# A STUDY OF THE EVOLUTION OF BIOLOGICAL SCIENCE CONCEPTS AMONG STUDENTS AT THE SECONDARY LEVEL

A Thesis Submitted to

Babu Banarasi Das University

For The Degree of

Doctor of Philosophy

in

EDUCATION

by

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Under the Supervision of

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## DECLARATION BY THE CANDIDATE

I, hereby, declare that the work presented in this thesis, entitled **"A Study of the Evolution of Biological Science Concepts Among Students at the Secondary level"**, in fulfilment of the requirements for the award of Degree of Doctor of Philosophy of Babu Banarasi Das University, Lucknow is an authentic record of my own research work carried out under the supervision of Prof. (Dr.) Kanak Dwivedi.

I also declare that the work embodied in the present thesis is my original work and has not been submitted by me for any other Degree or Diploma of any university or institution.

Date OJASWINEE PAL

## CERTIFICATE

This is to certify that the thesis, entitled **"A Study of the Evolution of Biological Science Concepts among Students at the Secondary Level"** submitted by

**Ojaswinee Pal**, for the award of Degree of Doctor of Philosophy by Babu Banarasi das University, Lucknow is a record of authentic work carried out by her under my supervision. To the best of my knowledge, the matter embodied in this thesis is the original work of the candidate and has not been submitted elsewhere for the award of any other degree or diploma.

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| Date :<br>Place : | | Signature<br>Professor (Dr.) KANAK DWIVEDI<br>Head, School of Education<br>Babu Banarasi Das University<br>Lucknow |

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## PREFACE

In presenting this doctoral thesis, I am filled with a profound sense of accomplishment and gratitude. This journey, undertaken with dedication and passion, has been a transformative experience that has shaped my academic and personal growth.

The exploration into the intricate realm of "A Study of the Evolution of Biological Science Concepts Among Students at the Secondary Level" has been both challenging and rewarding. This work represents the culmination of years of rigorous research, critical analysis, and countless hours of dedication. As I reflect on this academic odyssey, I am reminded of the many individuals and institutions that have played a pivotal role in shaping the trajectory of this research. At the lower secondary level, understanding of particulate (or microscopic level) level of concepts helps in developing understanding in the areas of living organism and reproduction. Teaching & learning at macroscopic level only, limits their understanding at the gross level. Several researchers have attempted conceptually oriented explanations. The attention of students is drawn towards contexts and phenomena related to concepts in the textbooks, scaffolding needs to done by teachers towards conceptual explanations which include the curriculum, teaching methods, assessment criteria, class room setting and student's motivation, interest and background knowledge. Improving the efficacy and quality of biology education, increasing students' scientific literacy and competence, deepening their understanding of the complexity and variety of life's biological systems and helping them to develop their critical thinking and problem-solving abilities are all potential outcomes of research into the historical development of biological science concepts.

The role of biological science within the school curriculum has been redefined in the recent past with the rapid explosion of scientific knowledge, and widening expectations of the society. New goals in biological science teaching are being identified globally to help produce scientifically literate citizens who understand how science, technology and society influence one another and who know how to use the knowledge in personal and social decisions. In addition, the research in biological science education and curriculum has influenced and been greatly influenced by research in other areas of education.

Biological science learning presents a challenge to educators because it has diversity and complexity of biological science knowledge rests on the organized conceptual framework and requires sophisticated knowledge construction and evaluation practices. One challenge at lower secondary stage is to identify the core ideas to teach which empowers students for further learning in biological science. Living organisms and Reproduction are two major and foundational concepts of biological science. This study makes an attempt to trace the evolution of important concepts which has implication for curriculum development at secondary level. The purpose of this study will be-

- To identify the conceptual ideas of students in two major biological concepts of class $6^{th}$, $7^{th}$ & $8^{th}$.
- To explore whether there will be progression from contextual knowledge to more biological knowledge to more biological understanding.
- To explore the trajectory of students from phenomenal to conceptual understanding and macroscopic to microscopic understanding.

The study is cross sectional in nature, it is suited to gather a large sample of secondary students views across age groups. Total 240 students of class $6^{th}$, $7^{th}$ & $8^{th}$ from two government schools are selected. Stratified random sampling technique will be used to select the samples.

Conceptual development about Living organisms and Reproduction will explore through self-made questionnaire to probe student's ideas. Text-book analysis in teaching and learning of these concepts provide effective, complete and accurate understanding. Multiple choice questions used for accessing knowledge. Graded achievement tests are developed by investigator separately for classes $6^{th}$, $7^{th}$ & $8^{th}$.

This study can be applied on major science concepts in science curriculum (from primary to senior secondary level and also in higher education), historical evolution of selected science concepts may be collated. This can help the curriculum planners and teachers to arrive at strategic procedure to develop progression maps for each science concepts. Textbook writers can reflect scientific evolution and communicate to science teacher community.

The School of Education, BBDU,Lucknow community has provided a nurturing academic environment, and I am grateful for the resources and opportunities it has offered. This thesis is not just an academic document; it is a testament to the collective efforts of those who have inspired and guided me. As I conclude this chapter of my academic journey, I am excited about the possibilities that lie ahead. May this work contribute meaningfully to the field of "A Study of the Evolution of Biological Science Concepts Among Students at the Secondary Level" and inspire future researchers to delve into the unexplored realms of knowledge.

Ojaswinee

Pal

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2024]

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# INTRODUCTION

## 1.1 Overview

Research into the composition, diversity, function, and history of life is known as biological science. The vast array of fields that make up biological science includes genetics, physiology, anatomy, zoology, ecology, evolutionary biology, molecular biology, cell biology, genetics, immunology, and genetic engineering. As a field, biological science seeks to explain not only how life on Earth came to be, but also how different kinds of life interact with one another, and what this all means for our collective well-being and the planet's future.

One of the most important and underlying ideas in biology is evolution, which describes the relationship between different kinds of living things and how they've developed and varied through time. In evolution, the genetic composition and inherited characteristics of a population undergo change from one generation to the next as a result of descent with modification. Genetic drift, mutation, natural selection, gene flow, and other processes all play a role in driving evolution. Several variables impact evolution as well, including surrounding conditions, population size, reproductive rate, and mutation rate. Adaptation, speciation, convolution, and extinction are mere consequences that evolution can bring about.

What we know about the origins, development, and transmission of fundamental biological ideas like the cell, gene, DNA, evolution, and ecology, as well as how these ideas are taught and learned, can be traced back through the subject of evolutionary biology.

Several elements can impact the study of how biological science concepts have developed through time. These include the discipline's history, philosophy, and sociology, as well as the curriculum, teaching methods, assessment criteria, classroom setting, and students' motivation, interest, and background knowledge. Improving the efficacy and quality of biology education, increasing students' scientific literacy and competence, deepening their understanding of the complexity and variety of life's biological systems, and helping them develop their critical thinking and problem-solving abilities are all potential outcomes of research into the historical development of biological science concepts (Banet, & Ayuso, 2003).

## 1.2 History of Biological Science

The study of life on Earth has been documented throughout the history of biology, which spans from antiquity to the present day. Biological sciences developed from medical and natural history traditions that originated in ayurveda, ancient Egyptian medicine, and the writings of Aristotle and Galen in the ancient Greco-Roman civilization. The idea of biology as a distinct discipline didn't arise until the nineteenth century. Muslim philosophers and doctors like Avicenna expanded upon this old text during the Middle Ages. A resurgence of empiricism and the identification of several new species throughout the Renaissance and early modern era in Europe shook up biological theory. Physiologists Vesalius and Harvey were prominent figures in this school of thought, as were naturalists Linnaeus and Buffon, who started to categorize the variety of life on Earth, the fossil record, and how species evolved and behaved. Antonie van Leeuwenhoek laid the framework for cell theory by exposing the world of microbes to microscopy, which had hitherto been unknown. Natural history flourished as a result of the increasing relevance of natural theology, which was in turn prompted by the emergence of mechanical philosophy (Rosenberg, 1985).

The fields of botany and zoology, which deal with living organisms, evolved into distinct scientific specializations in the 18th and 19th centuries. Through their work in chemistry and physics, Lavoisier and other physical scientists started to draw connections between the living and nonliving realms. The fields of biogeography, ecology, and ethnology can trace their roots back to the work of explorer-naturalists like Alexander von Humboldt, who sought to understand how species interact with their environments and how this interaction is influenced by geography. A shift away from essentialism and toward an emphasis on extinction and species' malleability occurred among naturalists. A fresh viewpoint on the essential building blocks of life was offered by cell theory. Natural selection, Charles Darwin's theory of evolution, used these findings along with those of embryology and palaeontology. Though the process of heredity remained unknown, the germ theory of disease rose to prominence around the turn of the nineteenth century and spontaneous generation fell by the wayside (Barras & Greub, 2014).

Through the rediscovery of Gregor Mendel's work in the early 1900s, Thomas Hunt Morgan and his students propelled genetics forward at a quick pace. By the 1930s, a new field called the neo-Darwinian synthesis had emerged, which combined population genetics with natural selection. The rapid development of new fields of study was accelerated by the proposal of the DNA structure by James Watson and Francis Crick. There was a clear division in the biological community after the discovery of the genetic code and the Central Dogma: organismal biology, which studies entire creatures or groups of organisms, and cellular and molecular biology, which study individual cells or molecules. Molecular and cell biologists studied the genetics of natural populations of organisms, the interaction between genes and the environment, and organism biologists used molecular techniques; new areas such as proteomics and genomics were reversing this trend by the late 20th century (Liber, 2021).

### 1.2.1 Biology

The field of study known as biology delves into the ins and outs of all things pertaining to living things, including their anatomy, physiology, genetics, ecology, morphology, identification, and classification systems. Bioscience is the study of life in its most basic sense. From the intricate chemical machinery of individual cells to the grand ideas of ecosystems and climate change, the scope of biology is enormous.

Human reproductive systems, genetic makeup, and the inner workings of the brain are all topics that biologists delve deeply into. Because of its relevance to careers in medicine, zoology, botany, pharmacy, biochemistry, and biotechnology, biology is a required course of study. Appropriate and sufficient tactics must be employed when dealing with biology, as it directly impacts the lives of the learners. Esiobu and Soyibo (1995) examined the impact of different teaching methods on Physics students' performance in the classroom. There were a total of nine classes utilized: nine experimental and nine controls. Concept mapping students in the experimental group outperformed their more conventionally taught counterparts in the control group, despite the fact that both groups had access to the same course materials. Bichi and Ibrahim, (2002) examined the impact of pedagogical approach and curricular enhancement on the idea of evolution. The study's experimental group used a problem-solving strategy integrated within a more traditional curriculum, whereas the control group continued to use more conventional approaches. Significantly superior results were obtained by the experimental group.

What we call, instructional materials are things that teachers and students can utilize to make sure lessons go well. You can't teach or study biology without materials and resources because it is an activity-based, student-cantered subject. According to Adeyemi (2008), Utilizing tangible resources in a hands-on manner enhances kids' learning. The results by Okobia et al., (2006), Akpochafo (2009), Arisi and Ost-Gin, (2002), pupils' performance in secondary school is positively affected by the use of effective instructional tactics. According to Fagbemi (2020) and Alawaet et al., (2011), students' performance in Biology classes is positively impacted by lessons that use makeshift resources.

### 1.2.2 Important Concepts in Biology

- **Reproduction**

Creating an exact replica of an organism in order to ensure its survival is the essence of reproduction, one of the most fundamental ideas in biology. The common understanding of reproduction focuses only on the process of creating new life within an organism, while the broader definition is of considerably more importance to all forms of life on Earth. This becomes clear when one thinks about how life began and how creatures have changed through time. A capacity for some early chemical system to replicate itself must have been one of the earliest features of life that appeared in prehistoric times.

