonomy intersects and acts upon different types and levels of knowledge factual, conceptual, procedural and meta-cognitive.

Why are well-written learning outcomes important?

Learning outcomes are produced by the teaching-learning activities which are in turn based on Instructional Objectives. They become so important from different points of view. Some of them are presented below:

- Student learning outcomes clarify faculty expectations for what students should know, understand, be able to do, and value by the time they complete the program.

- They help shift discussions about the curriculum away from "coverage of topics" to the improvement of student learning.
- Student learning outcomes at the course level can act as a guide for class activities, assignments, and exams.
- Assessment of student learning outcomes can provide information to students on their strengths and weaknesses with learning outcomes.
- Assessment of student learning outcomes can provide information for the improvement of educational programs and for demonstrating their effectiveness.

Check Your Progress - 3

The questions given below are followed by multiple answers, put √ mark for the correct answer:

1. Instructional Objectives are confined to
    a. Specific classroom activities
    b. Educational programme
    c. Curricular activities
    d. Assessment activities

2. Instructional objectives are also known as
    a. Educational goals
    b. General objectives
    c. Purpose of learning
    d. Specific objectives

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. Assessment of student learning outcomes will not help for the improvement of educational programs
    b. Revised Taxonomy of Instructional Objective is just replacement of noun by verbs
    c. Evaluation is the highest objective of human behaviour
    d. Evaluation is done by taking the judgement of Internal Criteria only
    e. In the Indian context, Application includes analysis, synthesis and evaluation
    f. Terms which are not clearly stating “action” should be avoided in instructional objectives

1.6.4. Let us Summarise

Instructional objectives are exclusively meant for students and their learning outcomes. They are specific, measurable, observable, short-term and modifiable learner’s behaviour. Often the instructional objective is considered as a statement that will describe what the learner will be able to do after completing the instruction. Instructional objectives are specific guidelines for the teaching-learning process of a stipulated time, maybe 45 to 60 minutes of classroom activities. Well written instructional objectives are answers to questions like, what to teach, where, whom, when, why and how to teach.

Instructional objectives are always written in behavioural terms which are nothing but the learning outcomes. Hence these are devoid of ambiguous statements, uncertainty and confusion. Good instructional objectives are precise, brief, to the point, meaningful with all clarity. They are specific, simple and will have a single action verb regarding the chosen content. Instructional objectives have been dispersed into the three domains of the human personality, namely, cognitive domain, affective domain and psychomotor domain. Benjamin S Bloom (1956) and his associate, University of Chicago developed and classified

the domains of educational objectives. Later Krathwhol (1964) introduced the affective domain and Simpson (1966) developed psychomotor domain. The cognitive domain deals with the intellectual aspect of cognition. It is concerned with sensation, perception and application of knowledge. Knowledge, comprehension/understanding, application, analysis, synthesis and evaluation are the sequential and the hierarchical levels of instructional objectives in the cognitive domain as proposed by Benjamin. S. Bloom. Receiving, responding, valuing, organization and characterization are the hierarchical levels in instructional objectives of the affective domain. And in the psychomotor domain, imitation, manipulation, precision, articulation and naturalization are the hierarchical instructional objectives.

NCERT has worked and adapted the blooms' taxonomy with some modifications to suit with Indian situation.In the cognitive domain, NCERT listed the Knowledge, Comprehension and application. But it merged the analysis, synthesis and evaluation into application objectives. Development of psychomotor domain intended by the development of skills related to the concerned subject. Affective domain indicates the student appreciation of personalities, events, culture, tradition and good deeds of individuals. NCERT also gave an important place to develop a positive attitude among students towards constructive persons, events, and programmes which may bring world peace, Social welfare, economic as well as national development and vice versa. Anderson and Krathwohl in the year 1995-2000 revised the taxonomy of instructional objectives previously propounded by Bloom.The revised instructional objectives show the expression shift from Noun to Action Verbs which are supposed to be used as learning outcomes in behavioural terms.

1.6.5. Answers to 'Check Your Progress-1, 2 and 3'

Check Your Progress - 1
1. c 2. a 3.a- √ b- X c- √ d- √ e- √ f- √

Check Your Progress - 2
1. b 2. b3.a- √ b- √ c- X d- √ e- X f- X

Check Your Progress - 3
1. a 2. d 3.a- X b- X c- √ d- X e- √ f- √

1.6.6. Unit end Exercises

1. What are the Instructional Objectives of teaching biological science?
2. Explain the nature and importance of instructional objectives.
3. What are the instructional objectives in different domains? Give examples.
4. Distinguish between Bloom's taxonomy and revised Anderson and Krathwhol's taxonomy
5. Illustrate the instructional objectives for action verbs with examples.
6. Explain the classification of the cognitive domain as envisaged by Bloom.
7. With suitable examples explain the instructional objectives as recommended in NCF 2005.
8. Represent the differences between the taxonomy proposed by Bloom and Anderson & Krathwhol with a neat diagram.

1.6.7. References

1. https://www.wku.edu/ste/objectives/definition_and_rationale.php
2. https://education.stateuniversity.com/pages/2098/Instructional-Objectives.html
3. https://ctl.tedu.edu.tr/sites/default/files/content_files/docs/instructional_objectives.pdf
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5. NCF 2005 NC

Block 2 : Approaches and Strategies of Learning Biology

Unit 1 : Process of Learning through Observation, Inquiry, Hypothesis, Experimentation, Collection, Interpretation and Generalization (Taking Suitable Example from Living World and related areas in an age as well as stage Appropriate Manner)

Unit Structure

2.1.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- After studying this unit you will be able to;
- Identify observation as one of the Science Process Skills;
- Distinguish between "just seeing" and "observation;"
- Recognise the scientific features of observation;
- Apply the skill of observation in studying biological concepts;
- Utilise the Inquiry technique in learning Biology;
- Experiment and draw generalization; and
- Describe the role of Observation, Inquiry and Experimentation in learning Biology.

2.1.2. Introduction

You all know that observation is a very basic requirement for any learning. Isn't it? Looking, seeing and observation at a gross level do the same function but there is a strong difference among them. Now let us take an example so that it will become clear to you. Suppose you have entered a class suddenly and realised later that it is not where you are supposed to attend classes. So soon you will come out of the class. If anybody asks, like, "What did you see?" your answer would be,

"It is a class but not of mine
Because there were more boys and fewer girls
All of them were waiting for their teacher".

This interaction explains only ‘seeing’ or ‘looking’ at an event/incident.

If the questions were asked like,
“How many girls were there?
How many boys were there?
What were they doing?
Was the class noisy?
Was it a classroom-cum-laboratory? If so, what experiment was going on?”

For such questions just seeing/looking is not enough. For that, you need to observe and give the answer. So in this unit, you will come to know about the salient features of Observation, and how it is linked with the learning of Biology.

2.1.3. Learning Points and Learning Activities

2.1.3.1. Learning through Observation

Activity 1

In the subject of Biology, there is ample scope for utilization of observation skills. For example, the concepts, like, locomotion, seed germination, heartbeat, heredity, hybrid varieties, etc. You can ask students to make their observations and prepare a report on the topics like,

How do we move while climbing and getting down from a hill? How is our body posture?

How do a Centipede and a Millipede move? What are the similarities and differences you observe in their locomotion?

How does an Earthworm contribute to soil fertility?

Do plants move? If so illustrate it. (Sunflower plant for Photo-tropism, Touch-me-not plant for Thigmotropism and roots t showing Hydrotropism)

Observation is not simply a process of looking or seeing but it involves the use of all senses and analysis of the obtained stimuli in mind. Observation needs attention, perception and concentration. For this visual, auditory, olfactory and even sometimes taste and touch sensory organs are involved. We call it a keen observation. Observation is one of the most fundamental Science Process Skills. It is fundamental to all scientific activities and scientific endeavours like researches. It will be the supporting pillar for the construction of hypotheses in any discovery or invention. And in turn, this will lead to the experimental planning and real execution of the experiments.

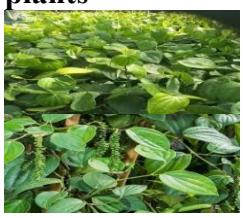
It is common to observe that young children learn so many things by gathering evidence, organising their ideas and trying to explain the world according to their perceptions and perspectives. For their any inquiry, observation becomes the cornerstone. We take the reference of some organisations which have laid certain steps to foster the skill of observation among children.

According to the National Research Council (NRC) 1996, students in the earliest grades should be expected to use simple tools, like magnifiers, thermometers and rulers to gather data and learn about what constitutes evidence. For example: let the children grow some of the common plants in their classroom laboratory garden. To compare the impact of organic fertilizers and the chemical fertilizer let them design the learning process in the following manner.

Sl. NO.	**Plants**	**Information on the rate of growth using length, branches, number of buds, leaves, flowers, fruits, etc.**	
		Use of organic fertilizer/Vermicomposting	**Use of Chemical Fertilizers**
1.	Tomato 		
2.	 Brinjal		
3.	 Rose		
4.	 Hibiscus		

Now ask the students to draw some inferences based on their observations on collected data and data analysis.

Give different species of the same genera in plants and ask the students to find the similarities and differences (for secondary school children)

Sl. No.	Plants	Similarities	Differences
1.	**Mirabilis jalapa** 		
2.	**Vincarosea** 		
3.	**Beetle and Pepper plants** 		
4.	**Chrysanthemum** 		

In the view of the American Association for the Advancement of Sciences (AAAS) (1989) Science teaching is consistent with the nature of scientific inquiry and shows the following features:

- Encourage students' activity, with varied opportunities for collecting, sorting and cataloging data.
- Provides opportunities for observing, note-taking, sketching, interviewing, surveying and using hand lenses, microscopes, thermometers, cameras and other common instruments.
- Encourage students to collect and use evidence, proofs, and documents.

For the aforesaid things to happen, teachers should give problems that are appropriate to the age, maturity and interest of the children. The problems provided must be in such a way that children should inevitably do a careful observation and thoughtful analysis.

Since observation is distinguished from just seeing or looking it has certain salient features also and they could be listed as follows: Observation is

- Purposive
- Systematic and objective
- Demands focused attention
- Demands alertness and carefulness
- Goal-oriented or need-based
- Access to measuring and quantify
- Factual
- Access to data collection, analysis of data, drawing generalization or inference

Check Your Progress - 1

The questions given below are followed by multiple answers, put (√) mark for the correct answer:

1. Observation is
    a. Seeing objects
    b. Looking at events
    c. Gazing at something
    d. One of the science process skills

2. Similarities and differences between any two species are obtained by
    a. Observation
    b. Experimentation
    c. Textbook reading
    d. Teacher's explanation

3. Below are given some statements, put (√) mark for the correct ones and (X) for the wrong ones:
    a. Observation does not need focused attention
    b. Observation is one of the essential activities in science learning
    c. Biology being a descriptive subject much depends upon observation
    d. Lack of observation skill will be a serious drawback in science learning
    e. Observation is a goal-oriented or need-based activity
    f. Small children cannot use observation skill for their learning

2.1.3.2. Learning through Inquiry

Activity 2: Show some reference or give activity so that, students will inevitably do inquiry, Example: Ask students to observe living things in a small area near their school/home. Let them write whatever they see and classify or group them. After this ask them the following questions:

- Why have you put the plants and animals in separate groups?
- What was the basis for putting plants in different groups?
- What was the basis for putting animals in different groups?

Discuss the meaning, nature and importance of classification.

Activity 3: The teacher can ask the following questions to a group of students that triggers the skill of inquiry in them:

- Why are Blue-Green Algae grouped under kingdom Monera along with Bacteria?
- Why Earthworms are called 'Farmer's Friends'?
- What is the secret/mystery behind the Bermuda Triangle?
- Why is the name 'Electric Ray' for a fish?

It is observed that in the 21st-century Inquiry-based learning is gaining a lot of prominence as constructivist teaching and its application is more effective through inquiry-based learning. Teaching must inculcate critical thinking among students. You know that teaching is a system in which various components are working together to produce quality learning. Planning for learning must begin well in advance with the development of teaching materials, encouraging them to interact with the environment and practice their thinking skills. To develop and transform a learner into a scientifically literate citizen and as envisaged in National Policy on Education 1986 and National Curriculum Framework (NCF) 2005, there is an imperative need for the learner to,

- Understand and apply the basic concepts of science
- Learn scientific inquiry skills of gathering information
- Develop desirable attitudes, values and appreciation for truth and objectivity
- Learn scientific method and apply it in solving problems and taking decisions to improve everyday living and environmental conditions and
- Promote development and use of technology

When a teacher adapts the inquiry approach to teach biological concepts, definitely it will be a replacement of conventional content-driven courses. The inquiry approach is devoted to building authentic research skills, through open-ended experiments. A teacher may include activities like, identifying the content/concepts/learning points in terms of a problem, and allowing students to construct hypotheses, testing hypotheses, analysing data, interpreting results, writing in disciplinary styles and working in teams, etc., In all these activities, reading of literature, reviews, critical study of earlier scientific reports, etc. will be parts and parcels of the main activity so that students build their own knowledge and skills through investigation of real-world problems (for example, pandemic, epidemic and endemic diseases). The goals of biological inquiries are to develop core scientific competencies (Association of American Medical Colleges, AAMC & Howard Hughes Medical Institute, HHMI 2009).

An inquiry is a need-based activity of raising questions to get some information. It is a process of asking about or investigating something to find out more about it. It is also a systematic investigation, an examination to get the facts or principles. There is ample scope in the subject of Biology to conduct the inquiry, which includes investigations.

In simple terms, the steps in inquiry include

1. A preliminary Activity
2. Teachers initiation/motivation for students
3. Research questions, Inquiry design
4. Sample Data, Data Collection,
5. Data analysis and Result Finding.

An inquiry approach is well suited for most of the topics like membrane permeability, osmosis, cellular respiration in yeast, plant respiration and its rate, photosynthesis, respiration in germinating seeds, water PH, soil PH, acid rain, factors that affect the heart rate, regulation of body heat, blood pressure, etc.

Now let us have a look at a model of inquiry approach suggested by NCERT Science (Class IX)

Sl. No.	Theme/ Sub-Theme	Questions	Key-Concepts	Resources	Activities/ Processes
1	**Health/How do we fall Sick?**	I. What are the various causes of diseases? ii. How diseases are prevented? Iii. How can we remain healthy?	Health and its failure, Disease and its causes, Disease caused by microbes, Prevention of typhoid, diarrhea, malaria, hepatitis, rabies, AIDS, TB, Polio, and Pulse-polio programme.	Articles in scientific journals, newspapers, information from health centres, photographs of various causal organisms, permanent slides of bacteria and photographs	Conducting the survey, Data collection (neighbourhood) on disease, occurrence pattern, studying the life cycle of the mosquito and malarial parasite. Discussion on how malaria is spread and how to prevent mosquito breeding. (10 periods)
2	**Heat and Temperature-Material on our Clothing**	What kinds of clothes help us keep cool? Why do wet clothes feel cool?	Cooling by evaporation Absorption of Heat	Glassware, heat source, black paper, thermometers	Experiments to show cooling by evaporation, Experiments to show white objects get less hot Experiments to show black objects absorb heat. (5 periods)
3	**Food-Higher Yields**	What do we do to get higher yields on our farms?	Use of fertilizers, manures, protection from pests, diseases, organic farming	Visit any fish/bee/dairy/ pig farms-data showing harmful effects of insecticides Process for the preparation of compost and vermicomposting	Weed collection in different crops, diseased crops, discussion on vermicomposting (8 periods)

Check Your Progress - 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Inquiry needs a
    a. Questioning mind
    b. Humble mind
    c. Obedient mind
    d. Pursuing mind

2. There is a strong correlation between Inquiry and
    a. Experiment
    b. Investigation
    c. Enquiry
    d. Substantiations

3. Below are given some statements. Use (√) mark for the correct ones and (X) for the wrong ones:
    a. The inquiry approach is a good substitute for the Conventional method of teaching
    b. Inquiry approach of teaching does not support Experiments in Biology
    c. Inquiry approach of teaching is not advocated in National Policy on Education
    d. Open-ended questions favour inquiry approach
    e. Constructivism is more nurtured by the inquiry approach

2.1.3.3. Learning through Experimentation and Drawing Generalization

Activity 4: Give the students mustard, pepper and papaya seeds. Ask them to identify the plants of these seeds. Ask them to find out to which group these plants belong to, as dicot or monocot. All of them look like monocot seeds/plants only. But actually, they are not. For this, the students can try to find out by cutting the seeds, sow the seeds to get the plants, observe the plants meticulously for about 15 to 20 days, and find the pattern of leaves and type of root system. Then only they can identify which seed has given rise to which plant.