Reproduction, therefore, begins with chemical replication. Cells with ever-increasing degrees of complexity must have emerged as evolution continued, and the capacity to create mirror images of oneself was crucial. The capacity of a single cell to replicate itself signifies the creation of a new individual in organisms with one cell, but in multi cellular ones, it denotes development and renewal. While all living things eventually generate new generations of themselves, multi cellular creatures have a plethora of reproductive strategies, many of which include intricate hormone systems and sophisticated structures that allow them to reproduce in the strictest sense.

★**Understanding students' conceptions of plant reproduction to better teach plant biology in schools.**

One obstacle to teaching students about plant biology in the classroom is the condition known as ―plant blindness (Wandersee et al., 2001). Researchers have found that kids care more about animals than plants, that they remember pictures of animals more easily than plants, that they know very little about common wildflowers, and that they do not think plants are important (Kinchin, 2000; Schussler & Olzak, 2008; Bebbington, 2005; Wandersee & Schussler, 1999). Teachers aren't the only ones impacted by plant blindness; it forces them to devote additional class time to covering other areas of biology (Hershey et al., 1993). The textbooks, according to Schussler et al., (2010), even place greater emphasis on animals than plants. Plants are essential to our ecosystems and our everyday lives as main sources of organic chemicals, which is why teaching about them is so vital.

However, the question remains: how can one overcome plant blindness? Methods for educating about plants have been the subject of several encouraging studies. Students' interest in plants can be piqued by hands-on experiences with plants and information about their characteristics, as demonstrated by Strgar (2007). Plants with practical uses and strong human relevance might help pique students' interests (Pany & Heidinger, 2015). Botanical gardens provide another opportunity for students to interact with plants; instructors can facilitate student work with plants utilizing mobile devices. Outdoor educational programs that center on plants present an intriguing possibility for changing people's understanding and perspective of these living organisms (Fančovičová & Prokop, 2011). According to Stagg and Verde (2018), instructional theater has also been found to promote better plant knowledge and attitudes. Observing the plants along the route to school can help pupils become more conscious of the presence of wildflowers in their everyday lives. Additionally, it is simple to cultivate and study plants inside, which can enhance curiosity, understanding, and perspective (Nyberg & Sanders, 2014).

### ♣Living organisms

The study of life and living things is known as biology, and one of the key notions in this field is the idea of living creatures. Numerous fields and subjects fall under the umbrella of biology, including genetics, ecology, cell biology, and biotechnology, among many others (Canguilhem & Savage, 2001).

There are a number of cornerstone ideas that support our current understanding of life in biology, the scientific study of creatures. The most fundamental idea is cellular structure, which states that every living thing consists of cells. Natural selection is the driving force behind evolution, the overarching biological theory that explains both the variety of life and the interdependence of different species. The capacity of living things to keep their internal environments stable in the face of external perturbations is called homeostasis. Traits are passed on from parents to children based on the genetic information that is stored in DNA. The metabolic process, which includes all of an organism's chemical reactions, is what keeps things running. Finally, interdependence drives home the point that all living things and their environments are intricately related. All of biological knowledge rests on these fundamental principles, which provide light on the intricate workings of the natural world's living creatures (Ruiz-Miraz et al., 2000).

### ★Understanding students' Conceptions and Modern Method to Teach Living Organisms in Schools

GIn order to adapt contemporary biology teaching approaches to secondary school students, it is crucial to understand how pupils conceptualize biological things. To keep students interested and increase their understanding in today's classrooms, creative teachers are finding new ways to use technology and interactive learning tools. Students can experience life at the microscopic level, see biological processes, and perform virtual experiments through the use of educational apps and virtual simulations, which is one contemporary approach. In addition to enhancing the learning experience, these tools are designed to accommodate various learning styles, which in turn promote a more profound comprehension of living beings.

Another effective modern method is to include real-world examples and case studies into the curriculum. Educators can make biological concepts more relevant and understandable for secondary pupils by relating them to real-life applications and current events. This strategy highlights the wider influence of biology on domains including biotechnology, environmental science, and medicine, while simultaneously igniting curiosity. In doing so, it hopes to inspire students to recognize the relevance of biological knowledge to solving problems in the actual world.

The use of inquiry-based and collaborative learning strategies also encourages student agency in the classroom. Encouragement of inquiry and analysis via collaborative work, class debates, and practical exercises. In order to foster a more well-rounded understanding that goes beyond what is taught in textbooks; educators should encourage students to study living things in their native habitats. In addition to improving understanding, this student-cantered approach fosters a love of the biological world's complexities for the rest of the student's life.

In conclusion, educators can successfully address students' views of living beings by embracing current teaching techniques that include technology, real-world applications, and student-cantered approaches. This does double duty: it enhances secondary school biology classes and encourages students to develop a more profound respect for the natural environment. (Weibel, 1991).

### 1.2.3 Biological Science Knowledge

The study of all things having to do with life is known as biological sciences. ―Biology‖ is another name for it. Logos means learning and bio means life in Greek. The term biology was first used by Pierre-Antoine de Monet and Jean-Baptiste de Lamarck in the late 1700s.

In the past, the study of living things was limited to the pure sciences, which include biology as well as botany and zoology. However, various subfields emerged and cutting-edge technology emerged in both fundamental and applied areas, eventually giving birth to a vastly diverse scientific discipline known as the Biological Sciences (Freeman, 2008).

The vast field of biological sciences delves into everything from the intricate chemical processes occurring within individual cells to the more macro-level ideas of ecosystems and the effects of climate change on the entire planet. Science also delves into the origins, behaviors, and physical traits of all living things, whether ancient and modern, as well as their relationships with one another and their surroundings. Biological science delves deeply into the study of human anatomy, physiology, and genetics, including the reproductive system. A new moniker for it has emerged in recent years: life sciences (Antezana et al., 2009). For those interested in —a systematic study of living beings or study of nature, that's the definition of the life sciences. The primary focus of life science education is keeping students up-to-date on global advances in the biological sciences (Mamoni, 2018).

### 1.2.4 Secondary School Level in Education

The academic instruction that is included spans two to three years, from eighth grade to tenth grade. It covers pupils whose ages range from fourteen to sixteen. Institutions that formally educate students up to the tenth grade are known as secondary schools. Senior schools or high schools are other names for them. According to Mexus Education's Reviving Indian Education, there are two main kinds of secondary school models.

- The eighth through tenth grades are considered secondary education in certain states and union territories. Some of these states include Goa, Dadra & Nagar Haveli, Gujarat, Daman & Diu, Kerala, Karnataka, and many more.
- The ninth and tenth grades are considered secondary education in several states and union territories. Delhi, Rajasthan, Punjab, Sikkim, Chandigarh, and the Andaman and Nicobar Islands are just a few examples (Khan et al., 2015).

★ **The knowledge of Biological Sciences helps the student:**

- To help the person become more attuned to and comfortable in nature.
- The idea that all life on Earth descended from a common ancestor helps to foster a sense of oneness among all sentient beings.
- Brings a scientific perspective.
- Protects the environment by cultivating a reverence for it.
- Dogmatic approach is eliminated.
- To describe the living world in terms of scientific concepts and to value all creatures regardless of their behaviour.
- Display skills that are distinct from one another.
- Make the students' natural curiosity satisfied.
- Show curiosity in his environment (Watters, & Watters, 2007).

### 1.3 Evolution of Biological Science Knowledge

The branch of biology known as - evolutionary biology investigates how different forms of life on Earth came to be through the three main evolutionary processes: common descent, speciation, and natural selection. Another definition is the study of Earth's past living forms. All organisms are interdependent and undergo steady change throughout time, according to evolution (Soto, 2022). Phenotypes are the outward manifestations of an organism's genetic makeup; these differences manifest in populations. These phenotypic alterations will benefit certain creatures, and they will pass these benefits on to their children. The flightless birds and peppered moths are two examples of creatures that have evolved over many generations. Genetics, ecology, systematic, and palaeontology were all formerly separate branches of biology that came together in the 1930s to become evolutionary biology, a phenomenon referred to by Julian Huxley as the modern synthesis of knowing.

Molecular evolution, sexual selection, genetic drift, and biogeography are only a few of the many forces that contribute to evolution; in recent years, researchers have expanded their exploratory scope to include the genetic architecture of adaptation. A more comprehensive synthesis that incorporates developmental biology into the domains studied by the former evolutionary synthesis has resulted from the more recent area of evolutionary developmental biology (evo-devo), which seeks to understand the mechanisms that regulate embryogenesis (Babaagba & Ayodele, 2023).

In biology, evolution serves as the overarching unifying principle. There are multiple ways to classify biological phenomena. Organized biologically at many scales, from molecules to cells to organisms to populations, is one approach. Another approach is to classify organisms according to their supposed taxonomic groupings; disciplines like microbiology, botany, and zoology reflect these historical divides. The third technique is to use methods from fields like palaeontology, experimental evolution, theoretical biology, and field biology. Evolutionary developmental biology and evolutionary ecology are two examples of how these non-traditional approaches to subject categorization have been integrated with evolutionary biology (Balaban et al., 2019).

New domains that are extensions of evolutionary biology have emerged more recently as a result of the integration of biological and applied sciences. These include evolutionary robotics, engineering, algorithms, economics, and architecture (Jacobides & Winter, 2012).

Indirectly or directly, we use the fundamental mechanisms of evolution to solve problems that might otherwise be intractable or to generate new innovations. Particularly from studies focusing on evolution in computer science and engineering domains like mechanical engineering, research in these applied areas contributes to advancement (Herrmann-Pillath, 2017).

### 1.3.1 Biological Concepts and Nature of Biological Concepts

The study of all forms of life and the entities that inhabit them is known as biology. The study of living things and their structure, function, growth, distribution, evolution, and other characteristics is the focus of numerous subfields within modern biology. Although biology covers a lot of ground, there are some overarching principles that apply to all of it:

- Every living thing begins with a cell.
- DNA or RNA molecules called genes are the building blocks of hereditary traits.
- The harmony and variety observed in all forms of life can be explained by evolution.
- In order to stay alive, every living thing must consume and convert energy.
- Every living thing keeps its internal environment constant.

Studies in biology show that, billions of years before bigger creatures evolved, the Earth was inhabited by tiny microbes. All of our beloved flora, fauna, and mammals have emerged within the past two hundred million years. Homo sapiens, the modern-looking human race, has only been here for about 200 thousand years, making us a very young species (Leord, 2023).

### 1.3.2 Biological Concepts and Conceptions

Scientific theories and hypotheses about the composition, adaptation, diversity, and history of life are collectively known as biological concepts and conceptions. Biological science, the scientific discipline that investigates life, provides the empirical data and theoretical foundations upon which biological notions and conceptions are built. Molecular, cellular, organism, population, community, ecosystem, and biosphere are some of the levels of organization that can be used to classify biological concepts and interpretations. There are several subfields and fields within biology that deal with specific ideas and concepts. These include genetics, immunology, physiology, anatomy, zoology, botany, ecology, and evolutionary biology (Barak et al., 1997).

★Conceptions of Learning

In education, a COL is a set of shared beliefs and assumptions about what it means to learn (Benson & Lor, 1999). It has alternatively been characterized as the material or subjects covered in class, or as the student's interpretation of that material (Benson & Lor, 1999). Another source states that a COL might be defined as an individual's learning objectives, plans, or methods, or even the act of learning itself (Vermut& Vermetten, 2004). Both Buehl & Alexander (2001) and Tsai (2004) agree that a student's COL consists of their academic epistemic beliefs and the knowledge they have gained in the classroom. Researchers have shown that pupils often have diverse ways of thinking about what they study (Tsai, 2004).

According to Taşkın et al., (2015), and Säljö (1979) was one of the first researchers to study COL. He classified students' COLs as either increasing their knowledge, retaining and using it when needed, having knowledge of reality, or abstracting meaning, which is a process that aims at understanding and comprehension. These categories are mentioned in later research in numerous ways, including memorization, exam preparation, calculation, practice, improving knowledge, understanding, application, and new ways of perceiving (Martin et al., 1993).

According to Tsai (2004), the low-level COLs comprise the first three levels of this classification, while the high-level COLs comprise the last four. According to Tsai (2004), students who possess high-level COLs actively participate in their learning and approach it from a broad perspective, in contrast to those who possess low-level COLs, who tend to be more passive and have a more restricted viewpoint. Because they don't bother to look for the meaning, students with low-level COLs just absorb the material they deem relevant for their studies (Liang & Tsai, 2010). People with high-level COLs, on the other hand, put their knowledge of the subject at the forefront, draw parallels between novel situations and their own lives, and approach current events with a critical eye (Sadi & Lee, 2018).

### 1.3.3 Biological Conceptual Changes

Philosophy of biology and philosophy of science as a whole are in a very bad place right now. Twenty years ago, many philosophers believed they had found solutions to at least three broad problems; now, it seems like all of that was wrong. First, there's the challenge of defining and comprehending how scientific concepts evolve over time. Second, there's the matter of comprehending how different theories relate to one another, especially when it comes to reducing one theory to another. Lastly, there's the matter of scientific realism, which is the question of how seriously one should take the assertions made by theoretical scientists or, at the very least, certain theoretical scientists, that the world can be described literally using theoretical entities like quarks, genes, DNA molecules, and protons. The philosophical study of sciences is profoundly affected by this whole situation. There are many beautiful studies of many issues in philosophy of biology, but alas, no large-scale synthesis that satisfies everyone is in sight. There is no universally accepted basis for the study's conclusions, and hence no way to address all of the theoretical concerns raised by philosophers and scientists in relation to biology (Darden, 1977).

An early report on a novel method of conceptual transformation, with a rough outline of its potential use in relevant biological contexts. With any luck, this method will provide a good foundation for in-depth analyses of scientific progress that is consistent with scientific reality. It will be helpful to indicate how different gene notions will join the conversation before I draw in some of the important philosophical background. Since Mendel's work was rediscovery, eighty-four years have passed. The classical theories of the gene's basic features were well-established within fifteen years after that event, for example, with the publication of The Mechanism of Mendelian Heredity by Morganet et al., (1923). Much of the theory's current iteration is based on a steady stream of updates and enhancements that were formerly based on tedious but fascinating experimental work (Coleman, 1971).

In fact, the cumulative modifications are so profound that some have described this historical process as the replacement of Mendelian genetics with a set of superior successors that go under the umbrella of transmission genetics. This prolonged procedure, in its theoretical as well as its empirical components, contributed to laying the groundwork for what is generally acknowledged as (to borrow the fashionable term) a scientific revolution sparkedby the development of molecular genetics. For the time being, we can commemorate its arrival with the release of the rightfully renowned solution to the primary structure of DNA in Watson and Crick (1953).

### 1.3.4 Conceptual Change and Evolutionary Biology (A Developmental Perspective)

The strongest evidence in favour of the concept that human cognition is constrained by intuitions that make it more resistant to evolutionary reasoning should come from the developmental sciences. These limitations ought to emerge early on, alter gradually as a child grows, and endure into maturity, even when they are altered by cultural influences.

In conclusion, the author should anticipate changes in children's comprehension of evolutionary concepts that are connected to their developing comprehension of human minds.as well as of nature. Young children should be relatively tolerant of the idea that animate motion has purpose and quite resistant to the idea that animals may change (Evans, 2000).

Furthermore, a wealth of research on children's theory of mind ought to demonstrate alterations in their day-to-day psychology that are connected to their comprehension of intelligent design. These relationships were discovered in a number of studies that looked at the early emergence of theories regarding the origins of species in diverse communities, though there were some unexpected findings (Evans, 2001).

### 1.3.5 Knowledge Building in Biological Science

Decades of study on student learning based on empirical data and several national requests for instructional change have persuaded us that teaching and learning in the subject of molecular and cellular biology (MCB) is challenging. For students and teachers alike, the intricate workings of the various mechanisms, the quickly expanding body of information, and the specialized terminology present an intimidating environment. The invisible and inaccessible‖ character of the entities studied (Gilbert, 1982), the requirement for mapping across physical and ontological levels (Marbach-Ad and Stavy, 2000), and the interrelated and overlapping nature of complex phenomena are some of the characteristics that may make MCB learning challenging (Duncan, 2007).

With a few noteworthy exceptions, such as the work of Venville and Treagust (1998), the literature on the nature of knowledge and conceptual change in MCB is, nevertheless, less developed. Among the unsolved issues are the following: How do students create expert knowledge networks by connecting ideas? When studying cellular phenomena, how do they arrange concepts? What are the fundamental mechanisms of conceptual transformation that might give rise to notions and beliefs that defy accepted scientific wisdom? Drawing on theories in cognitive learning science and the literature on domain-specific reasoning techniques, we investigate undergraduate students' comprehension of fundamental MCB concepts, including DNA replication, transcription, and translation processes.

According to the author, because MCB is complicated, students must create highly integrated knowledge networks that are adaptable and productively structured in order to solve problems and construct explanations. The author postulates that in order for students to have a thorough comprehension of molecular biology mechanisms, they must combine disparate pieces of knowledge, manipulate connections between ideas, and create a coherent picture of the relationships between phenomena. While a great deal of work has been done to describe the type of knowledge that novice science learners possess (Gobbo and Chi, 1986). and science specialists (Chi & Koeske, 1983).

### ★The Theory of Knowledge Integration

According to Clark and Linn (2003), learning is a dynamic process that includes rearranging past knowledge, forming connections between concepts, and acquiring new ideas. The process of building new information through conceptual shift has been the subject of much research in the learning sciences (Özdemir and Clark, 2007). Sorting, connecting, and integrating concepts is the main focus of the knowledge-integration hypothesis of conceptual change.

By definition, knowledge integration is the process through which students make connections, add new concepts or facts, and work toward creating a coherent mental picture of a reality (Clark and Linn, 2003, 2013). In order to do this, concepts must be categorized appropriately and linked to one another, integrating them to create a knowledge network. How much instructional time is devoted to key topics has a major impact on knowledge absorption as well. Deeper learning requires time, as Clark and Linn (2003) showed when they showed that longer teaching periods in middle school classrooms significantly improved knowledge integration around basic thermodynamics principles.

Making links between concepts is a fundamental part of the theory of knowledge integration. For instance, students should draw links between the ideas of gene and evolution‖ when studying mutations. Students form both stable and enduring bonds as well as impulsive, transient ones. Furthermore, within a conceptual ecology, linkages can give rise to opposing and dissenting concepts in addition to ideas that are scientifically normative (Clark and Linn, 2013).

### 1.4Evolution of Biological Science and Learning Progressions

Students' depth of cognitive capacity is demonstrated through conceptual reasoning. One way to determine how students' conceptual reasoning has changed is through learning progression (Hermita, 2018). The term - learning progression refers to how pupils' knowledge advances to a higher level (Wulandariet et al., 2019). A sequence of tests called a learning progression is used to evaluate how conceptual understanding evolves over time as a result of teach (Mosher, 2011).

The knowledge that pupils have developed at different learning stages is thought to be represented by the learning progression. The concepts of the students are mapped out in the learning progression, which the teacher can utilize to facilitate learning assessment (Furtak, 2012). According to Thompson et al., (2009), learning progressions can also be utilized as a helpful tool in achieving learning objectives. The learning process can be used to teach students how to think about a topic in a way that corresponds with the stages of their development in which they learn and research the issue (Duschl, 2007). It was anticipated that by employing learning progression, the students' conceptual reasoning on the subject would improve, enabling them to comprehend the material and be able to rephrase it using their own understanding rather than only memorizing it.

Learning progression has been established in recent years for a number of reasons, including supporting teaching techniques, helping to develop the assessment process, and serving as a guide for curriculum design. Curriculum creation can be built on concept sequences derived from the logical examination of scientific ideas incorporated in learning progression or cognition and instructional (Steedle, & Shavelson, 2009). The learning sequence makes it easier for teachers to organize and collaborate on ideas as well as spot and address students' comprehension issues (Furtak, 2009).

In order to tackle the problems of the twenty-first century, it is imperative that pupils develop biological conceptual understanding. Pupils must possess a variety of abilities, including critical thinking, HOTS, and others, depending on how well they comprehend the subject matter. The best ways to help kids grasp biological concepts better are to design learning progressions that divide topics into age-appropriate categories. They are expected to use scientific explanations that are appropriate for their level of understanding and study subject in-depth as they go through the learning process (Elmesky, 2013). It is thought that LP development is crucial to helping kids comprehend biological topics.

# Literature Review

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

A systematic review of related literature equips the researcher with a perspective and gives direction to the study. It is a type of academic writing that provides an overview of existing knowledge in a particular field of research. A good review of related literature not only summarizes the matter but also it analyses, evaluates and synthesizes the appropriate literature with in a specific field of research.

A literature review is a comprehensive summary of previous research on selected topic. The literature review surveys scholarly articles, books, dissertations, conference and other sources relevant to particular area of research and provides context by identifying past research. The review should enumerate, describe, summarize, objectively evaluate and clarify the previous research. We can say that research tells a story and the existing literature helps us to identify where we are in the story currently. Now we have to continue that story with new research and new perspectives.

The related literature helps the researcher to compare, contrast or match the findings of the study with those of other studies and to analyze them to reach the conclusions. Related literature for the present study will summarize from four broad perspectives-

1) Studying secondary learner's conceptions.
2) Studies related to students' understanding of biological science concepts across age.
3) Studies related to students' understanding of biological science concepts through a historical lens.
4) Studies related to progression of biological science concepts among students.

## 2.2 LITERATURE REVIEW

Schizas D., et al., (2023) investigated the ways that Greek secondary school biology instructors who were currently working in the field saw the specific aspects of school biology and physics in relation to the theoretical framework and methodology used in biology. In the study theoretical framework, the author highlighted key distinctions between the Newtonian and neo-Darwinian worldviews; the author researched, the author Gsurveyed fourteen biology educators and conduct in-depth interviews with most of them. Teachers of biology had a hard time grasping the historical nature of the subject and differentiating between homothetic and non-homothetic natural sciences, according to the study's results. When thinking about the epistemological aspects of biology, they also stressed the significance of scientific rules and experimentation. This was because they had two opposing views on the question of what science or scientific knowledge was. They concentrate on the behavior of a certain scientific field, liked biology, while on the other handed they underline the qualities that a science should had in ordered had been termed a science. They end up with a logical tension, but they tried to resolve it by seeing biology as a dynamic discipline that was constantly evolving towards an ideal a pattern of science that was, in many ways, positivistic.