Biology being one of the branches of science needs certain skills to be utilized during learning. Which are called, **"Science Process Skills".**Hypotheses construction, Experimentation, data collection, data analysis and drawing the inference and generalization - all these are the sequential steps in scientific study.

An experiment is a procedure carried out to support, refute, or validate a hypothesis. Experiments provide insight into the cause of effect by demonstrating what outcome occurs when a particular factor is manipulated. Experiments typically include controls, which are designed to minimize the effects of variables other than the single independent variable. One must be familiar with certain terms that are used in an experimental setup, like, variables and their types, hypotheses, inference and generalizations.

What are the variables?

Variables are something that can change, and that they are not constant. Variables have an inevitable reference in experiments. Example: temperature, pressure, presence or absence of some ingredients/salts or substances that can alter the process. Injecting steroids or some hormones by which the growth rate of an organism could be altered. Here, the steroids or hormone as well as growth rate - all these are variables. The types of variables are (a) Dependent variable, (b) Independent variable, (c) Intervening variable or Moderator variable, and (d) Control variable.

What is a hypothesis?

A Hypothesis is an intellectual guess, a tentative solution. Formulating hypotheses is one of the important steps for conducting scientific research or experiment. An experiment is testing the hypothesis to conclude. It is also testing the inter-relationship between different variables considered in the study. The design of the experimentation is determined significantly by the hypotheses formulated. It could be an assumption tested for its truthfulness. Scientists use their knowledge of past events to develop a general principle or explanation to help predict future events. Here the general principle is called a **hypothesis.** The type of reasoning involved is called **inductive reasoning** (deriving a generalization from specific details)**.** A hypothesis should agree with available observations, it should be testable and potentially falsifiable. In other words, there should be a way to show the hypothesis is false; a way to disprove the hypothesis.

What is an Inference?

An **inference** is an idea or conclusion that's drawn from evidence and reasoning. An **inference** is an intellectual product derived as a result of objective experimentation. It is a significant result of the scientific method. The inference is obtained by applying reasoning, which may be inductive, deductive or inductive-deductive patterns of logical analysis. An inference is drawn based on some strong rationale in which logical thinking, reasoning and critical analysis are applied.

Learning through experiments may have certain procedural parts, in which experiments may be conducted mainly for two purposes, firstly, to explore or find out new things and secondly to check empirically the already obtained results and to get the confirmations. Following are the common steps usually adapted while learning through experiments:

1. Aim of the Experiment
2. Materials required
3. Procedure to be followed
4. Conducting an experiment
5. Observation and Documentation
6. Analysis and Interpretation of the data
7. Finding the results
8. Drawing generalization/conclusion

Now let us look into the above steps through some illustrations:

1. Aim of the Experiment: Cultivate the Bacteria that grow on your hand
   Materials required: Small airtight container, gelatin dessert
   Procedure to be followed: Observe the following table

If you buy gelatin from a package, follow the instructions to make it. If you do not find gelatin to make, it should be even easier and just touch the gelatin from the glass jar and wait to see what happens.

Experiment	Observation	Inference
Heat water on the stove and add the package contents to it, stirring the mixture vigorously until the gelatin grains dissolve. While the solution is still hot, pour it into a container where you want to cultivate your bacteria, and close the lid to avoid contamination. Keep the container in the fridge overnight so the gelatin can solidify. Remove from the fridge once solid, touch the gelatin, put the lid on again and leave the container at room temp or near the radiator for a few days.	After some days you will see some white spots on the gelatin. These are your hands' skin bacteria. Even if you try to wash your hands and repeat the experiment, we will always have bacteria on our hands.	Microorganisms are everywhere but we do not normally see them through our unaided eyes since they are so tiny and dispersed. In this case, they use the gelatin as food, and since there are so many nutrients in it they can multiply (reproduce) many times and accumulate in the container until we can see them.

Note: Gelatin or gelatine is a translucent, colourless, flavourless food ingredient, derived from collagen taken from animal body parts. It is brittle when dry and gummy when moist. Gelatin desserts are desserts made with a sweetened and flavoured processed collagen product.

2. Aim of the Experiment: Change The Colour of Flowers
   Materials required: Flowers (preferably with white petals), ink, glass and Water.

Procedure to be followed: Observe the following table

Experiment	Observation	Inference
Place the flower in a glass with water and colored ink (red, black, blue, etc.). After a while observe the changes	After a while, you will see the petals have colored petal ribs or veins, of the same color of the ink you added to the water.	Normally we give water to plants to keep them alive. Plants have a tube system (called xylem) that distributes the water and some nutrients to all parts of the plant. Using the colored water we can see this tube system.

3. Experiment to show Geotropism in Plants

Materials Required: Small disposable plastic cups, garden soil, seeds of gram or moong and two pieces of wooden stand and black paper. Procedure to be followed:

1. Soak some seeds of gram or moong in water for one day.
2. Pierce slightly big holes (2 mm diameter) at the bottom of the cup.
3. Fill it with a 1 cm thick layer of garden soil.
4. Sprinkle soaked seeds (moong-1gram) over the soil. Water the seeds.
5. Put the cup on 2 pieces of wood or stone slabs so that there is a little gap between the top of the table and the bottom of the cup.
6. Cover the lower part of the setup with black paper.
7. Water the seeds regularly with little water.
8. Observe the bottom of the cup after 10 days.

What have you learnt? The roots come out from the holes and grow towards the earth showing positive geotropism. Extension Make a transparent cup by cutting the lower half of a mineral water bottle. Fill it half with soil. Place some soaked seeds towards the wall of the cup, water the seeds. When the seeds germinate, observe the direction of the root and shoot of the seedlings. The roots grow downwards and shoots grow upwards. Now keep the cup in the horizontal position for a few days. You will see that the roots bend downwards and the shoots bend upwards.

Check Your Progress - 3

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. A variable is the one
   a. Which varies
   b. Which remains constant
   c. Which is neutral
   d. Does not get affected by anything

2. A hypothesis is a
   a. Question
   b. Tentative solution
   c. Proof
   d. Intellectual guess

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:
   a. An inference is an idea or conclusion that's drawn from evidence and reasoning.
   b. An experiment is always for finding new things
   c. Inductive reasoning helps in drawing generalization
   d. Experimentation is one of the science process skills
   e. Experimentation does not depend upon observation
   f. Variables are inevitable for experiments

2.1.4. Let us Summarise

We learn anything by using our senses and brain. That is why sense organs are called gateways of knowledge. Knowingly or unknowingly we do observe, which takes the root cause of our learning. Observation needs attention, perception and concentration. For this, visual, auditory, olfactory and even sometimes taste and touch sensory organs are involved. Observation is one of the most fundamental science process skills. It is fundamental to all scientific activities and discoveries. Observation is purposive, systematic and objective, demands focused attention, alertness and carefulness. It is a goal-oriented or need-based activity.

An inquiry is a question asked to get some information. It is a process of asking about or investigating something to find out more about it. It is also a systematic investigation, an examination to get the facts or principles. An inquiry approach is well suited for topics, like, membrane permeability, osmosis, cellular respiration in yeast, plant respiration, rate of respiration in plants, photosynthesis, respiration in germinating seeds, water PH, soil PH, acid rain, factors that affect the heart, and heart rate, regulation of body heat, blood pressure, etc.

An experiment is a procedure carried out to support, refute, or validate a hypothesis. Experiments provide insight into the cause of effect by demonstrating what outcome occurs when a particular factor is manipulated. Experiments typically include controls, which are designed to minimize the effects of variables other than the single independent variable. In the subject of biology, there is ample scope to learn through experimentation.

2.1.5. Answers to 'Check Your Progress - 1, 2 and 3'

Check Your Progress - 1
1. d 2. a 3. A- X b- √ c- √ d- √ e- √ f-X

Check Your Progress - 2
1. a 2. b 3. A- √ b- X c- √ d- X e- √ f- √

Check Your Progress - 3
1. a 2. d 3. a- √ b- X c- √ d- √ e- X f- √

2.1.6. Unit end Exercises

1. What is Observation? Explain the role of observation in science learning.
2. Mention the characteristic features of Observation as one of the science process skills.
3. Illustrate with an example of the use of observation skills in classroom teaching.
4. Explain the salient features of Inquiry-based teaching of Biology.
5. What is an Experiment? How could it be utilized in teaching biology?
6. What is a Hypothesis? Bring out its significance in conducting experiments.

2.1.7. References

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Block 2 : Approaches and Strategies of Learning Biology

Unit 2 : Approaches and Strategies of Learning Biology: Experiential Learning

Unit Structure

2.2.1. Learning Objectives

After completing this Unit, the student teachers will be able to,

- Explain the meaning of Teaching Approaches and Strategies;
- Identify Experience Based Learning in Biology;
- Recognize the characteristic features of Experiential Learning;
- Illustrate with examples for experiential learning in biology; and
- Justify the need for Experiential Learning in Biology.

2.2.2. Introduction

Many times we have heard our elders saying "Experience" is the real teacher in our life because it makes everyone to learn one or the other things in life. We have also come across another viewpoint of common people, saying that, just reading thousands of books on swimming will not make a person a swimmer, rather really learning swimming in the water! All this reflects the importance of experience or experiential learning. A child learns the meaning of heat while accidentally touching a hot plate and such learning will last for quite a long time. Every teacher wants his/her students to understand whatever they teach, learn it meaningfully and retain the same for a longer period. For this, a teacher has to be creative enough so that she/he could create experiential learning situations in the classroom. In this unit, you will learn the meaning, nature, importance of experiential learning and its application in biology teaching-learning situations.

2.2.3. Learning Points and Learning Activities

2.2.3.1. Meaning, Nature and Importance of Experiential Learning

Activity 1

Take three bottles; label them as 1, 2 and 3. Fill ice-cold water in bottle 1, water having room temperature in bottle 2 and slightly warm warmer water in bottle 3.

Explain to students that in these bottles water samples are the same but only with different temperatures. Ask them to note down whatever the teacher says.

In the second situation, the same arrangement shall be made. But now allow the students to touch the bottles, and feel the differences in temperatures and now ask them to write what they experienced.

By comparing the experiences of the above-said situations, one can easily say that experience-based learning is more effective and efficient.

The teaching profession inevitably involves using different teaching approaches, methods and strategies. Apart from this, it also utilises teaching skills, techniques, tactics and good communications skills.

Teaching Approach: The teaching approach could be teacher-centered, learner-centered, activity cantered and subject cantered. It is a view of looking at things. It is an overall view or idea to face a problem. The approach can also have many methods. The teaching approach is like the form or the way we teach or ways and means of teaching rather. It is a set of principles, beliefs, or ideas about the nature of learning which is translated in the classroom. In the current situation, we have come across different types of approaches, like Interdisciplinary, Multidisciplinary, Collaborative and Self-instructional, etc.

Teaching Strategy: 'Strategy' is a term that originated from military science. The sequence of pre-planned steps followed in solving a problem could be an example of a strategy. To find out a fact one may use the skill of questioning, exploring, discovering, experimenting and what not! Usually, a strategy will have a mental plan before the execution of an action. To fight and eradicate the ignorance among students, a teacher may make use of several strategies in teaching.

Teaching strategy is a generalized plan for a lesson which includes structure, instructional objectives and an outline of planned tactics, necessary to implement the strategies (Stone and Morris, in Issac, 2010). Furthermore, Issac (2010) explains that teaching tactics are that behavior of the teacher which he manifests in the class i.e., the developments of the teaching strategies, giving proper stimulus for timely responses, drilling the learned responses, increasing the responses by extra activities and so on

Now we shall see how **Experiential Learning** could be an approach as well as a strategy for learning biology. It has all the important features that are identified in the principle "Learning by Doing" and John Dewey is the proponent of this principle. For Dewey, knowledge is not information passed down to students for future use, but instead, knowledge is understanding based on past and current experience, used constantly to test previous conceptions and inform new practices (Roberts 2003). According to Dewey, "Education must be conceived as a continuing reconstruction of experience… the process and goal of education are the same thing" (1897: 79).Dewey stressed the importance of experience in education: "there is an intimate and necessary relation between the processes of experience and education" (1938: 7).

Based on this work by Dewey, other notable theorists such as Kurt Lewin, Jean Piaget, Carl Rogers, and William James have contributed to the emergence of Experiential Learning Theory. By taking the strong basis of the theoretical aspects by Dewey and et.al, David Kolb produced his theory on Experiential Learning. David Kolb's book Experiential Learning (1984) is perhaps the best-known presentation of the approach. However, **David Kolb** is recognized as the creator of Experiential Learning Theory per se around 1975,

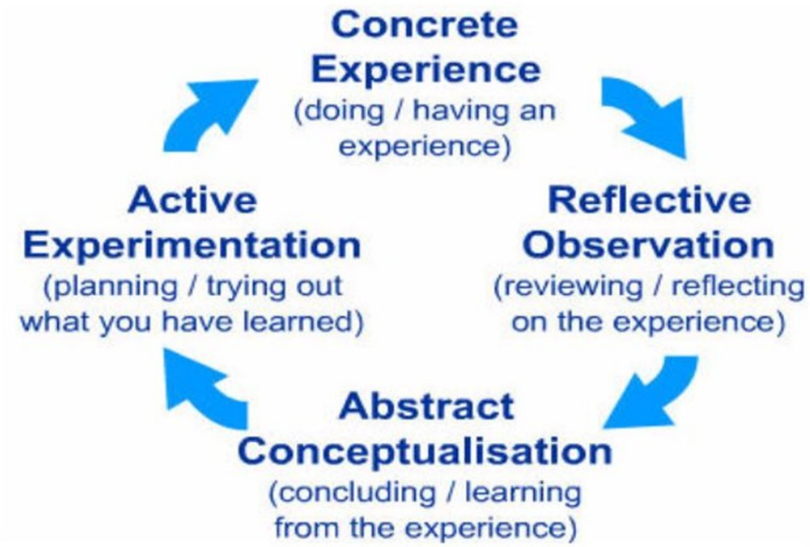
although **John Dewey** laid significant groundwork for the theory in his book, Experience and Education (1938).

According to Kolb "learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from a combination of grasping and transforming experience" (1984). Further, he continues to say that, previous experiences, hereditary characteristics, and current environment together drive the development of a preferred way of grasping and processing experiences. The combination of these preferred methods contributes to specific learning styles, such as initiating, experiencing, imagining, reflecting, analysing, thinking, deciding, acting and balancing. (Kolb & Kolb: 2005).

The theory proposed by Kolb on experiential learning proposes four essential process components, namely, **Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation.** While learning, students may get some first-hand experiences,- that is known as concrete experience, then they may critically think and analyse their first-hand experience which is said to be reflective observation, this will be followed by the formulation of a new idea that is recognised as abstract conceptualization. Students may apply the knowledge obtained in this manner into new situations, and that is called active experimentation. Each step may get a complex pattern depending upon the context. However, Kolb calls this process a continual cycle (2005).

Experiential learning is learner-centered in nature. When students participate in the experiential learning process, they get supporting conditions for the development of critical thinking, abstract thinking and problem-solving skills. In higher education, the same experiential learning will take up a different colour and there it is defined as Skills, knowledge, and experience are acquired outside of the conventional academic classroom setting, and may include internships, studies abroad, field trips, field research, and service-learning projects.

Kolb's Experiential Learning Cycle



John Dewey in his "Theory of Reflective Thought and Action" proposes that **Experiential Education** is a philosophy of education that describes the process that occurs between a teacher and student that infuses direct experience with the learning

environment and content. The term is not interchangeable with experiential learning; however experiential learning is a sub-field and operates under the methodologies of experiential education. Dewey advocated that education be based on the quality of experience. For an experience to be educational, Dewey believed that certain parameters had to be met, the most important of which is that the experience has continuity and interaction. Continuity is the idea that the experience comes from and leads to other experiences, in essence propelling the person to learn more. Interaction is when the experience meets the internal needs or goals of a person. Dewey also categorizes experiences as possibly being mis-educative and non-educative. A mis-educative experience is one that stops or distorts growth for future experiences. A non-educative experience is one in which a person has not done any reflection and so has obtained nothing for mental growth that is lasting (Experience & Education, Dewey).

Experiential learning focuses on the **learning** process for the individual. Examples: Visiting zoo and learning through observation and interaction with the zoo environment; observing a butterfly life cycle in the natural habitat; identifying modified roots or stems by their characteristics in the vegetables of daily use as against getting just bookish knowledge.

Kolb proposes that experimental learning has six main characteristics:

- Learning is best conceived as a process, not as an outcome.
- Learning is a continuous process grounded in experience.
- Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world
- Learning is a holistic process of adaptation to the real world.
- Learning involves interactions between the person and the environment.
- Learning is the process of creating knowledge that is the result of the transaction between social knowledge and personal knowledge.

What are the advantages of experiential learning?

Compared to traditional or conventional classroom learning the experiential learning has the following advantages:

- ✓ Access to first-hand information and scope for an independent analysis
- ✓ Scope for the immediate application of the obtained knowledge
- ✓ Access to real-time coaching and feedback which favours keeping the learning process on track
- ✓ Promotion of teamwork and communication skills and thereby assuring the social development of the individual
- ✓ Development of reflective practice habits sharpens intellectual power among the students
- ✓ Accomplishments and achievements will be obvious and smoothen the evaluation process
- ✓ Scope for the utilization of the maximum number of sense organs and interactions
- ✓ Enhances self-awareness among the students
- ✓ Motivates the students with ample scope for curiosity and involvement

Check Your Progress - 1
Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Experiential Learning is,
    a. Method of teaching
    b. Approach of teaching
    c. Technique of teaching
    d. Teaching skill

2. Experiential learning is,
    a. Learner-cantered
    b. Teacher-centered
    c. Subject-centered
    d. Exam-centered

3. Below are given some statements, put (√) mark for the right ones and (X) for the wrong ones:
    a. Concrete experiences are essential aspects of experiential learning.
    b. Field visits must be avoided as they are expensive.
    c. The laboratory is compulsory for experiential learning in Biology.
    d. Experiential learning promotes social development among students.
    e. Students get an opportunity for independent learning in the experiential learning situation.
    f. Experiential learning does not motivate students rather it scares them.

2.2.3.2. Experiential Learning in Biology

Activity-2: Ask the students to write down what all they know about their skin. Provide them with a few live aquatic animals, like, fish, frog, snail, etc., and insist them to give a comparative note on the respective skin of these animals and probable reasons for any differences if there be.

The above activity allows the students to feel the soapy nature of the frog's skin, scales on the body surface of fish and also how difficult to hold a fish by hand because of its slippery skin. A teacher can make use of this activity and students' experience to teach the concept of "Skin and its Function"

As said earlier, "Experience" is the real teacher that makes an individual inevitably learn many things. For the transaction of the prescribed curriculum, a teacher has to plan meticulously so that students will learn by their own experiences and not by hearing what is told by the teacher. Because, experiential learning is an important part of a student's personal, professional, and educational growth. Experiential learning in Biological Sciences at the school level may have, lab activities, field visits, simple surveys, "do it yourself activities" and usage of the internet for exploring certain recent and new information. For this, Planning with the support of appropriate material resources for individualized, small group and whole group work is the key to the effective management of instruction in multi-grade schools and vertically grouped classroom. Instead of finding ways of juggling lesson plans based on mono-grade textbooks, teachers would need to devise advanced thematic topic

plans to engage learners with exercises created for their level. The practices of teachers in classrooms, the materials they use, and the evaluation techniques employed must be internally consistent with each other.

NCF 2005 has proposed the following guidelines for organising experiences

Observing something happen, say, the process of seed germination, in a real situation or observing different stages of milk collection, processing and packaging different kinds of products in a dairy farm.

- Participating in an exercise involving body and mind such as planning a role-play around a theme and presenting it.
- Talking about and reflecting on something the child has experience (e.g. dialogue on gender-differentiated practices in the family and society or participating in a mental game of numbers).
- Making something, say, a system of gear wheels or trying out an experiment to lift a load using a system of pulleys.
- After the experience, teachers could organise a discussion, an exercise involving, writing, drawing and display. She could identify along with the children questions to be thought about and answered.
- The teacher could connect the experience with textbook knowledge and other references and can deepen the experience.
- Such experiences and post-experience activities would be valuable at any level of schooling. Only the nature and complexity of the experience would need to change over the years. Language is the key to organising experiences. Hence, there should be proper coordination between the kind of experience and the level of language development.

Simon Fraser University defines experiential learning as, "the strategic, active engagement of students with opportunities to learn through doing, and reflection on those activities, which empowers them to apply their theoretical knowledge to practical endeavours in a multitude of settings inside and outside of the classroom."

Following are some of the experiential learning situations which could be adapted to any level with suitable modifications:

1. "India Map by a Monocot Crop":

Give a challenge to students so that it could be motivating as well as developing a team spirit among them. The task is that they are asked to create the India Map on the ground (in the school playground or garden space) of 2X3 metres in size. For this, they are allowed to use only the seeds. Students may be divided into 3 or 4 different groups so that there will be a healthy competition among them. Let them be free to select any seed. And the time fixed for this will be 10 to 15 days. (The group that uses the "Ragi" seeds will get a good result). By doing this activity children will come to know about the process of seed germination, the rate of germination of different seeds, and creativity in drawing and growing the seed map on the ground, etc.

2. Observing Bacteria in Curd:

Curd contains Lactobacillus bacteria i.e. Lactic Acid **bacteria** while **yogurt** contains live strains of both Lactobacillus Bulgaris bacteria and Streptococcus thermophiles bacteria. **Yogurt** is an industrial product and can be flavoured.

Take one or two drops of buttermilk on a glass slide and spread it. Heat the slide slightly on a flame for 3–4 seconds. Add a few drops of crystal violet, leave it for 30–60 seconds and wash the slide gently with water. Observe the slide under the compound microscope. (Venkat Rao Habeeb 2018).

3. Scavenger hunts

Nothing is like a little friendly competition to teach students about the world around them. Scavenger hunts get students out of their seats and give them hands-on experience in their environment, inside and outside.

Take the samples of fungi, grown on the dead and decaying debris and observe them under a compound microscope. Study the Agaricus / Mushroom and prepare a report on how it is cultured. Ask the students to justify how a non-chlorophyll organism like a mushroom can be of significance to mankind.

4. Vermicomposting and Earthworm (Soil Fertilization)

"Vermicomposting is a process in which the earthworms convert the organic waste into manure, rich in high nutritional content." This process is mainly done to add nutrients to the soil. Compost is a natural fertilizer that allows an easy flow of water and for growing plants. The earthworms are mainly used in this process as they eat the organic matter and produce castings through their digestive systems which add fertility to the soil.

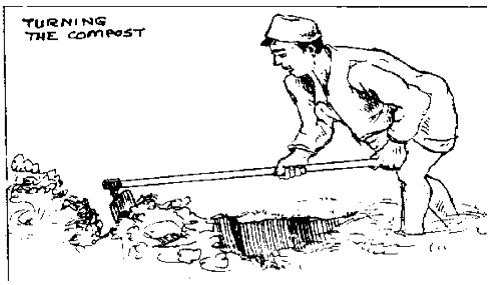
Materials Required: Water, Cow dung, Thatch Roof, Soil or Sand, Gunny bags, Earthworms, Weed biomass, a large bin (plastic or cemented tank), dry straw and leaves collected from paddy fields and biodegradable wastes collected from fields and kitchen.

Procedure: To prepare compost, either a plastic or a concrete tank can be used. The size of the tank depends upon the availability of raw materials. Collect the biomass and place it under the sun for about 8-12 days. Now chop it to the required size using the cutter. Prepare cow dung slurry and sprinkle it on the heap for quick decomposition. Add a layer (2-3 inches) of soil or sand at the bottom of the tank. Now prepare fine bedding by adding partially decomposed cow dung, dried leaves and other biodegradable wastes collected from fields and kitchen. Distribute them evenly on the sand layer. Continue adding both the chopped bio-waste and partially decomposed cow dung layer-wise into the tank up to a depth of 0.5-1.0 ft. Once, after adding all the bio-wastes, release the earthworm species over the mixture and cover the compost mixture with dry straw or gunny bags. Sprinkle water regularly to maintain the moisture content of the compost. Cover the tank with a thatch roof to prevent the entry of ants, lizards, mouse, snakes, etc. and protect the compost from rainwater and direct sunshine. Have a frequent check to avoid the compost from overheating. Maintain proper moisture and temperature.

Result: After 24-25 days, around 4000 to 5000 new worms are introduced and the entire raw material is turned into the vermicompost.

5. Preparing organic manure in the field

Arrange to compost material in a pit or heap. If composting is done in a heap, the site should be leveled and protected from rain by a roof so that nutrients will not leach. Compost is decomposed by fungi and bacteria. For proper microbial growth, add starter materials Complesal- is an organo-mineral *fertilizer* containing: Nitrogen, Phosphorus and Potassium (a few handfuls), lime or topsoil at each layer. Decomposed compost and wood ash can also be added if chemical fertilizer is not available. Add enough water to keep the compost moist; the material should be spongy - not too dry, not too wet. Turn the compost pit or heap at 30-40 day intervals for proper aeration. Cover the compost pit or heap with mud or straw or plastic sheets. This practice enhances decomposition. In the mid-hills, it may take approximately 3-4 months for complete decomposition.



Well-compost manure i**s** friable, does not stick in the hand, dark grey or blackish in colour and Original material cannot be distinguished.

6. Observation under a compound microscope of the following will give a sound basis for experiential learning:

Temporary mountings of onion peel, pollen grains, stomata openings, blue-green algae, like, Spirogyra, Zygonema, Chlamydomonas Oscillatoria, Nostoc etc. (these are easily available in running water).

Permanent mountings of cell division stages, mitosis, meiosis, unicellular organisms like an amoeba, paramecium, euglena, mouthparts of cockroach, house fly, mosquitoes, honey bees, and comparison of these parts. These observations should be followed by the preparation of a report of what they observed and the teacher should give feedback to students. Suggestions for further activities also could be taken care of.

Check Your Progress - 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Experiential Learning is popularized by
    a. David Kolb
    b. John Dewey
    c. NCF 2005
    d. Kurt Lewin

2. Experiential Learning Cycle includes
   a. Concrete experiences and Abstract Conceptualization
   b. Reflective Observation and Abstract Conceptualization
   c. Reflective thinking and Active Experimentation
   d. All the above

3. Below are given some statements, put (√) mark for the correct ones and (X) for the wrong ones:
   a. Microscopic observation should be avoided in the class because it takes more time
   b. The collection of certain microbes may infect children, hence it should be avoided
   c. Activities help students to get motivated and learn effectively
   d. Experiential learning is favoured in group activities as well as individual activities
   e. Teachers can make use of short and long term activities so that students get attracted and learn by experience
   f. A teacher has to plan in advance to give experiential learning situations to students

2.2.4. Let us Summarise

Experiential learning is not a new approach altogether, as it is reflected in John Dewey's principle of "learning by doing". John Dewey has laid significant groundwork for the theory in his book, Experience and Education (1938). However, David Kolb is recognized as the creator of Experiential Learning Theory per se around 1975.

According to Kolb "learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (1984). Experiential learning has four essential process components, namely, Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation. Experiential learning is learner-centered.

Learning is best conceived as a process, not in terms of outcomes. The major characteristic features of experiential learning are, Learning is a continuous process grounded in experience, Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world (learning is by its very nature full of tension), Learning is a holistic process of adaptation to the world, Learning involves transactions between the person and the environment, Learning is the process of creating knowledge that is the result of the transaction between social knowledge and personal knowledge. NCF 2005 had also categorically stressed experiential learning and given some guidelines for its adaption.

Examples for experiential learning could be a visit to the zoo and learning through observation and interaction with the zoo environment, observing a butterfly life cycle in the natural habitat, identifying modified roots or stems by their characteristics in the vegetables of daily use- as against rote learning.

2.2.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1

1. b
2. a
3. a- √ b-X c- √ d- √ e-√ f-X

Check Your Progress - 2

1. a
2. d
3. a-X b-X c-√ d-√ e- √ f-√

2.2.6. Unit end Exercises

1. Explain the meaning of Teaching Approaches and Teaching Strategies
2. Differentiate between Approach and Strategy with an illustration
3. List the characteristic features of Experiential Learning
4. Illustrate Experiential Learning with an example from Sec. Biology
5. Justify the significance of Experiential Learning in Biology

2.2.7. References

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Block 2 : Approaches and Strategies of Learning Biology

Unit 3 : Approaches and Strategies of learning Biology: Expository Approach

Unit Structure

2.3.1. Learning Objectives

After completing this Unit, the student teachers will be able to,

- Explain the meaning of the C Approach in teaching;
- Identify topics that are suitable for Expository Teaching Approach;
- Recall the characteristic features of the Expository Teaching Approach;
- Illustrate with examples for Expository Teaching Approach in biology; and
- Justify the need for an Expository Teaching Approach in Biology.

2.3.2. Introduction

By this time you all are aware of the different approaches in teaching, like, teacher-centered, learner-centered, activity cantered and subject-centered approaches, etc. In this unit, you will come to know about details regarding Expository Teaching Approach Biology which has all the features of teachers centered approach. Sometimes, it seems to be beneficial to have an expository approach to teach certain concepts, principles and generalizations. To make it more effective and efficient you must know the nature, characteristic features and applicability of the expository approach in specific. This unit will through light on these issues.

2.3.3. Learning Points and Learning Activities

2.3.3.1. Meaning, Nature and Importance of Expository Approach in Biology

Activity 1:

Have you come across any classroom situation in which there will be pin-drop silence and only one dominant voice and all other participants are silently listening to the voice? Now you try to jot down the role of the listeners, and the speaker and also how the session started, how it went on and finally how it was concluded. Because at the end you will come to know that all the features that you have listed would reflect the nature of the expository approach only!

Expository Teaching Approach is featured with the dominant role of the teacher as the teacher explains, instructs and presents the subject matter, provide examples, illustrations and give all the needed information to students. Here teachers may make use of one-way or two-way communication depending on the contextual needs. Usually, it appears like a lecture by an expert associated with some pictorial representations, visual aids and board work. Expository teaching deals with direct instructions. However, expository instruction goes beyond just presenting students with the facts. It involves presenting clear and concise information in a purposeful way that allows students to easily make connections from one concept to the next.

Expository Teaching Approach makes both the teacher and the students be focused on the topic. Therefore unnecessary explorations, distracting activities and debates or discussions are by and large avoided. There will be no scope for experimenting and students' self-learning. Many times it appears as examination-oriented and hence said to be the most popular approach. It is because a teacher can complete the syllabus well in advance and children can prepare well for the examination. Due to rich experience and in-depth knowledge in the subject a teacher can impress the students by her spontaneity and creativity in the expository approach. Teachers can give contextual elaboration and encourage the students to perceive the information from different angles.

Expository approach is teacher-centered whereby the topic, ways and means of teaching it, strategies and modes of evaluation-all such aspects are decided by the teacher only. Hence there will be little role to a student, as to learn. The teacher does the job like "Syllabus Covering" if they adapt an expository approach. As in this approach, there will be a feeble chance for exploration, discover, experimentation by the students, it is also called the Deductive style of teaching. It is because the teacher often begins with a definition/concept/generalization and this will be usually followed by examples and illustrations. Hence, **David. P. Ausubel** points out that the expository approach has a strong connection with rote learning. However, expository teaching can present rich content, with an economy of time and other resources. Practically it is observed that students also can learn either memorizing or remembering to the best extent as far as the reproduction of the taught concepts is concerned

It need not be always teacher domination in a classroom context. Even using textbooks by students in class is an example of expository teaching. As the subject varies, the nature and pattern of the textbook also vary, so also the expository approach varies from subject to subject and teacher to teacher.