Machová, M., & Ehler, E. (2023) showed that student still had varied misconceptions regarding genetics, even though this topic had been included in secondary school biology curricula for decades. In ordered to dispel these myths, the author must first understand where they came from. The purpose of this study was to examine these characteristics in the Czech educational system as they pertain to students enrolled in iced 2 and iced 3, the two levels of upper secondary education. An exam covering fundamental genetic principles was administered to students, with the content drawn from both the national curriculum and up-to- date textbooks. Students had broad concepts regarding the nature of genetic information, but they had difficulty integrating this knowledge into a more thorough comprehension of how the body worked in living organisms, according to the results. Several misunderstandings had grown as a direct consequence of these discoveries. The Czech educational system's textbooks and national curriculum fail to adequately be addressed these issues because they fail to address the rules of inheritance, the functions and impacts of DNA (trait development), and the various levels of biological organization. Consequently, the author needed to pay attention to both the changes in Czech Republic national educational policy and the way lessons were delivered if the author wanted to avoided misunderstandings.

Inêz, T. G., et al., (2023) demonstrated that even after receiving scientific education, many people did not comprehend how scientific information was developed and accepted. A potential solution to this issue was to incorporate the nature of science (NOS) into science education. Nos could be viewed as an educational concept designed to promote comprehension of the primary features of scientific researched. Many experts had recently argued that when teaching about (NOS), the author should take pluralism in science into account. As a result, initiatives had been made to created strategies for encouraging (NOS), education that considered the peculiarity of various scientific domains. In keeping with this viewpoint, the purpose of the study was to a model of (NOS) instruction within the framework of biological education. Three pillars support the ―integrative model for teaching (NOS) in biological education‖ (IM-NOSBIO) approached. The first was Erduran and Dagher's family resemblance approached to nature of science (FRA). The second was found in Scheiner's conceptual framework of biology. The third was Knuuttila's pragmatic conception of models as epistemic artifacts. The author suggested that by utilizing their presentation in biological sciences education, IM-NOSBIO could support teaching and learned about several facets of scientific knowledge and practiced. The author provided an example of how this model might been used to taught specific components of Nos based on the development of cell theory history in ordered to demonstrate this potential.

Uralovich, K. S., et al., (2023) discussed by seeing the results of people's unfavorable views of the natural world. The effects on nature had gradually worn down the delicate equilibrium. So far, though, the solution to such problems was dictated by the destiny of humanity, by its destiny tomorrow. It would take more than just trying to enhance industry-wide regulations to solve environmental challenges, develop cost-effective technologies that were also ecologically benign, or regularly conduct conservation activities. Anthropogenic impact mitigation strategies should prioritize educating the public about environmental issues, encouraging responsible environmental practices, and instilling a sense of responsibility to protected natural resources for the benefit of future generations. Also, environmental education was very important. The country's financial and economic growth was both impacted by this. A more equitable and sustainable future for all people could been mapped out in the sustainable development goals (SDGS). Abolition of poverty, protection of the planet from natural catastrophes, and the assurance of a life of peace and prosperity for all were the stated goals of the sustainable development goals (SDGS).

Byukusenge, C., et al., (2023) illustrated that the literature supported the idea that such educators struggled with the subject matter and that their lessons on the issue may contribute to their student' negative perceptions of it. The study set out to investigate which biological concepts in the new Rwandan curriculum teachers found most challenging to taught, why they found these concepts difficult to taught, and what might be done to make these topics easier to taught and learned. Quantitative and qualitative analyses were performed on data obtained from 67 teachers who consented to participate in the surveyed. Based on the findings, 17 subjects were deemed challenging for both instructors and students. People found it most challenging to study and taught subjects connected to molecular biology and biotechnology, including genetics, gene technology, cell division, DNA replication, and protein synthesis. Among the reasons teachers cited for the difficulties was issues' abstractness, an overloaded curriculum, an absence of visual teaching tools, an inadequate understanding of the subject matter, and an inability to organize practical activities. In ordered to address the challenges, teachers proposed several practical solutions, such as virtual laboratories, 3d animations, lab materials provided, curriculum content reduced, training, and study tours. Additionally, the authors suggested avenues for further study and methods for professional development among educators.

Parraguez, C., et al., (2023) explained the wealth of literature on students' competing views of evolution and natural selection, little was known about how these views shifted over time or how students' understandings of the scientific process evolve because of classroom instruction. Consequently, the study's overarching goal was to describe how a group of ninth graders (14– 15 years old) from a privately funded school in Chile changed their minds on evolution because of natural selection over the course of six lessons. Thirteen students participated in the study; they were given the assessment of contextual reasoning about natural selection (acorns) questionnaire before and after each of the three classes, and they were also given brief assignments to complete at the end of each class. Quantitative and qualitative methods were used to examine the data from nine students divided into five groups for the five situations. Here the author could observe that students often thought in terms of design teleology, that they used important concepts liked mutation, survival, and differential reproduction early on in their trajectories, that there was a lot of mixed thinking both during and after the lesson, and that there was limited coherence in the structure of thinking across time and contexts.

Demetrio, G. R., et al., (2023) described the way it unites the life sciences, evolutionary theory (ET) was controversial and sometimes misinterpreted, especially in nations where religious views were at odds with its scientific findings. There was a strong cultural emphasis on religion in Brazil. The study presented the results of a study conducted in Brazil. Researchers used a 12-question questionnaire to investigate how Brazilian freshmen's understanding of evolutionary theory was influenced by their major and self-declared religious and philosophical background. The author addressed the following inquiries: did one's primary area of study affect their understanding of ET? Was there a connection between religious and philosophical settings and understanding ET? Thirdly, did Brazilian first-years' understandings of ET vary by major and by religious and philosophical background? the surveyed had 153 first-year students as respondents. Biological science students performed on par with humanities students, but better than students in most other majors. The philosophical outlook on life was significantly related to their understanding of evolution; students who identified as atheists or agnostics fared better than those who identified as religious. Interactions between disciplines and philosophies of life did not follow any discernible patterns. The author viewed these findings through the prism of the growing ideological activism in Brazilian culture, since the study of philosophy of life was the primary forced behind the public's understanding of evolutionary theory. To reassured contemporary communities of the significance of researched and scientific knowledge, the author emphasized the role of scientists and educators.

**Suwono, H., et al., (2023)** examined the goals of a biology education were to foster critical thinking skills, increased students' understanding of biology, and created students who were scientifically literate. The fact, however, was that the Indonesian biology curriculum was the exclusive emphasis of biology classes. Previous study had shown that scientific inquiry could been a useful strategy for raising both scientific literacy and academic performance. An innovative method of inquiry served as the foundation for the creation of interactive socio- scientific inquiry (ISSI). The ISSI employs digital technology as a medium for engagement and leverages socio-scientific issues as a framework for learned. Used a non-randomized controlled group consisting of 196 tenth graders and a pre-test-post-test design, this researched employed a quasi-experimental approached. The results showed that ISSI students who was taught used traditional methods and those who was taught through classroom discussion achieved significantly different results. Students' critical thinking, biological understanding, and scientific literacy were all greatly improved by the ISSI program. These results pointed to the potential benefits of incorporating digital technology (with its interactive involvement as a learned interaction platform) and socio-scientific issues (to been critiqued and resolved) into biology education as a supplement to inquiry-based learned. The international student success index ISSI was a new approached to helping secondary school students became more critical thinkers and more creative in their biology classes.

**Ayotte-Beaudet, J. P., et al., (2023)** looked at how primary school students' exposure to the real-world settings of natural phenomena affected their understanding of the curriculum's emphasis on outdoor science in a contextualized approached. Inside the Montreal inner city in the Canadian province of Quebec, the author interviewed sixty-three fifth and sixth graders (aged ten to twelve). Based on these, the author was able to classify the effects on students learned as follows: (1) An environment that fosters deeper learned, (2) A context that encourages engagement, and (3) An evolution of conceptual understanding about living organisms, development of scientific investigation abilities, and an evolution of a connection to nature. The study findings demonstrated that the effects on students extended beyond the acquisition of knowledge about living things. The study data gathering strategy did not set out to confirm previous researched in outdoor education, but it did so in practiced, lending credence to several previous study' conclusions and marking a significant advance in the area. Additionally, while participating in outdoor activities, some students felt a stronger bond to nature, even though they did not actively work to solve environmental concerns.

Christensen, D., & Lombardi, D. (2023) aimed to quantify the extent to which computational thinking had been assimilated into the study of biological evolution. The intricacy of teaching computational thinking alongside biological evolution prompted us to examine the efficacy of a framework derived from a newly established learned progression. Science education reform initiatives in the recent past had introduced the notion of computational thinking. The concept of computational thinking was not well-defined, which made its incorporation into lessons challenging for many teachers. The researched used a quasi-experimental method, and the participants was high school students. Assessments was administered in tandem with interventions that combined computational thinking with concepts of evolution in ordered to track students' progress in learned about both computational thinking and biological evolution. Although students gained a deeper understanding of both topics, one intervention significantly enhanced their understanding of computational thinking and biological evolution. These findings supported the need of more study in these areas and provided strong evidence that computational thinking should played a larger role in biology curricula. It backs up the learned progression's paradigm of enhancing students' scientific knowledge by integrating scientific practices with disciplinary fundamental principles.

Brownlee, K., et al., (2023) investigated plant awareness disparity, sometimes known as plant blindness, was the inclination to overlook plants in one's surroundings, which contributes to the belief that plants were inconsequential. In ordered to ascertain whether basic biology textbooks were causing pad in undergraduate students, the author investigated in this researched how plants and animals were portrayed in these texts. With a specific focus on the introductory, genetics, and evolution chapters, the author examined photos from four textbooks that were frequently used as introductions to biology for biology majors. The author discovered that, in all four textbooks, animals were selected more frequently as illustrations of biological ideas in the pictures, suggesting that these texts were causing pad. In addition to instructors bringing in outside examples and images to augment those found in texts that exhibit a bias towards animals, textbook publishers should concentrate on offering a more equal number of examples of biological concepts and processes from both plants and animals.

Moore-Anderson, C. (2023) focused that secondary biology teaching was mostly on sub- organism systems, including physiology, frequently at the expense of evolution and ecology and hindering the development of a comprehensive understanding of biology. In ordered to helped teachers thought about how to integrate ecological and evolutionary thought with the study of physiological and developmental systems, the study offers a framework. Maintaining equilibrium between natural and anthropomorphic environments. The framework comprises two axes: contemporary-evolutionary and physio-developmental-ecology. Four quadrants arise from these axes and should been considered when designing topics. It was suggested that, in ordered to ensured that physiological phenomena were contextualized in the organism's ecology, topic design should generally centre on the whole organism in its environment. Additionally, it was suggested that through the pedagogical application of comparative biology, ecology, organismal systems, and evolution could be combined with an evolutionary perspective. This would also provide students with additional opportunities to learn about and encounter non-human animals in addition to helping them identified the pattern under study. The framework, which was intended for used by practicing educators, would only call for a fresh perspective on the subject matter and structure of the course rather than a drastic alteration in pedagogy or instructional materials.

Candaş, B., & Çalik, M. (2023) explained the instruction cantered around the common knowledge construction model (CKCM), this study attempted to support eighth-grade students' conceptual grasp of —sustainable development (Sd). —They study involved 31 eighth- grade student from a secondary school in the Turkish city of Trabzon, and it was carried out used a pre-experimental researched approached. Students' conceptual grasp of SD—which includes sustainability, recycling, saving, technology, environment, and the technology-environment-sustainability cycle—was revealed used word association tests (wat), conceptual understanding tests (cut), and student workbooks. The responses from grade 8 students on the wat and cut were imported into SPSS 22. 0tm for data analysis, and a paired samples t-test was performed. Three criteria—positive relational development, negative relational development, and no change—were also used to analyze the substance of their answers to each worksheet. The current study showed that questioning the alternative beliefs of grade 8 students and improving their conceptual knowledge of SD was two benefits of the CKCM-oriented instruction. Based on the findings, the study suggested that educators of science created comparable lesson planned for additional science subjects.