Salient Features of Expository Approach

- Expository approach will be teacher dominated in nature and has got all the similarities of a lecture method.
- Teacher will be the controlling authority of all the classroom activities.
- Teacher directs the students and gives instructions to be carried out by the students.
- Most of the time it utilizes Deductive Reasoning.
- Generalization / Principle / Rule are presented first and this will be followed by relevant examples and illustrations.
- Visuals in terms of charts, diagrams and portraits could be used as a support system in teaching.
- Both the teacher and students will be knowing what is taught and learnt respectively.

- It may include the application of maxims of teaching like easy to difficult, concrete to an abstract mode of explanation.
- Ausubels's Advanced Organiser model of teaching suits best to expository approach
- Learning points are presented hierarchically.
- Expository approach involves an organised teaching pattern in which the information is presented in a specific order.
- After the complete presentation of the learning points, the lesson results in a drawing summary of the class.
- Summary of the taught information makes it easy to remember the important facts and review them quickly.

Donald Johnson and Paul Stratton have identified expository approaches in three dominant types, namely, **Discovery Programme type, Programmed Instruction type and Mixed Programme type.**

A few examples for Discovery Programme maybe, like,

(i) Students are given definitions of terms, similar to those one finds in the dictionary. Although each term is related to a higher-order class, students will be getting relevant information from the teacher and then the students are required to write their definitions of the terms.

(ii) Any term is used in sentences that are a part of a short story may be given to students. After reading the story, the students are asked to complete a sentence that requires the usage of the term.

(iii) Students are given examples of objects and events and asked to classify them. Here the students have to discover the correct categories.

Programmed Instruction: According to **Glaser (1966)**, Programmed Instruction is a form of expository teaching especially when the Rule-Example sequence is used. In the rule-example sequence, the student is presented with an explicit statement of the rule (or principle) followed by one or more carefully chosen examples. He is then presented with one or more incomplete examples, which act as prompts to reduce the possibility of incorrect responses. The incomplete examples also provide the student with the reinforcing activity of directly employing the rule.

The rule-example technique is very frequently used in teaching. The teacher provides the student with a general statement of the principle and then offers a series of illustrations. Glaser suggests that this procedure is widely used because it leads to rapid reinforcement for both teacher and student.

Mixed Programme Type: Here, a mixed problem will be constructed out of materials and given to students. With suitable guidance by the teacher, students will classify the different problems and find out the respective solutions. The research studies have shown that the students who were taught with the mixed method did better than those in all the other groups. The experimenters concluded that the "superiority of the mixed program supports the common practice of teachers and textbooks".

Advantages of Expository Approach:

- Though the expository approach appears to be passive in nature, there are ample merits also. Now let us take the opinion of Ausubel who has analysed the expository approach. According to him, "Expository Approach is the one which is the art and science of presenting ideas and information meaningfully and effectively- so that clear, stable and unambiguous meanings emerge and are retained over a long period as an organized body of knowledge- is the principal function of pedagogy. This is a demanding and creative rather than a routine and mechanical task. The job of selecting, organizing, presenting, and translating subject-matter content in a mentally appropriate manner requires more than the rote listing of facts. If it is done properly it is the work of the master teacher and is hardly a task to be disdained….Beginning in the junior high school period, students acquire most new concepts and learn most new propositions by directly grasping higher-order relationships between abstractions. To do so meaningfully, they need no longer depend on current or recently prior concrete-empirical experience, and hence can bypass completely the intuitive type of understanding reflective of such dependence. Through proper expository teaching, they can proceed directly to a level of abstract understanding that is qualitatively superior to the intuitive level in terms of generality, clarity, precision and explicitness. At this stage of development, therefore, it seems pointless to enhance intuitive understanding by using discovery techniques."
- Teachers who use expository teaching present the learning points to their students in a purposeful way that allows students to easily make connections from one concept to the next.
- Students receive the information from an expert, which could be the teacher or a textbook author or educational video or any other authentic educational packages.
- The structure of an expository lesson is designed to help students stay focused on the topic at hand.
- Expository teaching is more popular because it is more efficient and takes less time and is economic in the usage of resources.
- Expository teaching offers the student the best opportunity to obtain an organized view of the discipline he is studying because the teacher can organize the field much more effectively for learning than the novice student can.
- This method is beneficial for the auditory learner who does best when listening to instruction.

Check Your Progress - 1

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Expository Approach is featured by
    a. Students' active participation
    b. Explorations by students
    c. Teacher's domination
    d. Experiments by students

2. Expository Approach is very useful for
    a. Auditory learner
    b. Visual learner
    c. Kinaesthetic learner
    d. Disciplined learner

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:

a. Ausubels's Advanced Organizer Model of teaching suits best to expository approach
b. Expository approach gives ample scope for students' domination
c. Expository approach favours the syllabus coverage in a stipulated time
d. Guided Discovery is also one of the types of expository approach
e. Expository approach helps both teachers and students to focus on the topic
f. The effectiveness of the expository approach depends on the examples and the illustrations provided by the teacher

2.3.3.2. Application of Expository Approach in Biology Teaching-Learning Process

The expository approach needs teachers with thorough subject knowledge and good communication skills. While teaching, a teacher has to establish a connection between the new knowledge with the past experiences of the students. This will make the class meaningful. Apart from this, both teachers and students should have a common viewpoint regarding what is to be taught and explained. Since exposition involves explanation and interpretation, there must be ample scope for this in the teaching-learning session. Whatever the resource materials a teacher wants to use, they have to be organised and be ready for use well in advance. The expository approach can become more effective and efficient by making use of strategies, like, analogy, stories, illustrations, models, diagrams/charts, experiments and demonstrations and outlines/summaries at the end of the teaching-learning session. This will help to set the facts in a proper relationship. Having scope for evaluation by means of tests, assignments, creative works and challenging follow-up activities will approach the best of its nature.

The teacher will be completely in charge and give directions to students. For effective execution of the expository approach, a teacher should know their students' level of learning, their ability to understand and the language used, illustrations are given must be within the students' experiences.

Activities which could be adapted for expository approach may be like:

- Teacher Talk/Lecturing
- Demonstration
- Assignment and Homework
- Memorizing
- Reviewing
- Questioning
- Discussion

The expository approach could be of a Directive type, Deductive type and Demonstrative type. A teacher decides the type of exposition depending upon certain factors. For example, if the teaching needs subject/content centered experience, learning factual information, if the aim of the lesson is enabling the students to acquire some basic skills and "Procedural Knowledge" and if the flow of content shows an inbuilt linear mode of the pattern then a teacher may go for the directive type of approach.

Focusing a microscope to study microbes, like, Paramecium, Spirulina, algae, observation of cell division and studying cell organelles, etc., will be very effective by the application of the expository approach.

A teacher can conduct a demonstration of temporary mountings on slides and expose the parts of microscopic organisms by making use of a compound microscope to students. Note that, students are getting all the information that they are ought to learn and the teacher is the decision-maker here.

Biology subject is understood well with the study of taxonomy. Here the terms used are scientific and technical. Let us take the example of the binomial nomenclature of the following:

Centipede –Lithobiusforfiatus

It is very easy for students to recall and recognise centipede, which are in their concrete experience, but look at its scientific name, Lithobiusforfiatus – we never call it like this in day to day situations. The systematic classification of centipede is as follows:

Kingdom	Animalia
Phylum	Arthropoda
Sub-phylum	Myriapoda
Class	Chilopoda
Order	Lithobiomorpha
Family	Lithobidae
Genera	Lithobius
Species	forficatus

Onion –Allium cepa

The scientific name of onion is Allium cepa, which is nowhere similar to the daily language used by the students. So for this just students have to memorize the term and associate that with the real object and the meaning for it.

Kingdom	Plantae
Sub-kingdom	Tracheobionta
Division	Magnoliophyta
Class	Liliopsida
Order	Liliales
Family	Liliaceae
Genera	Allium
Species	cepa

For assignments or homework, better the teacher gives innovative challenges so that it will make the students active participant. For example, challenges like,

1. Find a flower with only three petals and collect the details of that plant
2. Observe and study the behaviour of insects in their life cycle (moth, butterfly and wasp)
3. Try to grow rare plants in pots and make a document of it.

Such activities could be either long term (15 to 30 days) or short term (3 to 5 days) and these activities shall be relevant to the prescribed syllabus. However, the teacher's role here will be like that of a guide and students will be doing a guided discovery.

Certain topics are well suited for debate and discussion. This could be done by a teacher in which the teacher's role will be like that of a moderator. Topics, such as hybridization, use of plastics, biological industries and genetics including the human race will bring a live environment in the classroom debate and discussion. **Henderson (1963)** after analysing the recorded tapes of the verbal behaviors of mathematics teachers in the classroom, defined discovery teaching as a particular pattern or strategy of teacher moves. He has identified four basic moves, namely,

1. Statement of the principle
2. Clarification of the principle
3. Justification of the principle
4. Application of the principle

If the initial move of the teacher is the statement of the principle or referring of a student to a principle in textbook followed by clarification and application or justification moves, the sequence of moves is defined as an **Expository Strategy**; however, if the 'statement' move is not the initial move, but appears if at all, near the conclusion of a sequence, the sequence is then called as a **Guided Discovery Strategy.**

Ausubel (1963) claims that Expository Teaching and Reception Learning refer to the same process and defines reception learning as that in which "the entire content of what is to be learned is presented to the learner in final form."

Bruner (1960), claims that Expository Teaching produces bench-bound learners. He maintains that the decisions concerning the mode and pace and style of exposition are principally determined by the teacher as expositor; the student is the listener. The teacher has quite a different set of decisions to make than the learner. The teacher has a wide choice of alternatives for structuring; he/she is anticipating paragraph content while the student is still

intent on the words. That is, the teacher is manipulating the contents of the material by various transformations, while the student is quite unaware of these internal manipulations.

As the pedagogic experts have pointed out, the expository approach has both merits and demerits. It is the teacher who has to strengthen the positive features and trim the negative features in classroom transactions.

Check Your Progress - 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Exposition involves
    a. Explanation and Interpretation
    b. Notes giving
    c. Experiments
    d. Board work

2. According to Ausubel, Expository Learning is similar to
    a. Passive learning
    b. Active learning
    c. Reception learning
    d. Meaningful learning

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:
    a. The expository approach can become more effective and efficient by making use of, analogy, stories and illustrations
    b. Bruner (1960) claims that expository teaching produces bench-bound learners.
    c. Expository teaching nurtures rote learning
    d. Demonstrations are not at all conducted in expository teaching
    e. Inductive and deductive reasoning are rarely used in expository teaching
    f. Students' interaction is a must in expository teaching

2.3.4. Let us Summarise

The expository approach is teacher dominated in nature and the teacher is the controlling authority of the classroom activities. The expository approach in teaching will have a dominant role by the teacher where a teacher explains, instructs and presents the subject matter, provide examples, illustrations and give all the needed information to students. However, expository instruction goes beyond just presenting students with the facts. It involves presenting clear and concise information in a purposeful way that allows students to easily make connections from one concept to the next. As the subject varies, the nature and pattern of the textbook also vary, so also the expository approach varies from subject to subject and teacher to teacher.

Donald Johnson and Paul Stratton have identified expository approaches in three dominant types, namely, Discovery Programme type, Programmed Instruction type and Mixed Programme type. For effective execution of expository approach, a teacher should know their students' level of learning, their ability to understand and language used,

illustration given must be within the students' experiences. Teacher Talk/Lecturing, Demonstration, Assignment and Homework, Memorizing, Reviewing, Questioning and Discussion are the specific strategies that can take an effective and efficient role in expository teaching.

2.3.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1

1. c
2. a
3. a- √ b-X c- √ d- √ e-√ f-√

Check Your Progress - 2

1. a
2. c
3. a- √ b-√ c-√ d- X e-X f-X

2.3.6. Unit end Exercises

1. Explain the meaning of the expository approach in teaching.
2. Mention two topics of your choice that are suitable for expository teaching.
3. What are the characteristic features of expository teaching?
4. Illustrate with examples for expository teaching in biology
5. Justify the need for expository teaching in biology.
6. What are the relative merits and demerits of Expository Teaching

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Block 2 : Approaches and Strategies of Learning Biology

Unit 4 : Approaches and Strategies of Learning Biology: Investigation

Unit Structure

2.4.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Explain the meaning of the investigatory approach in teaching;
- Identify investigation as one of the science process skills;
- Recall the characteristic features of the investigatory teaching approach;
- Illustrate with examples for investigatory teaching in biology; and
- Justify the need for an investigatory approach in teaching biology.

2.4.2. Introduction

We know that biology is full of studying living organisms and hence the classroom activities must be lively enough! It is said that Learning occurs best when students are actively involved in the construction of their knowledge (Mestre and Cocking-2002). Teachers have to perceive their students as mini scientists or/and make them mini scientists. If the teaching-learning situations are filled with inquisitiveness/curiosity, challenging, and demanding a focused involvement by the students, then automatically they start learning with absolute seriousness! A learner will transform himself/herself into a professional learner. The investigatory approach is the one that facilitates all the aforesaid salient features in a classroom. So, in this unit, you will come to know about what is an investigatory approach, how it could be adapted to biology teaching and what its procedural designs are. To highlight the effectiveness of the approach certain illustrations are also cited. **Switzer and Shriner (2000)**believe that the practice of science using investigative, discovery-based, open-ended processes, with opportunities for designing experiments built on previous observations, represents an educational tool that effectively demonstrates to students how the scientific process works in the professional world.

2.4.3. Learning Points and Learning Activities

2.4.3.1. Meaning, Nature and Importance of Investigatory Approach in Biology

Activity 1

"Once I saw a dust particle big enough to be seen by the naked eye (3 to 4 mm) on the wall which was just in front of me. I was doing some work busily so, I forget about that dust particle and surprisingly when I saw it again it was not in that place rather a little bit farther away. This made me observe. After 5 to 10 minutes, the particle started showing some movement. Now I could not keep quiet, I collected this dust particle and put it on a sheet of white paper. By using a hand lens, I came to know that it is not a dust particle but an insect. It had the same colour as our house wall and almost diamond in shape. It showed movement to responded to light".

After illustrating her experience, the teacher gives this as a challenge for students to find such insects on the walls of the classroom/school/house. This made the children investigate all about that particular insect. These are called "Plaster Bagworms".

The investigation is a strong mental activity charged with keen and focused observation skills. In common parlance, an investigation is used in different contexts, but if it has to be applied to the teaching of biology then it has to have certain special features. The subject of science and investigation are inseparable. An investigation is the heart of science. It is just like how scientists do research. Scientific investigations produce evidence that helps answer questions and solve problems. If the evidence cannot provide answers or solutions, it may still be useful. It may lead to new questions or problems for investigation. As more knowledge is discovered, science advances.

An investigation will be similar to that of the scientific method, which is featured by its meticulous and systematic step by step procedure. The scientific method is a systematic process that involves using measurable observations to formulate, test or modify a hypothesis. A hypothesis is a threshold for experimenting, maybe to verify or illustrate and even to find new solutions for old problems. A hypothesis is a proposed explanation for some observed phenomenon, based on experience or research. It will be a tentative solution but to be tested for its effectiveness and truthfulness.

As we say scientific investigations are usually done by scientists, in the field of biology investigation usually begins with an observation. It is because biology is a descriptive subject. To study any organism we follow the 'structure and function approach' which is quite common. The discoveries and experimentations in this field will have several special features, in which observation is the most integral part. For instance, an Entomologist may find why in particular season locusts are outbreak and cause menace in the environment or maybe wonderstruck by the pandemic disease like Corona Virus or Covid-19. Such situations trigger the questioning and enquiry nature in mind. And this leads to investigations. How do biologists follow up on these observations? How can you follow up on your observations of the natural world? And how this type of study habit could be inculcated among students by teaching biology through investigations? For all such questions, we shall try to get answers in the following discourse.

An investigation is composed of certain techniques and approaches, for example, Laboratory Technique, Problem-solving Technique, Research Technique, Experiment Technique and Field study Technique are a few to name. Biological Science Curriculum Study (BSCS) also advocates the investigatory approach to the biology teaching-learning process. **Johnson and Johnson (1999)**believe that such investigative experiences are performed in cooperative learning situations, teaching methods that encourage students to work together to achieve a common goal, and that results in greater student achievement than conventional didactic methods. In addition to greater student achievement, engaging in cooperative learning leads to the development of higher-level thinking skills, greater intrinsic motivation, improved interpersonal skills, positive attitudes toward learning, and heightened self-esteem. The Investigative Case-Based Learning approach (ICBL) gives clear guidelines for carrying out investigations in classroom teaching.

The ICBL approach is a method of learning and teaching that gives students opportunities to direct their learning as they explore the science underlying realistically complex situations. Students then gather data and information for testing their hypotheses. There are three types of field investigations - **descriptive, comparative, and correlative**. Descriptive field investigations involve describing parts of a natural system. Students are encouraged and guided to make use of a variety of methods to investigate, like, traditional laboratory techniques, field techniques, software simulations and models, data sets, internet-based tools and information retrieval methods.

The cases drawn by students from real-life situations will allow them to apply the scientific reasoning technique. Thus the investigative cases are said to be useful for lifelong learning because they are open-ended and these will necessarily shift the focus of student learning beyond the facts to include using scientific knowledge to frame questions and to answer them. ICBL helps Students to develop questions that lend themselves to scientific investigation and develop their investigative approaches.

The investigatory approach being exactly similar to the scientific method has more common features and has the following five basic steps:

General Steps in a Scientific Investigation

- Make an observation and Identify a research question or problem.
- Formulate hypotheses.
- Gather evidence or data, and test the hypothesis.
- Analyse the evidence.

- Decide whether the evidence supports the hypothesis
- Conclude.
- Communicate the results.
- Apply in required contexts

Make an observation and Identify a research question or problem:

Here instead of announcing what the students are supposed to learn, the teacher presents the topic as a challenging or as a problematic situation. The very purpose of this step is to initiate the investigations and encourage the students to carry out the investigations so that by doing this it assures the teaching-learning activities in biology teaching.

A scientific investigation begins with the identification of a problem that raises a question. An **observation** is a need-based and focussed process by which necessary information is gathered with the senses. People often have questions about things they see, hear, or observe in other ways. For example, a teenaged boy was surprised to see on his hand a group of cells growing so fast seen obvious by its size and colour. Now he is worried about what is this and how to control such unwanted growth of cells.

Common warts are small, grainy skin outgrowths that sometimes occur on fingers or hands. Rough to touch, common warts also often feature a pattern of tiny black clusters of cells. They are caused by a virus and are transmitted by touch.

As in the above example, any catchy observations can trigger an investigation. Hence a teacher has to create or utilize situations that are attention-catching and prompting students to carry out investigations. In the cited example, topics like cell division-mitosis, virus, structure and function of skin, prevention of warts and also uncontrolled cell division may lead to callous formation/cancer cells, etc. may be linked. And this must be followed by questions so that it leads to further investigations to find measurable answers and questions like, 'what' 'how' or 'why' are helpful. Based on such explorations hypotheses could be generated.

Formation of a hypothesis:

A **hypothesis** is a potential answer to a question that can be tested by gathering information. It is a tentative solution to the selected problem and should be tested for its effectiveness. Hence during the later process, a hypothesis will have an equal chance of getting accepted or rejected. But it gives a strong foundation or basis to conduct the experiments and to study the variables. Here the variables, like, dependent, independent and intervening may take an active role in designing and executing the experiment. For example in the cited example, medical treatment, minor surgery or native Ayurveda treatment may be

used and the problem could be solved. In all these cases, data is generated by meticulous observation and focused study.

Developing a hypothesis may require rational guessing and reasoning ability. The Hypotheses could be formulated in three types, namely, (i) Assertive Type (ii) Question Type and (iii) If-Then Type.
In the Assertive type, it will be like a complete, meaningful sentence.
Ex. Surgery can be used to solve the problem of warts
The use of Ayurveda medicine will clear the warts

In question type, it will be in the form of a direct question.
Ex. Does the use of Garlic/surgery/solve the problem of warts?
Predictions are often phrased as "if-then" statements.
Ex. If surgery is done on warts, the problem is solved forever
If the garlic juice is used on warts, warts will get vanished

Gather evidence, or data, to test the hypothesis:

A hypothesis is a possible explanation that we can test to see if it is likely correct, or if we need to make a new hypothesis. To test the hypothesis, we need to make an observation or perform an experiment associated with the prediction. The results of a test may either support or contradict – oppose - a hypothesis. Results that support a hypothesis can't conclusively prove that it's correct, but they do mean it's likely to be correct. Thus the data gathered has to be analysed and results to be found out.

The last step of the investigation is to reflect on the results and use them to guide the next steps. If the hypothesis was supported, we might do additional tests to confirm or revise it to be more specific. For instance, we might investigate why the outlet is broken.

If the hypothesis was not supported, we would come up with a new hypothesis. For instance, the use of garlic juice or surgery could be used if either of them is failed to solve the problem.

Experiments are integral parts of biological investigations and hence we should know what an experiment is. An experiment is a controlled scientific study of specific variables. A variable is a factor that can take different values in different contexts. (Ex. The intensity of Sunlight, Temperature, Acidity, the Nutrient value of Soil, Plant height, Humidity etc.) However, there will be two types of variables in an experiment. They are Independent Variable and Dependent Variable. The Independent variable is the one that is controlled by the researcher. And the dependent variable is the one that alters according to the influence of the independent variable. (Ex. temperature, acidity, light intensity etc. are independent variables and plant growth, plant movement, fruiting, crop yield etc. are dependent variables)

After getting tested the hypothesis and consistent results, one has to disseminate it to others. So if a teacher adapts an investigatory approach in biology teaching and motivating students to do investigations either guided or self, it ought to be followed by communicating the obtained results or findings of their investigations. Researchers or scientists or students - should always communicate their results. By sharing their results, they may be able to get helpful feedback from other fellow participants. Reporting on research also lets others repeat the investigation to see whether they get the same results. Getting the same results when an experiment is repeated is called **replication**. If results can be replicated, it means

they are more likely to be correct. Replication of investigations is one way that a hypothesis may eventually become a theory.

An investigatory approach need not always be an experiment in the laboratory; it could be done using field studies, surveys, comparative studies, and experimental surveys also. For example,

- How does the use of fertilizer affect plant growth?
- What is the difference in the effectiveness of chemical fertilizers and organic fertilizers on soil?
- What is the impact of biodiversity on the environment?
- A cockroach is considered, the oldest organism which didn't undergo any evolutionary changes. Why?

Based on their explorations and investigations students must be encouraged to write articles and make them reachable to their peer group. Peer review means that the work is analysed by peers, which is the best way to ensure that the results are accurate and reported honestly. Creating websites and writing articles for newspapers and magazines are ways to share research findings with the public. This gives them academic satisfaction and helps them to become a professional learner.

Based on all the above explanations now you can list the salient features of the investigatory approach which could be as follows:

- It is empirical in nature and follows the principles of the scientific method
- Factual, unbiased and conclusions are strongly based on the evidence and documents.
- Sharpens the intellectual abilities of the students
- Involves all the science process skills, namely, observation, identification, classifications, hypothecation, experimentation, drawing inference, generalizations and application
- It is a learner-centered approach
- Create and sustains interest and inquisitiveness among students in the subject throughout the study
- Assures the active participation with first-hand information for students
- Results in very effective and constructive learning

Check Your Progress - 1

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Investigatory approach is similar to that of
    a. Expository approach
    b. Inductive approach
    c. Deductive approach
    d. Scientific Method

2. Investigatory approach is a
    a. Learner-centered approach
    b. Teacher centered approach
    c. Subject centered approach
    d. Activity centered approach

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:

a. The investigatory approach prepares the students as obedient, silent and passive learners
b. The investigatory approach develops a questioning attitude among students
c. Teachers cannot adapt the investigatory approach to slow learners
d. Students scoring in the examination is more important than doing experiments and developing inquiry skills
e. Students must be guided for hypotheses construction
f. Investigations and their findings should be disseminated to all.

2.4.3.2. Application of Investigations in the Biology teaching-learning process

The first caption of this unit has described the salient features of the investigatory approach and now it is the time for its application in classroom contexts and other activities. For this the teacher has to motivate and guide the students with some testable questions and queries so that they do investigations and come out with their results. This practice makes them become independent learners. It may be like, laboratory-based or field-based investigations, and both will have an immense effect on their learning. However, there must be thorough and repeated observations in whatever activities they do. To start with, the teacher can give some directions or instruction like,

.....Now it is time to start your scientific investigation! Here you are going to find an answer or a solution or find the new impact of one variable on another variable. And you must be sure enough that the study you conduct will give enough scope for observations, testing and measuring…….

Let us see the following questions or queries and their procedural part in the respective investigations:

Activity 1:What are the favourable conditions for the germination of a seed?

For this, you can have three to four sets of experiments and collectively find out the favourable conditions at the end of your investigations. You can have the following tabular column for documentation purpose:

(Materials required: Been Seeds, small identical pots, soil, water, and space to provide sunlight and air).

Sl. No.	Experimental Set-up	Observations	Inference
1	Pot with sowed Been Seeds and watered properly (No other support)		
2	Pot with sowed Been Seeds in which only soil is there. (No other support)		
3	Pot with Been Seeds in which there is no water, soil but only air /sunlight		
4.	Pot with sowed in soil, but no water, no air/sunlight and kept in a dark place		

5	Pot with sowed in soil, but no water, no air/sunlight and kept in an ice-cold place (Refrigerator)		
6	Pot with sowed Been Seeds in soil, with water and kept under air/sunlight		

Now you have to write down what you did for investigations and what is the data you obtained. Meanwhile, you can explain as many as six hypotheses in the above investigations. And finally, find out the ultimate answer to your investigation.

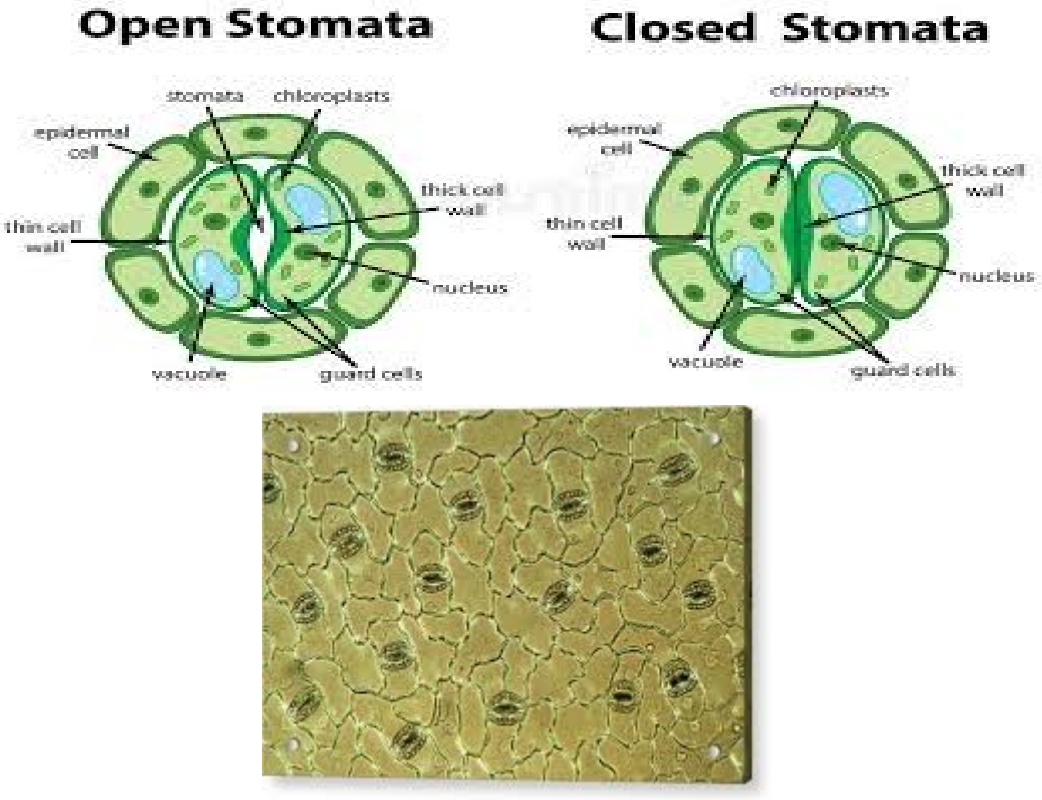
Activity 2: To study the movement of water molecules from cell to cell (OSMOSIS):
(Materials Required: Glass troughs, sugar solution, and Salt solution, Potato, Carrot, Radish, Beetroot and Noolkol).

Procedure: Make a scoop in all the vegetables so that it will be like a cavity and can hold some liquid in it. Though all the samples taken are vegetables, some are modified roots and some are modified stems. Try to find out that in case of root, which solution exhibits the movement of a water molecule (Salt solution or Sugar solution) faster and similarly in case of modified stem which solution exhibits the movement of water molecule faster (Sugar solution or Salt solution). You may come across no difference at all! That is what you have to investigate and develop a rationale for whatever the result you get:

Sl. No.	**Experiment Set-Up 1** **Potato Scoop**	**Experiment Set-Up 2** **Carrot Scoop**	**Experiment Set-Up 3** **Radish Scoop**	**Experiment Set-Up 4** **Beetroot Scoop**	**Experiment Set-Up 5** **Noolkol Scoop**
1.	Put the potato scoop containing sugar solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the carrot scoop containing sugar solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the radish scoop containing sugar solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the beetroot scoop containing sugar solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the Noolkol scoop containing sugar solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**

2.	Put the potato scoop containing Salt solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the carrot scoop containing Salt solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the radish scoop containing Salt solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the beetroot scoop containing Salt solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**	Put the Noolkol scoop containing Salt solution in a glass trough which is filled with water to its half of the height so that the scoop is surrounded by water but never sinks. **Observation:** **Inference:**

Activity 3: How do plants exchange gases?



Materials Required:
Leaves of mango/banyan/bougainvillea/Salvia/Petunia/balsam, micro slide, forceps, water, cover glass, needle, Compound microscope

Procedure:

1. Take a mature leaf from any of the plants listed above.
2. Tear the lower epidermis and you will notice a thin, peel on the edges of the torn portions of the leaf.
3. Carefully remove a small peel with the help of forceps and place it on a micro-slide in a few drops of water.
4. Place a cover glass on it without allowing any air bubbles beneath.
5. Observe the peel under the low power microscope and note the different types of cells
6. Locate the pores in the cells and with the help of your teacher, observe it under high power.
7. Draw the diagram of a pore along with its surrounding structure.
8. Repeat the same procedure for the upper epidermis.

What do we observe?

- ✓ We observe many compactly arranged cells.
- ✓ In between the cells we see several tiny pores. Epidermal cell, stomata-pore Guard cells and Stoma. Each pore is surrounded by two specialized bean-shaped cells.
- ✓ There are several pores scattered in the peel with no specific arrangement.

What do we conclude?

- ➢ The leaf peels comprise many cells that are more or less identical in shape and size. They are epidermal cells.
- ➢ Tiny pores along with their bean-shaped cells (guard cells) are called stomata (Singular-stoma).

Let us answer

1. Which surface of the leaf has more number of stomata?
2. Name the bean-shaped cells of stomata.
3. What are the functions of stomata?
4. Are stomata present in submerged water plants?
5. What is the function of the pore in stomata?

Following are the activities that favour the investigatory approach:

- ➢ What is the relationship between the size of the seed and the rate of germination?
- ➢ A comparative study to find out which seed germinate faster?
- ➢ What is the role of moisture in the soil on the activity of earthworms?
- ➢ Blue-black colour appears on the bread slice and potato slice, whereas, chickpea seeds do not show any colour change. Why is this so?
  (Bread and potato contain starch which gives blue-black in colour on the addition of iodine solution. Whereas chickpea seeds do not contain starch and thus do not show any change in colour)
- ➢ Does temperature affect the number of “chirps” per minute that crickets make?
- ➢ Is it that true, plants do photosynthesis during the day and respiration atthe night?
- ➢ Do plants release carbon dioxide at night because they respire?
- ➢ Find the pattern of stomata arrangements in monocot and dicot leaves.