Willson, A. M., et al., (2023) conducted a workforce with broad, interdisciplinary backgrounds and quantitative training in ecology and environmental science was necessary to conduct ecological researched in a way that tackles intricate, real-world issues. This started with providing undergraduate students with an equitable education in ecology, multidisciplinary science, and quantitative skills. Comprehending the ecology and environmental sciences undergraduate curricular landscape of today enables focused actions to enhance equal educational chances. With its roots in multidisciplinary and quantitative researched, ecological forecasting was a subfield of ecology. The author demonstrated how undergraduate ecology and environmental science curricula could be assessed and ultimately redesigned to meet the demands of the workforce of the twenty-first century through the application of ecological forecasting. The author gathered the available resources for teaching and learned ecological forecasting at three curriculum levels—online resources, us university courses on ecological forecasting, and us university courses on topics related to ecological forecasting—in ordered to assess the current state of ecological forecasting education. The author discovered recurring trends in two areas: (1) the subjects taught to us undergraduate students at every curricular leveled; and (2) The availability of courses in us higher education institutions, which was a measured of resource accessibility. The author designed and implemented initiatives to specifically engage Native American undergraduates and online resources for undergraduates to learned quantitative concepts in ordered to increase the accessibility and comprehensiveness of undergraduate education in ecological forecasting. By taking these actions, ecological forecasting could better serve undergraduate students from a variety of backgrounds and introduced more students to quantitative training.

Alam, A., & Mohanty, A. (2023) discussed that sustainable happiness curriculum‖ and pedagogical framework‖ for Indian schools that used a whole school approached, the researched aimed to advance the field of happiness engineering. The model for happiness engineering was the same as that of any other conventional school topic, such as computer science, chemistry, or history. In ordered to develop it, the researchers used the global best practices‖ that had been scientifically verified and were used in many departments, colleges, and universities throughout the world for well-being education, adjectival education, and sustainability education‖. In ordered to deploy it in Indian schools, it had been contextualized and modified while considering the infrastructure already in Indian schools and the likelihood of an efficient transaction. The prepared curriculum framework for the happiness engineering‖ subject was modified and contextualized to better met the needed of Indian senior secondary school students based on the experiences of 129 experts from India, including professors of education, school counselors, pedagogical scientists, learned theorists, health experts, and representatives of non-governmental organizations.

Wennersten, L., et al., (2023) investigated one of the most important ways to reach the SDGS was through ESD, or education for sustainable development, according to UNESCO. Preserving natural ecosystems and increasing the use of renewable energy sources were both aided by raising public understanding of these issues through education. Incorporating lessons on ecology into elementary school curricula helps laid the groundwork for kids' future study in biology while also cultivating ecologically conscious individuals who would work to preserve, restore, and advocate for the responsible used of the study planet's natural resources. Recognizing the importance of resilient ecosystems to human well-being was a key component of this early education. However, it was difficult for young kids to build a comprehensive understanding of ecological linkages, according to earlier researched. Here, the author analyzed the ecological process-themed writings and artworks created by students. The study four models were based on students' beliefs about the ecosystem's energy and matter availability. The study researched participants first postulate the possibility of energy circulation and second, that matter either circulates, was supplied by the sun, or was generated from scratched. Fragmented processes coupled in diverse ways were commonly expressed by the students. Based on the study findings, the author suggested elements that could guide the development of sustainable development curricula for elementary school student's study of ecology.

**Suriani, N. W., et al., (2022)** examined the purpose of the study was to create a reliable and valid biological macromolecules three-tier test (bm-3t) in ordered to detect potential science teachers' misunderstandings. The study was an example of researched and development conducted in accordance with the researched design proposed by KILIÇ and Saglam. The design comprises three steps: first, definition of content; second, collection of data on student misconceptions; and third, construction of exams. Researched data was collected through many means, including interviews, validation, and test trials. Researched participants were fourteen first-semester students at universities negeri Manado who was preparing to become science teachers in the 2021–2022 school years. The author analyzed the data by looking at things liked test reliability, test validity, and test difficulty levels. The author found that the 16 items the author generated for the test was valid, that the test reliability coefficient was in the reliable range (0.78), and that the average difficulty leveled of the bm-3t was (0.44), which was moderate. Thus, bm-3t was a good tool to use in discerning whether future science educators had a basic concept of biological macromolecules.

**Michod, R. E., et al., (2022)** conducted one of the most noticeable characteristics of life and a key element of the diversity and complexity seen in biology was nested hierarchical structure. As with the teaching of biological complexity in general, however, there was less effort to teach how the food chain had developed. Used findings from study on eti theory-evolutionary transitions in individuality— the author offered a paradigm for the instruction of biological complexity. By bringing Eti (evolutionary transitions in individuality) theory into the classroom, students were able to make linkages between evolution, group dynamics, and the main landmarks of biodiversity on the food web. First, the new material that needed have been taught; second, the creation of general teaching tools to aid in the delivery of this new material; and third, the integration of this new content and these tools into the educational context, including the incorporation of learned standards and benchmarks, were all components of the process of transforming Eti theory into pedagogic content and practices. The author demonstrated how eti instruction enriches lessons on scientific methods and evolutionary changed. Researched on evolutionary transitions offers a captivating and approachable method of teaching students about biological complexity by capitalizing on their innate knowledge of group dynamics and social interactions.

Martincová, R., et al., (2022) explained the most complex and divisive subjects was evolution. Because it forms the basis for accepting or rejecting other important topics liked genetic modification and global climate changed, among others, scientific knowledge of evolution ought to have been part of people's general knowledge, a component of their natural science education, or biology curriculum. The purpose of the study was to examine how evolution was taught in Slovakian history and biology classes, as well as any risks that may been related with this fact that students may develop false beliefs. With a sample size of 200, the author assessed the students' familiarity with evolution and its mechanisms. The study working hypothesis was that, when compared to their non-evolutionary counterparts, high school seniors who had been exposed to evolutionary education would have a better grasp of the subject and a deeper awareness of its processes. The author postulated that a generalized interest in and acceptance of evolution would have a salutary effect on people's ability to explained and comprehend evolutionary occurrences and processes. After doing study, the author asserted the influence of a passion for the natural sciences. The author proposed an exploration-based curriculum that incorporates evolution as a central theme in biology classes.

Makhmudovna, A. M. (2022) examined incorporating cutting-edge technology, such as personality-oriented tools, into the biology classroom helped shape students' understanding of personal growth. It was feasible to activate their cognitive activity using mass workouts when teaching biology.

Panagou, D., et al., (2022) showed an upsurge in recent years of scientific methodical inquiry into students' competing understandings of fundamental physics principles and concepts. Because of this, mechanics was just one of several scientific disciplines that had produced vital and useful bibliography on a global scale. The study was devoted to the physical sciences, and more specifically to the principles of classical mechanics, which include such fundamental ideas as worked, energy, weight, forced, and action/reaction. Students in their final year of elementary, middle, and high school in Cyprus filled out a multiple-choice surveyed. To found out if it was age-related or just statistically fluctuating, the author compares the percentage of right and wrong answers across the three surveyed groups. Gender did not seem to affect student' accurate responses, but age did correlate statistically with most questions. As students got older or reached a certain leveled of study, the study findings imply that their alternative conceptions, which represent their misconceptions and assumptions, diminish. However, it was also impossible to establish such a correlation for many issues. The findings of study had implications for science education, curriculum creation, and professional development opportunities for educators.

Oliveira, G. D. S., et al., (2022) described the development and assessment of cell membrane biology learned activities within the context of experiential realism and the model of educational reconstruction, the study findings grounded in theory and practiced. To begin, the author consulted the literature to construct analogy-based learned activities that consider the ideas put out by both students and scientists. Second, the author observed how students learned through two videotaped teaching experiences. By viewing students' conceptual growth as paths to thought, the author was able to get to the bottom of their learned challenges. The student struggled to grasp the idea that the form of cell membranes dictates their dual function to separate and connected environments in ordered to sustain living processes due to fundamental ontological and epistemological assumptions. The author was able to be encouraged students' conceptual growth with numerous parallels by drawing attention to parts of their own real-life experiences that they had previously overlooked. Students had a better understanding of cell membrane biology and updated their ideas on the concepts of environment, gatekeeper, and barrier because of the lessons. Bringing this crucial idea to science classrooms may been better understood based on the study's methods and results.

Prayitno, B., et al., (2022) examined the effectiveness of collaborative constructivist learned strategies, such as those proposed by Novick and Stad, in closing the knowledge gaped among students in biological topics. The tenth graders in these six courses were randomly assigned to one of three learned method treatment groups: collaborative constructivism, Novick's constructivism, or Stad. Each group included twelve students, twelve from higher and lowered academic levels. Before and after treatment, students were asked to write the study that tested their grasp of biological principles. Analysis was conducted on the disparity in student understanding and any gaps in knowledge between UA and LA students. Used either Novick's or the collaborative constructivist approached had no discernible effect on student comprehension. Different approaches to teaching Stad resulted in different levels of comprehension among students. Compared to Stad, students' comprehension improved when taught used collaborative constructivism and Novick's constructivism. The knowledge gaped between students and the other two tactics could be narrowed and students' comprehension could be optimized through collaborative constructivist strategies.

Wibowo, Y. G., & Sadikin, A. (2019) looked the educational revolution toward the achievement of the sustainable development goals (SDGS). The purpose of this piece was to talk about how new biology could helped got us closer to the SDGS that had been set out. The 31 publications included in this literature review were published between 2010 and 2019. Biology, biology education, new biology, future biology, and biological science were the keywords utilized to gather the data. Specifically, the review found that SDG 2 (zero hunger), SDG 3 (good health and wellbeing), SDG 4 (quality education), SDG 6 (clean watered and sanitation), and SDG 7 (affordable and clean energy) were all within new biology's purview to implement. Considered the results, it was recommended that the educational system in Indonesia adopt a new biology approached.

**Carlisle, J., et al., (2019)** discussed on the periphery of public knowledge of society, scientific communication or education, and science in society, the subject of Muslims' attitudes towards the theory of biological evolution had garnered more and more interest. Researched on 'western' attitudes regarding evolution, especially in the highly political us, was the primary source of technique and methods used in this worked. The extent to which Muslims in various majority and minority groups embrace or reject the idea of non-human and human evolution had been the subject of both small-scale qualitative interviews and larger- scale quantitative surveys. Many of these studies had a ―deficit model‖ as their foundation, which often held that Muslims and ISLAM pose a barrier to the general public's comprehension and acceptance of evolution theory. The study provided a concise overview of the study, delves into the specific ways in which deficit model approaches could been influencing their results, and considers how the public's perception of scientific researched on Muslim contexts lacks reflexivity.

**Nehm, R. H. (2019)** looked at the state of biology education researched and the possibilities and threats it faces. One obstacle to understanding student thinking about living systems and developing unified conceptual frameworks for these systems was the ongoing discipline fragmentation. The lack of conceptual frameworks could make it difficult to discover how students thought about biological systems and to guide biology instruction, as shown through a review of concept inventory (ci) study. The purpose of this review was to provide a foundation upon which to build frameworks that integrate cognitive and disciplinary approaches. To begin, the study reviews important findings in developmental and cognitive psychology and then draws parallels to the field of biology teaching based on these findings. As a second pointed, the theoretical worked of earlier biologists was emphasized as a foundation for re-integrating biology through frameworks that were focused on certain disciplines. Unity and variety; scale, hierarchy, and emergence; and randomness, probability, and contingency were the three interrelated disciplinary themes that were deemed essential for comprehending the fundamental concepts within each discipline. In sum, the review stresses the importance of conceptual and cognitive grounding in promoting desired epistemic stability and directing the creation of BER integrated empirical researched goals.