Check Your Progress - 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Investigation is
    a. Procedural and empirical
    b. An indoctrination
    c. Just an enquiry
    d. One of the processes followed by scientists

2. Implementing an investigatory approach in teaching helps students to acquire
    a. Knowledge
    b. Science process skills
    c. Questioning skill
    d. Experimentation skill

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:
    a. The experiments suggested in the textbook are enough to teach by an investigatory approach
    b. It is very difficult to conduct investigations in the subject of biology
    c. Since biology is said to be a descriptive subject, there is no need to conduct experiments or investigations
    d. Many schools are devoid of laboratory, hence it is impossible to adaptan investigatory approach for teaching biology
    e. By taking the basis of simple observations (on available plants and animals) a teacher can very well adapt the investigatory approach in teaching biology
    f. Since hypothesis formulation is a mental process, students may get bored out of it

2.4.4. Let us Summarise

Learning occurs best when students are actively involved in the construction of their knowledge. The investigatory approach is one of the best measures which encourage students to construct their knowledge. An investigation will be similar to that of the scientific method, which is recognized by its meticulous and systematic step by step procedure. The scientific method is a systematic process that involves using measurable observations to formulate, test or modify a hypothesis. A hypothesis is a threshold for experimenting, maybe to verify or illustrate and even to find new solutions for old problems. A hypothesis is a proposed explanation for some observed phenomenon, based on experience or research. It will be a tentative solution but to be tested for its effectiveness.

The investigatory approach is made up of the following five basic steps, namely, Make an observation and identify a research question or problem, Form a hypothesis, Gather evidence, or data, to test the hypothesis, Analyse the evidence, Decide whether the evidence supports the hypothesis, Draw conclusions and communicate the results.

The advantages of the investigatory approach could be cited as follows: It is empirical and follows the principles of the scientific method, factual, unbiased and conclusions are strongly based on the evidence and documents; Sharpens the intellectual ability of students; Involves all the science process skills, namely, observation, recognition, classifications, hypothecation, experimentation, drawing inference and generalizations;

Learner-centered; Creates and sustains interest in the subject throughout the study; Assures active participation by the students and first-hand information is acquired by them and leads to effective learning.

2.4.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1

1. d
2. a
3. a-X b-√ c-X d-X e-√ f-√

Check Your Progress - 2

1. a
2. b
3. a-X b-X c- X d-X e-√ f- X

2.4.6. Unit end Exercises

1. What is Investigatory Approach in teaching Biology?
2. What are the skills that could be developed among students by adapting an investigatory approach in teaching Biology?
3. List the characteristic features of the investigatory approach of teaching Biology
4. Illustrate with examples for using the investigatory approach in the teaching of Secondary Biology.
5. Justify the need foran investigatory approach in teaching biology
6. What are the relative merits and demerits of the Investigatory Approach?

2.4.7. References

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Block 2 : Approaches and Strategies of Learning Biology

Unit 5 : Approaches and Strategies of Learning Biology: Project

Unit Structure

2.5.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Explain the meaning of 'Project' and its approach in the teaching-learning process of Biology;
- Recognize Projects as one of the best strategies for learning Biology;
- Recall the characteristic features of project approach/strategy for learning Biology;
- Illustrate with examples for projects in teaching-learning of Biology;
- Identify the advantages of having projects in teaching Biology; and
- Identify the relative merits and demerits of the Project as a method ofteaching-learning of Biology.

2.5.2. Introduction

In the juncture of the paradigm shift in every field, the education system as a whole is looking forward to more dynamic, socio-emotional situations in classrooms that provide freedom as well as responsibilities to students and make them more democratic. Many experts and eminent scholars from different fields have put their effort to design instructional patterns that fulfill this requirement. For that, they have coined the term "PROJECT". You might have come across people talking about different projects and performing the tasks. Even it has become an inevitable strategy for students and even little children studying in the schools at primary levels. In schools, students are assigned some projects, and they will be carrying out the projects for weeks, months and the whole semester. But in all these cases, it is teaching not learning highlighted. Hence in this unit, you will come to know about **"PROJECT"** not as a method of teaching but as a way of learning. Hence it is titled **"LEARNING BIOLOGY THROUGH PROJECTS".**

2.5.3. Learning Points and Learning Activities

2.5.3.1. Meaning, Nature and Importance of Projects in Biology

As it is said earlier the project is an educational enterprise in which children solve a practical problem over a period of time. Depending upon the situation, age of students and level of education, the projects may be suggested by the teacher. It could be executed by a group of students or each student which are called Group Project and Individual Project

respectively. But they are planned and executed as far as possible by the students themselves. Basically, a project will work as a learning strategy in which **John Dewey**'s principle **"Learning by Doing"** is charged with socio-emotional aspects. Here the role of a teacher is not as a transmitter of knowledge but to make the students focus on applying specific knowledge or skills. Teachers will be putting their efforts to improve student's involvement and motivate them for independent thinking, self-confidence, and taking social responsibility.

Consideration of projects as one of the best strategies of learning is not confined to India only, rather it is all over the world. **'Project Based Learning' (PBL)** is a term that is universally accepted and recognised. So now, we shall try to understand the meaning and nature of PBL. In common parlance, project-based learning is inquiry-based learning which demands active participation by the students. Hence it is learner-centered in nature. Here the learning situations will be live and energetic with maximum scope for student's first-hand experiences. The opportunities given to the students during the execution of the project will make the students acquire deeper knowledge and skills by interacting with real-life situations. Project learning helps the students to think critically, collaborate with resource persons, become creative, and develop good communication skills.

However, it is better to look at the conventional project method once, so that you may come across many commonalities in project-based learning also. The project method is a significant landmark in the history of the methodology of education. The method is not new. It owes its origin to the American philosophers belonging to the pragmatic school of philosophy. **W. H. Kilpatrick** was a chief proponent of this method. He was influenced by John Dewey's principles of pragmatism. He published a paper on 'The Project Method' in 1918. Kilpatrick mainly focuses on the purposeful activity and problem-solving capacity of the students based on their needs, interest, attitudes and abilities.

The **project method** is a medium of instruction that was introduced during the 18th century into the schools of architecture and engineering in Europe when graduating students had to apply the skills and knowledge they had learned in the course of their studies. The essence of the project method lies in allowing students to explore and experience their environment through their senses and, in a sense, direct their learning by their interests. Very little is taught from textbooks and the emphasis is on experiential learning, rather than rote and memorization. Kilpatrick devised four classes of projects for his method: construction (such as writing a play), enjoyment (such as experiencing a concert), and problem (for instance, discussing a complex social problem like poverty), and specific learning (learning of skills such as swimming). Hence **Kilpatrick** has defined the Project as a "*Whole-hearted purposeful activity proceeding to completion in a social environment.*"

According to **Ballard**, a project is a *"bit of real life that has been imported into the school"*. Supporting this viewpoint, **Thomas and Lang** have defined that, a project is a *"voluntarily undertaking which involves constructive effort or thought and eventuates into objective results"*. All these definitions are in consistent with the meaning of what is called Project-Based Learning.

Project-based learning (PBL) is an instructional approach designed to allow students to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world. Students work more independently through the PBL process, with the teacher providing support only when needed. Students are encouraged

to make their own decisions about how best to do their work and demonstrate their understanding. The PBL process fosters student independence, ownership of his/her work, and the development of 21st century/workplace skills. The specialty of PBL lies with the nature of learning, because, PBL demands the application of knowledge and skills and not just the reproduction or memorization of concepts. Unlike rote learning encouragement, PBL emphasizes on to explore how the students learn and apply a variety of academic content in different contexts. The activities students carry out in PBL will lead them to use the content in real-life situations, address to solve the problems, face the challenges in reality and create or construct innovative things that will benefit society.

The salient features of PBL could be listed as in the following manner:

- Being a learner-centered approach, it adapts mainly inquiries, challenges or problem-solving and conducting research
- Uses 21st-century skills such as critical thinking, good communication and interpersonal relationship, collaboration and creativity
- Focuses on engaging students with real-world situations and problems
- Teachers' role shifts from content-deliverer to a facilitator
- As students do the work, they often use the content knowledge and skills from multiple academic domains to complete the project effectively.
- Always there will be scope for feedback and revision of the plan and the project
- It will be content-specific and also provides an open option for integrating multiple subjects. PBL encourages students to make meaningful connections across content areas, rather than thinking about each subject area in isolation.

According to **Kokatsaki et al**., PBL is characterised by students' autonomy, constructive investigations, goal-setting, collaboration, communication and reflection within real-world practices (2016). So if at all we want to prepare our students to be successful in life, we need to prepare them for project-based learning and in turn for the world.

A teacher can design projects in the following step by step manner:

- **Creating Situation:** The teacher creates a proper situation for the students in the class to create a mindset to undertake an issue for the project. It may be through brainstorming, discussion or debate so that it gives a meaningful picture to students. The teacher also gives knowledge about the project method, the procedure to be followed, the steps involved in it and its uses to students. After that, the teacher motivates them through a conversation about daily life experiences and how the chosen project is relevant to this.

- **Selection of the problem:** Then the teacher gives freedom to select the project-problem to students and helps them to choose properly so that it will be under the possible range for the capacity, interest, ability and calibre of the students. While approving the problems selected by the students, the teacher will check thoroughly in many directions and gives proper guidance to them.

- **Planning:** Planning is always done based on either the objectives or hypothesis. Many times it will be through surveys or collection of data and data analysis also. Planning will help the students to conduct the activities within a time frame. The discussion will lead the students to understand the chosen problem from different angles.

Ultimately when the students come out with their own opinions about the problem, the teacher writes down the procedural part of the project with a stepwise description.

- **Execution:** This is the dynamic part of the task. Because until this stage it will be doing reference, table work or reviews. So execution will be effective and efficient only when planning is perfect. And the planning will be perfect only when the hypothesis or the objectives are properly taken into consideration. The students start their work in this step. There will be a collection of the data and resources, for this, they need sufficient time. Teachers should give time to the students to execute the project according to their own pace, capacity and interest. However, they should be insisted to complete the project work in a stipulated time.

- **Evaluation:** Evaluation is done with reference to the objective or the hypothesis which will are the main pillars of the project. Teachers can encourage the students for peer-group evaluation and self-evaluation too.

- **Reporting and Recording:** This is the last step in any project. Here the obtained results and the findings are showcased through reporting to the authorities like experts or teachers. Keeping the documents and reports in the form of records will help for others to study and follow, also it will help in sustaining and maintaining the continuum of the project/research spirit.

Types of Projects

As said earlier, according to Kilpatrick there are four types of projects.

1. Constructive project:

Practical or physical tasks such as the construction of an article, making a model, making an aquarium, terrarium, vivarium, gardening, growing potted plants and maintaining honey bee box, learning about the mushroom culture and growing orchids, etc., will come under constructive project type.

2. Aesthetic project:

The appreciation attitude of the students is promoted in this type of project. To suit this purpose, in biology, projects on the beatification of the school campus, maintain plant nursery, maintaining hygienic classrooms, cleaning the aquarium, green-house maintenance, etc. could be allotted.

3. Problematic project:

This type of project develops the problem-solving capacity among students through their experiences. It is mainly concerned with the cognitive domain. For instance, how to harvest rainwater, how to recycle the wastewater, how to make the wastes into manure, etc. could be taken as projects.

4. Drill project:

It is for the mastery of the knowledge and skills of the students. It improves the work efficacy and execution capacity of the students. For instance, practicing the scientific diagrams, memorizing the scientific names of plants and animals and use of compound microscopes and temporary mountings could be taken up.

Other types

Individual and Social (Group) projects:

In individual projects, every student solves the problem in his/her interest, capacity, attitude and needs. It develops problem-solving qualities individually. Learning certain preservative activities like, herbarium preparation, preparation of mouldings could be taken. In Group projects, the problem is solved by a group of pupils in the class. Here the projects, like, awareness programmes, community services regarding health and hygiene could be taken up.

There are quite a good number of merits or advantages of Project-Based Learning and they could be as follows:

- Real-world tasks give the students a deeper understanding of the concepts using relevant and authentic learning experiences
- Project-Based Learning will result in connecting students to the real world.
- It brings a positive attitude towards education and schooling among students mainly because of the freedom and the responsibilities they get while executing the project
- It assures intrinsic motivation. As **Daniel Pink** says, people are intrinsically motivated by three things, namely, autonomy, mastery and purpose.
- Learning responsibility, goal setting, independence, and discipline are outcomes of
- PBL.
- Students acquire a deeper knowledge of contents, skills as well as feelings of commitment and ownership of their learning (Han et al., 2015)
- It creates interest in science and develops an understanding of various scientific concepts and generalizations
- It promotes curiosity and develops scientific temper, interest and appreciation
- It develops scientific hobbies for the right use of leisure time

Check Your Progress - 1

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. The chief proponent of Project Learning is,
    a. W. H. Kilpatrick
    b. Watson
    c. Skinner
    d. Pavlov
2. Project-Based Learning results in,
    a. Rote learning
    b. Problem-solving ability
    c. Domination by the students
    d. Inferiority complex in students

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:

a. Projects help in developing scientific hobbies for the right use of leisure time
b. Projects which are guided by teachers only will be successful
c. Students will get a connection between their learning and real-life through projects
d. Drill projects are of no value in science learning
e. Projects will not help student face examination successfully
f. Project-based learning is suitable only at higher levels of learning

2.5.3.2. Application of Projects in Biology teaching-learning process

The whole education system is focusing on making our students able to think independently so that they become autonomous learners and their out of the school life will have the implementation of what they acquire as knowledge and abilities in the schools. For this, they need positive experiences gained in the course of the learning process, which are sources of energy and enthusiasm. For this project-based learning is said to be the best approach. However, while writing for Edutopia, Andrew Miller gives a hint to teachers and says that "Dream Big but Start Small"- let the scope and duration of a project be limited so that it gives them time to get meaningful feedback and encourages professional reflection.

There are two major approaches for the implementation of projects,

(i) A conventional approach, in which the teacher explains all the necessary roles to be performed by the students, gives guidance and helps them in every step till the completion of the project.

(ii) Students selecting the project-here the instruction need not necessarily precede the project but it is integrated throughout the activity. In this type students will choose the project first, then they discuss what they ought to know, and do. By executing the project work they learn the required techniques and concepts. In both approaches, there will be scope for feedback and reflection. Anyway, both the approaches are seen to be popular enough, because, many teachers especially in the field of vocational and industrial education use quite a good number of small-scale projects and this has enhanced the competence among students in solving several practical problems in their daily life situations.

Any project will have two essential components,

1. A Driving Question or Problem that serves to organize the project activities

2. Activities: These are the means of the project which should result in artifacts that culminate in a final product that addresses the driving question. The driving question designed by students and/or teachers should not be so constrained that the outcomes are predetermined, leaving students with little room to develop their approaches to answering the question.

A teacher can start the projects by approaching the students also; here students' perspective is taken into consideration. The teacher facilitates by giving the resources they need to make sense of project-based learning as a concept and the practical steps once they are engaged in the process. As a result of this, PBL places students in realistic,

contextualized problem-solving situations. Hence **Blumenfeldet al., (1991)** opines that projects can serve to build bridges between phenomena in the classroom and real-life experiences; the questions and answers that arise in their daily enterprise are given value and are shown to be open to systematic inquiry. Responsibility is passed on gradually from the teacher to the students; at the beginning, it is the teacher who guides the process and establishes the main lines, later the students take over the project management, and the teacher becomes an observer. The teacher controls the advancement of the students; he ensures the possibility to change roles by developing the knowledge and skills of the students, assessing their performance with criticism, and introducing new ideas and methods in the learning process, thus eliminating the factors which limit their development.

Now let us try to see some of the examples with an illustration about projects in learning Biology:

1. Visit Zoo: In one of the science-based projects, students visited Zoo to learn about animal habitats and prepared a report on which habitats best suit a selected animal.

2. Mushroom Culture: This being a very interesting activity will motivate the students. This project will not only enhance the knowledge about non-chlorophyll plants but also nurture the vocational and utilitarian value. Edible Mushroom is the best nutritious food that suits developing and underdeveloped countries, where children because of poverty suffer from malnutrition and under-development.

Milky mushroom (Calocybeindica) is the second tropical mushroom after paddy straw mushroom, suitable for cultivation in tropical and subtropical regions of the country. This variety is a new introduction to the world mushroom family from India. During the last decade, it has become a major variety for cultivation in South India and during the last 2-3 years, its cultivation has become popular in North India particularly in Haryana. Its high biological efficiency, better keeping quality, simple cultivation process and attractive white colour have increased its popularity. The steps to be followed to execute the mushroom cultivation will include, Substrate and substrate preparation, Spawning and spawn run, Casing, Cropping, Crop management.

3. Vegetative propagation- Cutting Grafting and Layering:

Plant Cutting, also known as striking/cloning, is a technique for vegetative (asexual) propagation of plants in which a piece of the source plant containing at least one stem cell is placed in a suitable medium such as moist soil, potting mix, coir or rock wool. The cutting region develops new roots, stems, or both, and thus becomes a new plant independent of the

parent. To have a fair number of cuttings catching on, the cutting should have good, moist soil with sufficient nutrients, a humid environment and partial shade (to prevent the cutting from drying out). After cuttings are placed in soil, they are watered thoroughly with a fine mist. After the initial watering, the soil is allowed to almost dry out before misting again, to keep the soil moist but not wet and waterlogged. Besides, the cutting needs to be taken correctly at the right time; with the right size and amount of foliage. Plants parts like, stem cutting, root cutting, scion cuttings, leaf cuttings could be used for this technique.

Similarly, students can proceed with vegetative propagation techniques, like, Layering and Grafting also.

Layering is a means of reproducing plants by placing an intact branch or stem in contact with soil, encouraging it to send out roots. Once rooted, the branch can be severed from the mother plant, roots and all, and planted elsewhere. Layering is also utilised by horticulturists to propagate plants with desirable properties. The horticultural layering process typically involves wounding the target region to expose the inner stem and optionally applying rooting compounds. In ground layering, the stem is bent down and the target region is buried in the soil.

Grafting is yet another horticultural technique used to join parts from two or more plants so that they appear to grow as a single plant. In grafting, the upper part (scion) of one plant grows on the root system (rootstock) of another plant. In grafting, one plant is selected for its roots, and this is called the stock or rootstock. The other plant is selected for its stems, leaves, flowers, or fruits and is called the scion. The scion contains the desired genes to be duplicated in future production by the stock/scion plant. For successful grafting to take place, the vascular cambium tissues of the stock and scion plants must be placed in contact with each other. Both tissues must be kept alive until the graft has taken, usually a period of a few weeks. Successful grafting requires that a vascular connection takes place between the two

tissues. Grafting is most commonly used for the propagation of trees and shrubs grown commercially. Grafting is limited to dicots and gymnosperms.

3. Microbes in human welfare: Useful Microbes – Microorganisms include bacteria, fungi, protozoa, some algae, viruses, viroid and also prions. **Microorganisms** may be single-celled like bacteria, some algae and protozoa, or multicellular, such as algae and fungi. For example Yeast, Lacto bacillus and Spirulina algae are beneficial to humankind. Any one of these topics will give ample scope to conduct a project study.

Apart from the above activities, there are several very interesting projects which promote all the science process skills among students. Some of them are given below; you can try these projects (of course with modifications) with your students.

- Growing orchids
- Growing Anthurium
- Preparation of working models
- Antibiotics and Resistance.
- Global Warming.
- Hormones and their roles.
- Pollination in flowers and allergies.
- Hybrids
- Biology in daily life

Check Your Progress - 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. Essentially a project should have
    a. Guidance
    b. Activities
    c. Table work
    d. Self-discoveries
2. the project must
    a. Confine to the textbook
    b. Go beyond the textbook
    c. Relate to the real-life
    d. Make the content learning contextual

3. Below are given some statements, put √ mark for the correct one and X for the wrong one:
    a. The teacher can start the project by taking students' perspectives into consideration
    b. Projects make the students always dependent on their teachers
    c. Left to students only, it will be impossible to carry out the projects
    d. If a teacher adapts project-based learning, then completion of the syllabus will be very difficult
    e. Projects help to educate students catering to the development of Head, Heart and Hands (3Hs)
    f. Projects fulfill educational, vocational and utilitarian values.

2.5.4. Let us Summarise

The whole education system is focusing on making our students able to think independently so that they become autonomous learners and their out of the school life will have the implementation of what they acquire as knowledge and abilities in the schools. Projects as a means of learning have been strongly identified in this direction. A project fulfils all the democratic values and educational aims. According to Ballard, a project is a bit of real-life that has been imported into the school. Supporting this viewpoint, Thomas and Lang have defined that, a project is a voluntarily undertaking which involves constructive effort or thought and eventuates into objective results. The project method is not new. It owes its origin to the American philosophers belonging to the pragmatic school of philosophy.

W. H. Kilpatrick was a chief proponent of the project method. Project-based learning (PBL) is an instructional approach designed to allow students to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world. Students work more independently through the PBL process, with the teacher providing support only when needed. According to Kokatsaki et al., PBL is characterised by students' autonomy, constructive investigations, goal-setting, collaboration, communication and reflection within real-world practices (2016).

Irrespective of any type of project will have the following steps, namely, Creating a Situation, Selection of the problem, Planning, Execution, Evaluation and Reporting and Recording. Though some time projects take a deviated route than the traditional one in the school system and thereby becoming uneconomical in time and resources, the benefits that students get will be more. Growing orchids, Growing Anthurium, Preparation of working models, Antibiotics and Resistance Global Warming, Hormones and roles, Pollination in flowers and allergies, Hybrids and Biology in Everyday-are some of the example for project-based learning.

2.5.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1

1. a
2. b
3. a-√ b-X c-√ d- X e-X f-X

Check Your Progress - 2

1. b
2. d
3. a- √ b-X c-X d-X e-√ f-√

2.5.6. Unit end Exercises

1. What is a Project?
2. Explain the salient features of a Project.
3. How a project could be used as an approach in the teaching-learning of Biology?
4. Mention the best strategies for learning Biology through projects.
5. Illustrate with examples for projects based learning in Biology
6. Bring out the advantages of having projects in teaching Biology

2.5.7. References

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Block 2 : Approaches and Strategies of Learning Biology

Unit 6 : Approaches and Strategies of learning Biology: Collaborative Approach

Unit Structure

2.6.1. Learning Objectives

After completing this Unit, the student teachers will be able to

- Explain the meaning of collaborative approach in learning Biology;
- Identify the salient features of a collaborative approach in teaching-learning of Biology;
- Develop a rationale for the use of a collaborative approach in the Biology Classroom;
- Illustrate with examples for the collaborative approach of teaching-learning of Biology; and
- Mention the merits and constraints of the collaborative approach in learning Biology.

2.6.2 Introduction

Man being a social animal should learn to live and adjust with others. "Live and Let Live" is the main principle for human beings. Coordination, Cooperation and Collaboration are the factors that make man's life sustainable. We know that collaboration has become a 21st-century trend. The need in society to think and work together on issues of critical concerns has increased (Austin J.E – 2000). There appears to be a shifting of emphasis from individual efforts to group work and from independence to the community (Leonard and Leonard-2001). If we take up the education field, collaboration is considered as one of the educational approaches. As an educational approach, it involves groups of learners working together to solve a problem, complete a task, or create a product. In this unit, you will come to know about the meaning and nature of the collaborative approach and how it is used in the teaching-learning of Biology. You will find illustrations that give a clear idea regarding the salient features of the collaborative approach. The unit also explains the constraints that one may come across while implementing this approach.

2.6.3. Learning Points and Learning Activities

2.6.3.1. Collaborative Approach in learning - Meaning, Nature and Importance

Gradually we see the fading of behaviourism and rising of constructivism in the dawn of the 21st century. **Lev Vygotsky** is one of the eminent proponents of constructivism. The collaborative approach leads to construct knowledge among students. So there is a strong

link between constructivism and the collaborative approach. Hence people recognize the root of collaborative learning in Lev Vygotsky's concept of learning called Zone of Proximal Development. According to Vygotsky, there are tasks that learners can and cannot accomplish. Between these two areas is the zone of proximal development, in which a learner can learn but with the help of guidance. In Vygotsky's definition of a zone of proximal development, learning through communication and interactions with others is very much important rather than just through independent work. This has made the way for the ideas of group learning, one of which being collaborative learning. In the collaborative learning environment, the learners are challenged both socially and emotionally as they listen to a different perspective and are required to articulate and defend their ideas. In so doing the learners begin to create their unique conceptual frameworks and are actively engaged.

Collaborative learning represents a significant shift from the typical teacher-centered or lecture-centered classrooms to an active working group of students. Of course, listening to lecture, notes taking may not disappear completely, but it gets associated with the students asking questions and queries, doubts and discussions in the class. The outstanding feature of collaborative learning is that learners in a small group help each other to learn. It is not just students talking and making noise in the class yet will be doing their assignments. And it is not that those who finish first will help others who are doing slowly, and it is not even one or a few students who do all the work, others append their names to the report (Klemn.W.R 1994). Here the shared learning allows learners to engage in discussion, take responsibility for their learning. People who support collaborative learning believe that the active exchange of ideas within small groups not only enhance interest among the participants but also promotes critical thinking.

Now let us look into some of the definitions and expressions given by experts so it will put more light on the understanding of collaborative learning:

- **Johnson & Johnson (1999) -** Collaborative learning (CL) can be defined as "a set of teaching and learning strategies promoting student collaboration in small groups (two to five students) to optimise their own and each other's learning".
- **Mac Gregor. J.T (1990) -** Collaborative Teaching and Learning is a teaching approach that involves groups of students working to solve a problem, complete a task or create a product.
- **Smith B.L & Mac Gregor (1992) -** Collaborative is an umbrella term for a variety of educational approaches involving joint intellectual effort by students or students and teachers together. Usually the activities centre on students' exploration or application of the course material not simply by the teacher's presentation or explanation.
- **Gerlach J.M (1994) -** Collaborative learning is based on the idea that learning is naturally a social act in which participants talk among themselves. It is through the talk that learning occurs.
- **Golub et al., (1988) -** Collaboration learning has as its main feature, a structure that allows for students to talk in which students are supposed to talk with each other and it is through this talking that much learning occurs.
- **Dillenbourg (1999) -** Collaborative learning is a situation in which two or more people learn or attempt to learn something together. Two or more - may be interpreted as a pair, a small group (3-5 subjects), or a class (20-30 subjects) Learn something – may be interpreted as following a course, perform learning activities such as problem-solving and together- may be interpreted as different forms of interaction which may be face to face or computer-mediated.

- **Pugach M & Johnson L.J. (1995) -** In education collaboration is intended to promote the most effective teaching possible for the greatest number of students.

By going through all these definitions, it will be clear that **Collaborative learning** is a situation in which two or more people learn or attempt to learn something together. Unlike individual learning, people engaged in collaborative learning capitalize on one another's resources and skills (asking one another for information, evaluating one another's ideas, monitoring one another's work, etc.). More specifically, collaborative learning is based on the model that knowledge can be created within a population where members actively interact by sharing experiences and take on asymmetric roles.

In the context of teaching-learning, collaborative learning refers to methodologies and environments in which learners engage in a common task where each individual depends on and is accountable to each other. These include face-to-face conversations and computer discussions (online forums, digital platforms, chat rooms, etc.). Hence methods for examining collaborative learning processes should include conversation analysis and statistical discourse analysis.

Gokhale (1995) expresses that collaborative learning is very important in achieving critical thinking. Individuals can achieve higher levels of learning and retain more information when they work in a group rather than individually, this applies to both the facilitators of knowledge, the instructors, and the receivers of knowledge, the students. Collaborative learning occurs because individual participation in learning occurs on a horizontal plane where children and adults are equal.

Johnson and others have pointed out five basic elements of collaborative learning. Collaborative learning is not simply a synonym for students working in groups. A learning exercise only qualifies as collaborative learning to the extent that the following elements are present and well satisfied:

1. **Clearly perceived positive interdependence:** Team members are obliged to rely on one another to achieve the goal. If any team member fails to do their part, everyone suffers consequences. Members need to believe that they are linked with all others in a way that ensures that they all succeed together.
2. **Considerable interaction:** Members help and encourage each other to learn. They do this by explaining interactively providing one another's conclusions and reasoning and perhaps most importantly teaching and encouraging one another.
3. **Individual accountability and personal responsibility:** All students in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned.
4. **Social skills:** Students are encouraged to and helped to develop and practice trust-building, leadership, decision-making, communication and conflict management skills.
5. **Group self-evaluating:** Team members set group goals, periodically assess whether they are doing well as a team, and identify changes they will make to function more effectively in the future.

Collaborative learning as an alternative to the conventional teaching-learning process is quite challenging and problematic also. Both teachers and students may face some critical problems while implementing the collaborative learning approach. Some of them are:

Problems among Students:
Research has shown that students encounter several problems during collaboration (Janssen et al., 2007) such as

- Lack of collaborative skills among students
- Low-quality coordination among group members when they participated in problem-solving tasks.
- Group members may not pay attention to others' opinions, interrupt them, and reject alternative suggestions without justification. These inappropriate behaviours inhibit group functioning and individual learning.
- The quality of students' explanations in group interaction in primary and secondary classrooms is often below a level that enables shared knowledge construction.
- Help-seekers may be unable to collaborate effectively.

Problems faced by Teachers:

- Teachers often face challenges while structuring collaborative activities such as monitoring students' on-task behaviour, managing group-work time, providing relevant materials, assigning individual roles, and establishing teamwork beliefs and behaviours
- Insufficient attention of teachers towards organising collaborative work such as determining group norms and facilitating activities.
- A large number of primary and secondary school teachers often place students in groups and let them work together without preparing students to perform collaborative activities productively (Blatchford et al., 2003).
- Teachers frequently find it difficult to assess students' performance and achievements as they implement CL in classrooms at all levels of education (Strijbos, 2011).
- The criteria or rules for assessment may lack transparency and concreteness. Furthermore, the lack of assessment tools to measure the collaborative performance of every group member may cause student disappointment about the transparency and evenness of the assessment (Strom & Strom, 2011).

If teachers, for example, are not sure about how to monitor students' group discussions, and cannot adequately intervene when necessary or model appropriate collaborative behaviour, it may affect the quality of the collaborative process among students also. However one cannot deny the advantages and the possibilities of developing powerful personalities among students through adapting collaborative learning.

Collaborative learning is recognised for attaining higher-level thinking and retain information for longer times than students working individually. It is because,

There will be intense interaction among the members of the group and groups tend to learn through "discussion, clarification of ideas, and evaluation of other's ideas." This may result in the retention of the information in long-term memory. Research by Webb suggests that students who worked collaboratively on math computational problems earned significantly higher scores than those who worked alone. Apart from this, students who demonstrated lower levels of achievement improved when working in diverse groups. As Vygotsky is considered as the father of 'social learning,' advocated assessing students' ability to solve problems rather than merely acquire knowledge. The idea of collaborative learning has a lot to do with Vygotsky's idea of the "zone of proximal development." It considers what a student can do if aided by peers and adults.