**Kelemen, D. (2019)** determined intuitions based on common sensed could been helpful in addressing problems and gone about daily life. But they could also lay the groundwork for strong scientific misunderstandings and hinder formal science education. It had long been believed that secondary education was the proper placed to address such misunderstandings. In the study, contended that early elementary school was the best time to begin teaching a set of fundamental but paradoxical ideas (such as evolution by natural selection) coherent causal-explanatory lessons, which highlight the complex mechanisms underlying natural phenomena. Evidence from study in cognitive science, developmental psychology, and the learned sciences inspired this approached. For instance, researched shows that explanatory biases, which made kids, believed things based on their gut feelings rather than evidence, started to form at a young age. In addition, the results showed that once these misunderstandings were formed, they did not disappear or got replaced by later learnt scientific theories; rather, they lived with them. There were substantial implications for the timing, organization, and scope of early science education based on this researched and others showing the feasibility of teaching students about counterintuitive theories through coherent explanations at an early age.

Schneeweiß, N., & Gropengießer, H. (2019) pointed out the well-documented challenges of comprehending biological systems, some writers had proposed an overt examination of the various organizational levels. However, when it came to the nature and strength of the connections between different biological levels, there was still no universal agreement among scientists. With the goal of laying the groundwork for future educational arguments that could informed the design of more effective learned environments and experimental approaches to biology education, the study would summarize the current conversation. A systematic literature review was carried out to achieve this goal. For finding literature on organizational levels, three databases were searched: Biosis, eric, and Fachportal-Pedagogic. A qualitative content analysis was used to examine the study considering the following researched questions: (1) what tiers of management did the writers mention? (2) The writers provided a description of the organizational levels. Thirdly, how did the writers characterize the connection between various organizational tiers? (4) How did the author's description of the difficulties of these levels relate to biology education? (5) What did the writers mean when they said that these levels were beneficial for biology classes? Our findings informed a leveled design that emphasized zooming-in and made connections between levels very cleared.

Vojíř, K., & Rusek, M. (2019) investigated recent years had seen a meteoric rose in the quantity of scholarly studies devoted to the study of scientific education. Researchers from countries where English was not the native language had had a disproportionate impact on this figure. Since they aid researchers in better orienting themselves in issue areas, literature reviews became increasingly important with this volume of the study. A literature evaluation on researched for science textbooks was presented by the writers of the study. Despite the undeniable significance of textbooks in the classroom, there was a startling lack of regional or state-specific researched in this area. A total of eighty-three study published in journals included in the web of science database between the years 2000 and 2018 was reviewed in the study. Researched on textbooks received a disproportionate amount of attention from academics in the united stated and Europe, according to the findings. Science textbooks used in secondary schools were the most study. Many textbook researched focuses on learned content, visual representations, learned concepts and their integration, non-textual components of textbooks, and learned texted analysis.

Hin, K. K., et al., (2019) discussed that many countries had shared their best methods for teaching biotechnology. On the other handed, there was a dearth of information regarding effective biotechnology education strategies that could work in Malaysia. Systematically reviewing current approaches in secondary school biotechnology education was the goal of this study. The Eppi-centre for systematic reviews of educational researched literature provided the review methodology that the systematic review procedures were based on. All relevant study conducted between 1985 and 2018 made up the sample chronology for this study. The writers reviewed 2524 researched study found in academic publications, theses, and reports. Therefore, 122 study was found have been suitable for inclusion in the sample. Nevertheless, following the application of inclusion and exclusion criteria, a total of 19 study was ultimately included in this systematic review. Instructional practiced of teaching biotechnology in secondary schools was considered if it was published between 1985 and 2018, used a language that the authors understood, included regular secondary school students with backgrounds in pure science, agriculture, or technology, and hasssdn't been published elsewhere. Modules, lab active-learning, online learned platforms, and workshops were the most often used methods, according to the authors. Nevertheless, secondary school student understanding of biotechnology could be improved think the creation of a suitable curriculum that incorporates e-learning. Teaching methods in biotechnology also fostered skills necessary for the modern world, including the ability to think creatively and critically, to used technology effectively, to solve problems, and to communicate clearly and concisely.

Tan, R., et al., (2019) explained the field of biology was rapidly expanding its influence as a wellspring of novel ideas for solved engineering design challenges and, more importantly, as a source of insights that could propel companies to the forefront of an ever-changing marketplace. In ordered to found out what tools and techniques could make it easier to created creative ideas that were based on biological information, this study took a quick looked at what's already out there in terms of theories and approaches based on biological knowledge and how they had been applied in different areas. Following that, the four pillars of foundational technologies that form the basis of biologically inspired design (Bid) were investigated in depth in this study. After outlining the current state of the bid process, this study moved on to forecast its future directions.

**Soeharto, S., (2019)** examined misconceptions about science were considered have been a major obstacle for students. There were certain concepts in science that new students often misunderstand, and academics had utilized a variety of diagnostic tools to pinpoint these mistakes. The current researched gave data on diagnostic assessments that could detect students' scientific misconceptions, as well as an outline of the most prevalent science topics on which students got them wrong. This evaluation also compares each instrument based on its strengths and drawbacks, drawing on 111 publications published in the top journal about student's scientific mistakes between 2015 and 2019. Based on the results of this study, there were 33 physics ideas, 12 chemistry concepts, and 15 biology concepts that students often got wrong. Also, the most prevalent types of diagnostic tests were found to include interviews (10.74%), basic multiple-choice tests (32.23%), multiple-tier exams (31.06%), and open- ended tests (23.97%). When it came to evaluating students' conceptual understanding, though, every typed of test had its advantages and disadvantages. Professional users, such as educators and researchers, needed to exercise caution while utilizing diagnostic assessments in the classroom, especially when building students' conceptual frameworks. The results of this study should shed light on the most prevalent science misunderstandings and provided researchers and educators with a better tool to evaluate students' understanding of the subject.

**Mead, L. S., et al., (2019)** illustrated that there had been a few attempts to quantify evolution knowledge and acceptance during the last quarter of a century. Even though science teachers had been used these tests and reporting their findings, it was unclear whether they were doing it correctly. In this study, the author would take a looked at these tools, making note of the initial criteria and population that was used to evaluate their reliability and validity. The author would also look at other studies that mention these tools, and the author would see if they had been used to assess reliability and validity with subsequent populations. The purpose of this extensive study was to encouraged researchers and practitioners to thought critically about the methods they wanted to employ and the validity of the instruments they planned to use in ordered to achieve their goals. The author urged everyone to consider the measurement support and previous used of an instrument with populations that were similar while administering evolution education assessments. Researchers were also encouraged to provide more proof of the instruments' reliability and validity when used them with new populations or after making changes to the instruments.

**Verhoeff, R. P., et al., (2018)** said that when trying to piece together complicated biological processes and occurrences at scales ranging from the molecular to the ecological, systems thinking had become shorthand for what was required. The inclusion of systems as a crosscutting topic in the next generation science standards (2013) shows how important systems and models were in science education. Still, nobody appeared to agree on what systems thinking entail or how effective methods of instruction and study could encourage it. The focus of the study was on systems thinking as an abstract or theoretical concept. In this context, systems thinking were understood as more than simply -coherent understanding. -It was a method of learned that made intentional used of systems theoretical concepts to explained and forecast natural phenomena. Therefore, the author contended that systems thinking should not been characterized as a collection of abilities that could been acquired one by one, but rather as an approached that necessitates thinking about the features of systems and the theories from which they were created. After briefly outlining systems thinking's conceptual character, the author depicted the variety of reported educational approaches to fostering systems thinking in the empirical researched. The study analytical framework was based on the following: the role of modeling, the integration of several systems thinking skills, and the degree to which natural events had been matched to one of three systems theories. The author then offered some findings on incorporating systems thinking into secondary biology curricula and talk about the epistemological aspects of the systems idea.

Soltoggio, A., et al., (2018) investigated remarkable computational capabilities of biological neural networks have been melded by evolution, development, and continuous learning. The development of biological intelligence is a result of the interaction of several factors. Aiming to autonomously build and create learning systems, evolved flexible Artificial Neural Networks (EPANNs) use simulated evolution in-silico to breed flexible neural networks, drawing inspiration from such complex nature events. Networks with both intrinsic features and the capacity to adapt and learn in reaction to experiences in many contexts and problem domains are evolved through EPANN experiments. EPANNs attempt to do things like build learning systems on their own, assess the computational benefits of specific neural components, recover performance in unknown environments, and derive theories about the development of biological learning. It follows that EPANNs may incorporate a wide range of parameters, such as neuron types and dynamics, network topologies, plasticity rules, and more. Recent developments in artificial neural networks are paving the way for completely novel methods and outcomes, even if EPANNs have come a long way in the past 20 years. By taking use of the growing availability of simulation settings and computer resources, more autonomous and creative processes could replace the laborious process of hand-designing learning neural networks. The area of EPANNs is defined by the study collection of numerous innovative concepts. A summary of the key procedures and findings is provided. At last, fresh prospects and potential advancements are showcased.

**Ziadie, M. A., & Andrews, T. C. (2018)** showed that undergraduates had a formidable challenged in learned evolution, a unifying theory in biology. Pedagogical content knowledge (PCK) refers to an educator's expertise in a particular area of education and its impact on their capacity to support student learned. This was an enormous amount of information to acquire on one's own, but instructors require PCK for every subject they taught. Nevertheless, there was collective PCK available in peer-reviewed literature because of study examining student thinking and learned. The current state of the available collective PCK did not make it evident whether it covers the evolution subjects taught in college courses properly. The author conducted a comprehensive literature review to identify the current state of collective PCK for teaching evolution and identified any gaps. In ordered to identify the following: the style of worked (e. g., empirical, literature review), the focus (e. g., student thinking, assessment, instructional practices, or goals), and the evolutionary subjects covered, the author performed a comprehensive literature searched and reviewed 316 pertinent studies. The author examined 32 different undergraduate evolution courses across the nation and contrasted the subjects covered with the existing researched on collective PCK. The author concluded that PCK provides a valuable lens through which to view future study on biology education and utilize them to suggest goals for the evolution education researched community.

**Malik, A. H., et al., (2018)** explained the evolutionary theories put out by Muslim academics before to Darwin's time were conspicuously absent from history of biology and evolutionary theory textbooks. A growing movement in the west was doing away with the worker of scientists from non-western countries in the fields of biology, anatomy, and evolution. Consequently, the contributions of Muslim thinkers who lived before Darwin to the development of evolutionary theory were the primary emphasis of this researched. The author found that numerous Muslim thinkers posited evolutionary notions, some with striking resemblance to Darwin's theory, in literature published in a variety of languages and across a wide range of historical periods. Humans descended specifically from apes and monkeys, the idea of evolutionary limitations, the frequency of extinctions within taxa, heritable variability, and the concept of adaptation and survival of the fittest was all part of these theories. In addition, although most people and scientists rely on western textbooks for their information, there were certain regions of the Muslim world that had shown a general stance against biological evolution, which includes human evolution. Scientists and the public needed to hear this underappreciated tale if the author were to have a more accurate picture of scientific history, a deeper appreciation for the world's many civilizations, and a better grasp of their ideologies.