The salient features of the collaborative approach in learning are,

- Always students are associated with one another, forming groups and sharing ideas
- The teacher's role will be minimized and students are given both freedom and responsibilities
- Students are free to move with peers and here each individual brings new knowledge to share with others
- It will be almost synonym with the Principles of Constructivism
- If any member of the group is not reciprocating means, the whole group has to bear the consequences
- Every member of a group will work
- Any defective or productive aspects will get balanced by the involvement of the members in collaboration
- Collaborative learning occurs in a social set up impregnated with democratic values
- It is the practical expression of Vygotsky's "Zone of Proximal Development"
- There will be ample scope for quality learning and for this scaffolding from the more knowledgeable other persons who are in collaboration is the cause

Advantages of Collaborative learning:

- Students will learn how to work in a group setting and collaborate their conceptual ideas
- It gives a concrete platform for the sharing of ideas and constructs new knowledge
- There will be strong chances for cognitive, affective, and psychomotor development
- Students will get a forum/platform for valuing other opinions and looking at things from another person's point of view
- Students will learn the benefits of being in partnerships with healthy relationships
- Make the students understand the value of dignity of labour
- Students feel the satisfaction of belongingness and realise the significance of working together
- Students explore and discover on their own and learn to maintain the integrity of the group
- Collaborative learning makes the students goal-oriented and focuses on achievements with team spirit

Check Your Progress - 1

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. The root of a collaborative approach is identified with
    a. Vygotsky's Zone of Proximal Development
    b. Jean Piaget's Assimilation and accommodation
    c. Bruner's Concept Formation
    d. Skinner's Chaining

2. Collaborative Learning occurs in
    a. Teacher dominated and disciplined class
    b. Exam-oriented classroom activities
    c. Classroom with the traditional environment
    d. Social set-up impregnated with democratic values

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:

a. Since it is a group learning approach, any single member's passiveness will not affect the collaborative approach
b. Collaborative learning makes the students learn working in a team
c. Principles of constructivism are rarely found in the collaborative approach
d. Collaborative learning is a situation in which two or more people learn or attempt to learn something together.
e. Collaborative learning will not give any scope for individual expressions
f. Students will lose their identity in collaborative learning

2.6.3.2. Application of Collaborative Approach in learning Biology

One of the measures to provide collaborative opportunities for students of biology is cooperative learning, a theoretically grounded and well-researched approach in education that can increase students' learning of subject matter and improve their attitudes toward both academics in general and the subject matter in specific. However cooperative approach and collaborative approach are not the same. While both models use the principle of division and dignity of labour, collaborative learning requires the mutual engagement of all participants and a coordinated effort to solve the problem whereas cooperative learning requires individuals to take responsibility for a specific section and then coordinate their respective parts together. Another differentiation is that cooperative learning is typically used for small children to make them understand the foundations of knowledge while collaborative learning applies to higher secondary students; there it is used to teach non-foundations of learning as well. Anyhow, both measures are meant for group learning mechanisms to acquire a set of skills or knowledge.

We know that learning is a social process by nature. Using different mediums, whether it be books, discussions, technology, or projects we study and develop new ideas. We impart ideas and share perspectives with others. Collaboration is a learned process. If managed correctly, it is a powerful tool that can allow educators to tap into new ideas and information. Hence teachers must keep the following points in their mind for establishing a collaborative approach in learning irrespective of the subject:

1. Determining the Goals and Objectives

For any planning, a strong goal and objective are very essential. Since collaborative learning is a social event, it has to be planned meticulously. And this planning starts with determining the goals and objectives of the specific learning process. It has to be group goals as well as individual and should reflect the accountability of the group members. This will keep the task on track and enhance the effectiveness of the collaborative approach.

2. Size of the Group:

If the size of the group is too small then it will lack enough diversity and this may limit the divergent thinking process. Similarly, if the size of the group is very large, then it may create chaos and many may not participate also. So the size of the group matters here, better if it is of having 4 to 6 who can actively contribute to the collective task.

3. Prescribe group norms that are flexible enough:

Collaborative learning is founded on interactions among students in the group. Research studies have suggested that collaborative learning is influenced by the quality of interactions.

Here interactions and negotiations are important for collaborative learning. Jacobs and Campbell (1960) suggest that norms are pervasive and hence establish rules for group interactions for younger students and older students might create their norms. But it is best to have flexible norms. Norms should change with situations so that groups do not become rigid and intolerant or develop sub-groups.

4. Encourage open communication

Open communication is the key to success in collaborative learning. For successful open communication, everyone in the group should have faith and trust in each other. Any interpersonal problems or emotional issues should get cleared off then and there. Research studies have shown that students who provide and receive intricate explanations gain most from collaborative learning.

5. Assigning individual roles to group members:

Students could be assigned different roles like leader, recorder, reporter, and a fact-checker. The students might have turns to choose their roles and alternate roles. It's always better to keep them free from any role-based prejudices.

6. Create an inbuilt mechanism to check the effectiveness of collaborative learning:

To make it more scientific it is better to have a pre-test and post-test design for the task. This will give a sort of seriousness to students. Based on the feedback further improvement could be done while the process is still in progress.

According to Robert Slavin, Social and Psychological effects on self-esteem and personal development are equally important as learning itself. Hence for assessment, he says that it may be beneficial to grade students on the quality of discussion, student engagement, and adherence to group norms. Collaborative learning is somewhat a new type and it is a process that needs explicit instruction in the beginning phase. Assessing the process itself motivates students to learn how to behave in groups. It shows students that you valued meaningful group interactions and adhering to norms.

7. Consider using different strategies, like the Jigsaw technique.

The jigsaw strategy is said to improve social interactions in learning and support diversity. The workplace is often like a jigsaw. It involves separating an assignment into subtasks, where individuals research their assigned area. Students with the same topic from different groups might meet together to discuss ideas between groups. This type of collaboration allows students to become 'experts' in their assigned topic. Students then return to their primary group to educate others. Strategies here include using clusters, buzz groups, round-robin, or fishbowl discussions.

8. Ample scope for group interactions and measures to reduce anxiety

Collaborative learning will be successful by the source of support. Groups often use humour and create a more relaxed learning atmosphere that allows for positive learning experiences. Allow groups to use some stress-reducing strategies as long as they stay on task.

The quality of discussions is a predictor of the achievement of the group. It will be better if the instructors provide a model of how a successful group functions. Shared leadership is usually more effective. Roles delegation and execution are important in group development. If the goals are clear, instructions are free from ambiguity, and proper guidance during the

discussion is there, then students will feel relaxed and perform with quality efforts. The teacher should give a clear picture of what they have learned during collaboration.

9. Maintenance in collaborative learning:

Maintenance involves the harmony and emotional well-being of a group. Maintenance includes roles such as sensing group feelings, harmonizing, compromising, time-keeping, encouraging, relieving tension, bringing people into the discussion, and making it a live socio-emotional set up.

10. Use real-world problems:

Real-world problems can be used to facilitate project-based learning and often have the right scope for collaborative learning. Curriculum, syllabus, and textbook activities including the evaluation system should be relevant to real-life situations. So keeping real-world problems as contexts for collaborative learning will make it more meaningful and effective.

11. Focusing on problem-solving and critical thinking skills will make collaborative learning more live and authentic:

Design assignments that allow room for varied interpretations. Different types of problems might focus on categorizing, planning, taking multiple perspectives, or forming solutions.

12. Nurture the diversity of groups:

Always diversity is the symbol of a rich life. So try to have a variety of groups that include a range of talents, backgrounds, learning styles, ideas, and experiences. Studies have found that mixed aptitude groups tend to learn more from each other and increase the achievement of low performers. Rotate groups so that each student will have a chance to learn from everyone in the group.

13. Consider gender as one of the variables in collaborations:

In research studies, it is found that equally balanced gender groups were most effective. It is common to observe that, boys were more likely to receive and give elaborate explanations and their stances were more easily accepted by the group. In the groups where boys are more girls were ignored. And in groups where girls are more, they tend to direct questions to the boys who often ignored them. So keeping all these points very clear will make collaborative learning more effective.

14. Use scaffolding and diminished responsibility as students begin to understand concepts:

In collaborative learning the teacher's role will be a facilitator, such as by gauging group interactions or at first, providing a list of questions to consider. Allow groups to grow in responsibility as time goes on and allow teams to develop their topics or products as time goes on as increased responsibility for learning is a goal in collaborative learning.

15. Include different types of learning scenarios

Collaborative learning focuses on rich contexts and challenging questions. This will produce higher-order reasoning and critical thinking ability. Hence for collaborative learning, a teacher can give assignments that include laboratory work, study teams, debates, writing projects, problem-solving, and collaborative writing.

16. Technology makes collaborative learning easier

In the present situation, much collaboration is needed while making use of technology and digital-based resources. Its indeed becoming more useful to have digital platforms to have collaborations based on online/virtual learning with Google meet, Zoom, or Edurite. In collaborative learning, students need to respect and appreciate each other's viewpoints for it to work. For example, class discussions can emphasize the need for different perspectives. Hence, the classroom environment encourages independent thinking. Let students get accustomed to divergent thinking and lateral thoughts.

Examples and Illustrations for Collaborative Learning Approach in Biology:

Collaborative learning with well-defined objectives and meticulous planning will result in effective communication among peers, peer evaluation, problem-solving, and the possibility that students will begin to teach each other.

1. **Think-Pair-Share OR Write-Pair-Share:** The teacher may start by giving students a discussion prompt, questions, or a burning issue to consider. Students may take a few minutes to think and analyse. They may turn to form small groups and share their opinions or responses. Peers report their responses to each other in pairs. Lastly, some or all pairs will summarize their discussion for the large group. Students must work independently, communicate their ideas to peers, consider peer responses, and share that discussion in a way that begins to synthesize an exchange. While it is unlikely that all pairs in a class will have the opportunity for the last step, calling on random pairs means that most should be prepared. Think-pair-share or Write-pair-share requires that student acts instead of passively listening.
   Example: Eye-sight Problems, Types of Eye-sight Problems, and Causes-Vitamins defiance and remedial measures through food intake.

2. **Group Study:** Think of the 11 organ systems of the human body. Divide the class into groups and give each group one of the organ systems of the human body. For example, the Circulatory System. Then allow students to find out more information about the system. They would each pick an organ or part of the system to study as a mini-topic. They would then come together to share their results and learn how to be present to the class. Then allow the students to do various methods of displaying their findings. They can do PowerPoint, poster, video, pamphlet, etc. The limits are endless. The goal is that everyone learns about the systems and can later take a quiz on the material.

3. **Fish Bowl Debate:** Ask students to sit in groups of three. Assign roles. For example, the person on left takes one position on a topic for debate, the person on right takes the opposite position, and the person in the middle takes notes and decides which side is the most convincing and provides an argument for his or her choice. Debrief by calling on a few groups to summarize their discussions.
   Example: Is there any Bad-Cholesterol at all? Or Cholesterol is bad only?

4. **Case Study:** Create four or five case students of similar difficulty. Let them work in groups and analyze their case study. Interact with the students if they come across any hurdles and clarify those, facilitate their work. Give them sufficient time may be up to one week or a fortnight. One fine/final day call on groups randomly and ask them to share their task. Run the activity until each case study has been addressed.
   Example: How Malaria, Polio, Diphtheria, and Small Fox were eradicated?

5. **Group Problem-Solving:** This includes many strategies that involve collaboration among students and with higher authorities to solve a problem. Specifically, it may include, inquiry-based learning, discovery learning, and team teaching. Though each of these hasits features, essentially there will be certain fundamental principles, namely, i. Presenting students with a problem, ii. Providing some structure or guidance toward solving the problem which is student-centered in nature and may have a very minimal teacher's role and iii. Reaching an outcome or solution.
   Example: Discussing a solution to a waterborne viral outbreak in the community.

6. **Jigsaw strategy:** The ***jigsaw strategy*** breaks problems into small parts and assigns parts to groups who report back, contributing a piece of the puzzle's solution. For example, each student in a group might be assigned a distinct article to read on a shared topic or issue; each would present that article to the group in preparation for a synthesis of all articles.
   For example Topic on Stem Cells and their uses in the medical field, extending the same principle for deciduous teeth or milk teeth.

There are certain things to be borne in mind as you go on developing a collaborative approach with the students and it is better to ponder the following points in this context:

- Instead of starting the class with vague directions and initiating the discussion, it is better to focus on a particular topic with a meaningful question and then encourage the class to discussion
- Let the groups be formed with a definite objective and a purpose. Even a teacher can leave it to the students to form their group, but it should be weighed with its effectiveness of learning process and supported. Otherwise, it will be just chaos.
- Collaboration approach should get the output of the interactions/process at the end. Be it just a draft or informal summary of their discussion but it has to represent the product of a group's work. This is what we can call accountability. Accountability will motivate the students to put in their full effort and the product will represent their understanding of the task.
- It is better to have a spokesperson/facilitator or recording secretary instead of a "Leader" on whom more responsibilities will fall than his peers. While assigning roles there must be some norms/criteria.
- If the task is meant for the long-term then insist on regular interim reports. Teachers must be always alert and attentive to students' schedules. Use of grading rubric for collaborative projects is needed.

Check Your Progress – 2

Statements given below have alternative responses. Indicate (√) mark against the right one:

1. In a collaborative approach the role of a teacher will be,
   a. Facilitator
   b. Instructor
   c. Trainer
   d. Examiner

2. The pattern that supports the collaborative approach is,

a. Jigsaw strategy
b. Debates
c. Discussions
d. Teachers' explanation followed by notes

3. Below are given some statements, put (√) mark for the correct one and (X) for the wrong one:

a. Case studies cannot have any place in a collaborative approach
b. Instead of a Leader, the whole group with individual responsibilities is good
c. Collaborative approach is facilitated by indoctrinations
d. Students will learn to respect and accept the other's point of view in collaborations
e. In no way collaboration approach helps a teacher to complete the teaching portions
f. Collaborative approach lack systematic evaluation

2.6.4. Let us Summarise

A collaborative approach flourishes in a social context. It leads to the construction of knowledge by students' involvement and first-hand experience. Lev Vygotsky is one of the eminent proponents of constructivism. There is a strong link between constructivism and the collaborative approach. Hence people recognize the root of collaborative learning in Lev Vygotsky's concept of learning called Zone of Proximal Development. Collaborative learning represents a significant shift from the typical teacher-centered or lecture-centered classrooms to an active working group of students.

A collaborative approach may pose several problems to teachers as well as students, as it is not free from some difficulties in execution. But still, it is advocated to have a collaborative approach as one of the best teaching-learning processes. As there will be intense interaction among the member of the group and groups tend to learn through "discussion, clarification of ideas, and evaluation of other's ideas" this may result in retention of the information in long-term memory. There are certain points to be kept in mind while a teacher tries to adopt a collaborative approach, like, having clear and well-defined objectives, meticulous planning, and assigning the appropriate roles to the students, and also rigorously insisting on the output of the collaborative approach.

Despite the term collaborative learning (CL) has been used in a wide variety of ways across different disciplines and fields, there is a lack of consensus upon the definition of the term (Jenni, R. &Mauriel,J., 2004). While there is no consensus on what CL is, there are some underlying features that will be identified.

Collaboration has become a twenty-first-century trend. The need in society to think and work together on issues of critical concern has increased (Austin, J. E., 2000; Welch, M.,1998) shifting the emphasis from individual efforts to group work, from independence to the community (Leonard, P. E.& Leonard, L. J.,2001).

CL is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product. In the CL environment, the learners are challenged both socially and emotionally as they listen to different perspectives, and are required to articulate and defend their ideas. In so doing, the learners begin to create their unique conceptual frameworks and not rely solely on an expert's or a text's framework. In a CL setting, learners have the opportunity to converse with peers,

present and defend ideas, exchange diverse beliefs, question other conceptual frameworks, and are actively engaged (Srinivas, H., 2011).

CL represents a significant shift away from the typical teacher-centered or lecture-centered milieu in college classrooms. In collaborative classrooms, the lecturing/ listening/note-taking process may not disappear entirely, but it lives alongside other processes that are based on students' discussion and active work with the course material. Teachers who use CL approaches tend to think of themselves less as expert transmitters of knowledge to students.

2.6.5. Answers to 'Check Your Progress - 1 and 2'

Check Your Progress - 1

1. a
2. d
3. a- X b-√ c-X d-√ e-X f-X

Check Your Progress - 2

1. a
2. a
3. a- X b-√ c-X d-√ e-X f-X

2.6.6. Unit end Exercises

1. What is the meaning of a collaborative approach in learning Biology?
2. List the salient features of a collaborative approach in teaching-learning of Biology
3. Justify the use of a collaborative approach in the Biology Classroom
4. Illustrate with examples for the collaborative approach of teaching-learning of Biology
5. Mention the merits and constraints of the collaborative approach in learning Biology

2.6.7. References

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