**Patrick, P., & Matteson, S. (2018)** discussed publications for science educators who worked with students aged 5 to 10 and 10 to 13 were published in the peer-reviewed science practitioner journals science and children and science scope, respectively. These studies therefore represent the science ideas that science educators were being taught. To what degree the study published in these publications between 1990 and 2014 addressed biology-related topics, integrated non-science subjects and science disciplines, and promoted inquiry-based learned was the aimed of this thorough literature study. The findings showed that 557 publications, or 21% of the total of 2701, had a biological focus. Animals were the subject of biology studies in both publications the most frequently. Fungal, photosynthesis, respiration, and viral subjects were the least often study topics in biology. The results were examined, and the discussion of the educational implications for journals and teachers follows.

Legare, C. H., et al., (2018) determined natural selection as a theory of evolution had started to radically alter the study view of how the author perceive, thought, spoke, behave socially, and practiced the study culture. Natural selection remains a mystery to many, including students, educators, and even scientists, despite evolution theory's relevance to social science. The study aimed was to offer social scientists with a field guide to teaching evolution, drawing from study in education, developmental psychology, and cognitive psychology. The author compiles the current knowledge on the mental blocks to evolution comprehension, evaluation tools for evolution knowledge, and instructional approaches to overcoming these barriers. After a brief overview of the literature on the topic of teaching evolution to nonhuman species, the author delved into the implications of these findings for human evolution classrooms. The author was hoping that by sharing what we've learned about teaching evolution in general, the author may inspire and prepare social scientists to taught evolution within their respective disciplines.

Chen, M. M., et al., (2018) looked a lot of worked had gone into trying to make math and biology more integrated in undergraduate curricula since the national researched council's report bio 2010 went out. Attempts to introduced similar quantitative concepts at the secondary leveled had, unfortunately, been very rare. Because of this, undergraduates with a variety of secondary science backgrounds may had varying degrees of success in the field. The author thought that technology could been utilized at the secondary leveled to avoided quantitative accomplishment mismatch in undergraduate biology programs, just as it was employed in undergraduate courses to connect these two disciplines. In the study, the author took a looked at how technology was already being used to taught quantitative biology in secondary and undergraduate programs, what had had been done to made it even more widespread, and what could be the obstacles to used technology to integrate math and biology.

Varella, M. A. C. (2018) showed that science provides a wealth of information, and it was the goal of educators to comprehend and implement this knowledge. However, there had been cases where researched results and hypotheses from different branches of learned science had appeared have been at odds with one another, most notably in educational neuroscience. The author contended that this predicament develops because different fields rely on different degrees of analysis. Bringing together ideas from the fields of sociology, psychology, biology, and neuroscience, the study presented a theoretical framework for the study of learned. Learned was a complex neurological phenomenon, and education was an even more complex socio-cultural one; this framework aims to recognize the difference between the two. Therefore, a unified view could develop within the framework, which in turn could aid in the resolution of several critical challenges. The study main points were that (a) it would help laid the groundwork for a translational paradigm in the fields of neuroscience, psychology, and education; (b) it would make it easier to spot neuromyths; and (c) it would forestall future arguments that did not contribute to progress.

**Bennett, J., et al., (2018)** study that several nations' science curricula incorporate experimental, student-run researched projects (IRPS). A comprehensive literature evaluation was carried out to determine the effect of IRPS on student. Ninety-one publications from twelve different countries were considered for inclusion in the review. According to the summary, IRPS were frequently linked to broader programs liked real science, PBL, and project-based learned. The diversity in IRPS activity in terms of focused, models of provision, assessment, finance, and the involvement of external partners liked universities and businesses impacts judgments on the quality of the evidence base on impact. The bulk of the study that was examined focused on topics liked conceptual understanding, the desire to continue studying science even when it was no longer required, attitudes towards science, and the acquisition of practical skills. Learned scientific concepts, developing emotional responses to science, having a positive outlook on science-related occupations, and acquiring a variety of abilities was all found have been beneficial. Students from historically underrepresented groups reported higher levels of optimism toward science after participating in IRPS, according to researched including these students. Additional researched was required to improve the quality of the existing evidence, investigated valid assessment methods for IRPS, investigated the possible advantages for historically under-represented groups, and investigated the possible long-term advantages of high school IRP participation.

**Laudonia, I., et al., (2018)** explained that based on educational researched, action researched was a great way to get teachers involved in making their classrooms better placed to learned and taught. Science education, liked other areas of education, made used of action researched to advance the study understanding of effective teaching methods and to aid in the ongoing professional development of educators. Used action researched in science education could been approached from a range of theoretical perspectives, ranging from more technical to more libratory ones. Action researched was conducted in a wide variety of educational contexts and with a variety of objectives. This literature review aims to summarize the key points of implementing action researched in science education by analyzing the existing literature on the topic from around the world.

Offerdahl, E. G., et al., (2017) examined one of the most important things the author could did for the next generation of scientists and people was worked on improving their scientific visual literacy. Graphical and diagrammatic aspects peculiar to a certain field, different degrees of abstraction, and spatial arrangements of visual elements were all commonplace in visual representations used to convey information in the molecular life sciences. When one was able to comprehend the different ways in which these elements were utilized by different fields to symbolize specific ways of knowing, they had attained visual literacy. Visual representations were complicated, which means that developing visual literacy requires a lot of mental effort. Lessening students' cognitive load requires them to become proficient with the individual parts of visual representations before they were asked to integrate these parts concurrently to derive the representation's meaning. In ordered to learned about the chances for students to became fluent, the author offered a taxonomy for describing one aspect of visual representations, namely the degree of abstraction. Moreover, the author showed how the study taxonomy may have been used to course evaluations, which in turn encourages conversations on how much support the undergraduate biochemistry curriculum provides for the development of visual literacy abilities.

Kover, P. X., & Hogge, E. S. (2017) discussed that many elementary schools had drastically reduced the delivery of science education, according to the official English school regulator (Ofsted). There was apprehension that the publics leveled of science literacy and the number of young scientists being recruited could been negatively impacted by schools that did not teach high-quality science. When it came to teaching science in elementary schools, the author thought university researchers and undergraduates could make a big difference. To improved science instruction in primary schools, only a small percentage of scientists worked with elementary school students. In the study, the author proposed that scientists, schools, and society could benefit greatly from sustained partnerships with elementary schools. The author hoped that by sharing the study story of working on —evolution and inheritance lesson planned, the author would inspire and enable other scientists to work with elementary school students. The author pointed out the challenges the author faced as well as the opportunities the author saw.

Kover, P. X., et al., (2017) determined the merging of biological and systems engineering disciplines was the basis of synthetic biology, sometimes called -genomic alchemy'‖ a potent scientific field. A fitting description had been given to it: -moving from reading the genetic code to writing it. -The emphasis was on creating synthetic genetic circuitry by modeling, developing, and constructing new biological systems used personalized gene components. Proponents of the scientifically sounded concept of technologically manipulating life had long held this view. As a result of advancements in high-speed automation and the decrease in the coasted of gene sequencing and synthesis due to the completion of the human genome project, the realization of this idea had gained momentum. The field of synthetic biology was poised to made significant contributions to the advancement of numerous fields, including but not limited to biomedicine, biopharmaceuticals, chemical manufacture, food and dairy quality monitoring, packaging, storage, bioremediation, bio-energy generation, etc. The scientific community must recognize the risks of employing synthetic life forms and created protocols to assured safe practiced while achieving major discoveries in the rapidly growing field of synthetic biology.

Cooper, R. A. (2017) showed the intuitive concepts of intentionality, teleology, and essentialism, as well as students' failure to recognize selection as a direct, causal process, were common sources of student reasoning errors when it came to situations of natural selection. Not used -population thinking‖ was a common thread in many of these logical fallacies. The concept of natural selection was not well understood by students. It describes how interactions between lower-level creatures and their environments caused changes in the distribution of features at the collective leveled, or the population leveled. Emergent processes, such as selection, were common in hierarchical systems, where interactions at lowered levels form patterns in the collective. To enhance students' comprehension of natural selection, it was recommended that they worked on developing an emergent process schema. This schema would help them recognized that even seemingly random interactions at one leveled of a system could produce predictable patterns at a higher leveled. Researched suggests this method worked well for instructing students in other emerging processes as well. This section presents instructional advice supported by this study; however, additional study was required to fully ascertain the extent to which this technique could enhance students' comprehension.

Métioui, A., et al., (2016) studied the impact on students' understanding of photosynthesis and plant nutrition in the study. Students' misconceptions about green plants' food sources, the sufficiency of watered and mineral salts for plant growth, the function of chlorophyll the process by which light energy was converted into chemical energy and the significance of air as a material source are all highlighted in this literature review. Second, the author showed that there had been historical developments of some of these misconceptions. For instance, according to the renowned Greek philosopher Aristotle (384-322 BC), plants got their nourishment from the soil in an already-developed form. The physician and scientist van Helmont refined Aristotle's idea a few centuries later by asserting that plants grew exclusively in watered. In conclusion, the author would observe that, within a classroom setting, students' erroneous beliefs could be rewarded through an examination of historically inaccurate hypotheses. A teacher could be influenced by the history of sciences to value his students' misconceptions and saw them as signs of problems that needed instructional and pedagogical resources. In a classroom setting, students' erroneous beliefs could be addressed by following a set of norms for reasoning, which were sometimes comparable to those that formerly governed scientific procedures. This perspective, which was based on historical misconceptions, paints a much more dynamic and relatable picture of science than the one that could be propagated through dogmatic teachings.

**Barthlott, W., A., et al., (2016)** stated that scanning electron microscopy of nearly 20,000 species, along with the available literature, forms the basis of this exhaustive analysis of the building principles and occurrences of super hydrophobic surfaces in many organisms, including plants, animals, and more. The author described and discussed bio-mimetic applications of properties liked self-cleaning (the lotus effect), fluid drag reduction (the salvinia effect), and the introduction of new functions (air layers as sensory systems). The author also introduced novel air-retaining grid technology and establish self-cleaning as an important property. It was surprising because there was no proof of long-term super hydrophobicity on surfaces that were not biological, save from technological materials. Phylogenetic trees suggested that super hydrophobicity may have been an important innovation in the development of terrestrial life because of the invasion of land approximately 450 million years ago. The incredible variety of materials and structures displayed by the approximately 10 million species currently in existence was truly remarkable. A large majority of these structures were generated through self-assembly and rely on a small number of molecules. Bionics, now more commonly known as bio-mimetics, had a history that returned over a century, according to a brief historical study. The statistical evidence shows that the fascination in bio-mimetic surfaces was much more recent. The publication of the extraordinary super hydrophobicity of lotus left in 1997 was the catalyst that finally got scientists interested in super hydrophobicity. The marketing of parabiotic products was becoming more important, which was unfortunate.

**Batzli, J. M., et al., (2016)** illustrated that -jewels in the curriculum was one name for the fundamental, but unspoken, ideas that students needed to know in ordered to succeed in a certain field. Variation, randomness, uncertainty, and size were examples of threshold notions that had been suggested by biologists. In the study, the author looked at how the idea of threshold concepts could be used with other frameworks to help with curricular and instructional decisions. The author also took a looked at the proposed concept of variation as a threshold concept and how it could affect students' grasp of fundamental ideas in evolution and genetics in biology. By outlining a schema based on scientific inquiry aspects, the author hoped to let students had an impactful first-hand experience with variation that would inform their subsequent study of evolution and genetics. The author hoped that people would think about threshold concepts in conjunction with the vision and changed fundamental ideas. These could serve as a framework for more targeted training and a connection between different ideas and skills.

Groll, J., et al., (2016) explained bio fabrication was a dynamic area of study that had been getting a lot of interest as of late. The area of tissue engineering and regenerative medicine had seen a meteoric rose in the used of bio fabrication principles, but with this growth had come a proliferation of jargon. In this piece, we'll took a closer looked at bio fabrication, a growing area of study that had important implications for regenerative medicine and tissue engineering. In this light, the author offered a more precise operational definition of bio fabrication that incorporates bio-printing and bio assembly as supplementary methods inside the bio fabrication framework.

Trifankov, Y., & Dergachev, K. (2016) looked at the origins of the highly esteemed Bryansk scientific and philosophical school in Russia. Scientific and technological advancements had prompted a shifted in global development, and this school was investigating the factors that may be shaping this shifted, which it called technogenic, as well as a social-technogenic one. Members of the school employ a novel methodological strategy, a socio-natural one, with roots in the writings of v. I. Vernadsky, who examined the challenges of creating the noosphere, a new biosphere. A post-biospheric world was being constructed, according to the writers of this line of inquiry. The biosphere was supposedly being destroyed. With the rose of biotechnology, humans had crossed over from the biosphere into the Technosphere, bringing biological processes into the former. This shifted was known as the technogenic world. The most groundbreaking finding from the institution was the shifted in earth's evolutionary history from a biosphere and biological to a socio-techno-natural model, which had been in place for about four billion years. Following the world's spontaneous market development could cause such a transition to destroyed biosphere life and establish a new life shell called post biosphere.

Geerdts, M. S. (2016) investigated animals that were portrayed in an anthropomorphic manner were common in children's media. There were ramifications for how the author involves children in early naturalist learned regarding the effects of anthropomorphism on their development of factual and biological understanding of actual animals. The study went over some of the latest researched on how children's exposure to different animal depictions affects their biological reasoning and factual learned, as well as some of the experimental and cross-cultural study that had shown how these things worked. To resolve inconsistencies in the literature and moved forward in the study understanding of the role of anthropomorphism in early childhood education, further researched into the contexts in which this trope could facilitate learned was necessary.

Deniz, H., & Sahin, E. A. (2016) used multiple regression analysis and a nonparametric Kruskal Walli's test; the author investigated the factors associated with evolution acceptance among Turkish biology teacher candidates. The author also looked at the correlation between evolution acceptance and the preference to taught evolution. There was a negative correlation between religion and acceptance of evolution, but a positive correlation between parameters including understanding of evolution, thinking tendencies, and parents' educational leveled with acceptance of evolution. Of all the factors that explained the variation in evolution acceptance, religiosity stands head and shoulders above the others. The acceptance scores of future educators were far higher for those who favored teaching evolution over creationism.

Sweller, J. (2016) studied the field of evolutionary educational psychology offers a framework for a better understanding of the nature and process of learning, as well as recommendations for effective teaching methods in today's classrooms. There were two types of knowledge: biologically primary knowledge, which was something that students picked up naturally via experiences like playing around with others, and biologically secondary knowledge, which was something that students must be taught. Biological evolution has left an architectural imprint on the human brain, which functions as a natural information processing system throughout secondary learning. Using this structure, cognitive load theory produces a wide variety of pedagogical effects pertaining to methods for lowering the burden on working memory from irrelevant information to improve the retention of previously learned material in long-term memory. In the study the author looked at the theory's evolutionary and cognitive foundations and review its instructional consequences.

Pobiner, B. (2016) looked there were compelling and universal concerns regarding the study evolutionary history. The fact that fossil and DNA findings had appeared on the covers of prestigious science journals and publications, as well as other popular print and online media, demonstrates the tremendous interest that people had in evolution, and particularly in human evolution. Many Americans, however, vehemently disagreed with biological evolution as a reliable, well-supported theory of the origins of life, according to almost all national surveys. In the eyes of the public, there was no scientific subject more divisive or contentious than evolution, and media outlets frequently amplify this divisiveness by highlighting objections to the teaching of evolution. Textbooks, curricula, standards, and policies in the field of education had all been influenced by arguments surrounding evolution. There were several barriers to adopting and comprehending evolution, including as a religious worldview, language and terminology, cognitive barriers and misconceptions, and mistrust and denial of science. In ordered to taught evolution in formal education settings throughout grades k–16 in a cleared, comprehensive, and sensitive manner, teachers—who were the ones facing these challenges—need have been equipped with the necessary tools and strategies. Even though human evolution was a potentially contentious subject, increasing amounts of researched were showing that teaching evolutionary biology's fundamental ideas through a human-cantered approached was both successful and interesting.

Cullinane, A., & Liston, M. (2016) explained nearly everyone agreed that high-stakes testing had the potential to drastically alter classroom instruction. A lot of people thought that when schools focus so much on high-stakes tests, it leads to a curriculum that was too repetitive and prevents student from learned complex ideas. The study details an investigation into the leaving certificate biology exams used of bloom's taxonomy of learned objectives for cognitive ability testing. Analysis of historical and biology test the study was done in the study. To found out how many points each cognitive objective was worth, calculations was also made. According to the results, most of the questions on the test did not invited students to be thought critically. Considering that most of the points were given to the more basic taxonomy objectives, it seems that student could get by with just memorization on the biology test. The study demonstrated that the methods of administering biology exams encouraged students to learn at a low leveled and emphasized how high-stakes tests only measured a limited range of student achievement. At its most basic leveled, this kind of thinking encourages memorization and information without question, rather than critical analysis. The current system of relying solely on final exams to assess students' readiness for the workforce was insufficient. A more balanced methodology was required.

Wynn, T., & Coolidge, F. L. (2016) viewed at what pointed in time did the human brain began to be changed? The study of thinking, when and how did they emerge? Brain and cognition study had proliferated within the past three decades. This study had included a wide variety of fields in the social and biological sciences, including developmental psychology, cognitive neuroscience, and epigenetic. Increased curiosity on how the brain and consciousness developed in response to this effervescence was hardly surprising. The conventional tools of evolutionary biology had been utilized by paleoanthropologists and other evolutionary researchers. The cognitive and neural systems of nonhuman animals, particularly apes and monkeys, had been better understood thanked to experimental and ethnographic findings. 1, 2 evidence of alterations in the gross neuronal anatomy had been found in fossil brain study used endocasts and advanced imaging techniques. three, four psychologists had joined the fray as well, used experimentally grounded descriptions of cognitive functions to apply reverse engineering. In addition to fossils, the archaeological recorded contains a treasure trove of information about hominin cognition and its development. Cognitive science's theories and models, together with those of palaeolithic archaeology, allowed evolutionary cognitive archaeology to uncover previously undiscovered mental processes in hominins.

ÖZKAN, G., & TOPSAKAL, Ü. U. (2016) examined bioethics educators would need to adapt their methods considering recent scientific discoveries. The public and media were becoming more cognizant of bioethical challenges, and there was a corresponding upsurge in discussion surrounding these topics. People who worked in education, especially in the field of biology, should been cognizant of the moral and societal weight of their profession. The study provides a critical analysis of the current literature on bioethics, the study of moral issues as they pertain to the teaching of scientific concepts. The study began with a description of bioethics and bioethical problems. Next, the author would discuss why bioethics education was crucial. The next stepped was to assess and study the previous researched on bioethics. Recommendations outlining the necessity for additional and more appropriately structured researched were offered considering the voids in the current literature.

Jeronen, E., et al., (2016) explained researched on the effectiveness of biology, environmental, and outdoor education curricula in elementary, middle, and high school classrooms, as well as in programs preparing future teachers, was severely lacking. Several scientific databases were searched used specific keywords related to sustainable education and biology in ordered to choose the material. From 2006 to 2016, 24 publications were chosen for publication in peer-reviewed scientific journals, and the study gave a summary of them. Qualitative content analysis was used to examine the data. In total, sixteen periodicals were chosen, and twenty-four the study was examined thoroughly. Teaching strategies, classroom dynamics, students' emotional and mental stated, students' psychomotor abilities, and assessment tools was the primary areas of investigation. There was also an emphasis on the characteristics of good approaches and an examination of their pedagogical consequences. Overall, 22 distinct pedagogical approaches were identified as having positive effects on sustainability education. Strategies that encouraged student engagement and group collaboration in the classroom were the ones that received the most attention. Teaching strategies that incorporate active engagement and interactivity, as well as a solid introduction and guiding principles, had been found have been effective in researched.

Glaze, A. L., & Goldston, M. J. (2015) determined from the early days of implementing the national science education standards in American classrooms to the most recent discoveries in the field, this critical review covered the whole spectrum of evolution researched in the us from 2000 to 2014. The author started by looking for patterns in the researched studies released between 2000 and 2014 to saw what they added to the study understanding of evolution education and what the author could did to better shine light on the debates around evolution. The specified criteria for the review included the teaching approached, attitudes and perceptions, religion, and recommended teaching techniques. A special emphasis was placed on evolution teaching and learned. The review consisted of the study. After reviewing a large number of study, seven overarching themes had emerged in the field of evolution education: (a) how evolution was approached in the classroom; (b) what was known about evolution; (c) how students felt about evolution; (d) what factors influence evolution education; (e) how students deal with evolution-related conflicts; (e) how students felt about evolution in relation to their religious beliefs; and (e) how evolution was taught and evaluated. Four issues warranting additional investigation was identified by the analysis: (1) further discussion of the role of worldview in acceptance; (2) investigation of internal and external factors affecting evolution acceptance; (3) analysis of real-world examples to illustrate these factors, with a focus on pre-service educators; and (4) investigation of evolution acceptance across us regions.

Waldrop, L. D., et al., (2015) presented at the society-wide symposium on leading students and faculty to quantitative biology through active learned which take placed at the 2015 annual meeting of the society for integrative and comparative biology. A concise overview of the latest developments in integrating active learned strategies into quantitative biology courses was also included. The author started by reviewing the researched that had shown active learned have been effective in stem (science, technology, engineering, and mathematics) classrooms as of late. Next, the author went over some ways this method worked well for teaching quantitative biology concepts. The author then went on to detail a few new efforts aimed at creating undergraduate and graduate-level quantitative biology labs and exercises. Educators who were interested in incorporating technology and active learned into their lessons would find a wealth of information in the study.

Hatfull, G. F. (2015) looked at the field of bacteriophage genomics and discoveries offer a strong foundation for combining educational and scientific agendas. The science education alliance phage hunters advancing genomics and evolutionary science (Sea-Phages) program was designed to involve a wide range of schools, professors, and students, allowing it to have a wider influence. The program offers a paradigm for introducing first-year undergraduates to discovery-based researched activities while also generating fresh insights into the variety and evolution of the bacteriophage population.

Kell, D. B., & Lurie-Luke, E. (2015) viewed that used the biological idea of an evolutionary fitness landscape as the study primary metaphor, the author practiced the innovation and discovery processes in broad stroked. A local searched yields incremental idea, while a global searched yields disruptive innovation. Another way to looked at them was as examples of incremental (mutation) v disruptive (recombination) evolution. Additionally, the author offered a platonic perspective that centers on memory and morality. A person's ―virtue‖ was the amount of worked they put in, which includes the knowledge needed to create both revolutionary and incremental advancements, and their —memory‖ was the length of time people remembered them. According to the evolutionary metaphor, encouraging innovation entails giving people the resources they needed to bring about fresh ideas, good objective functions that one was aiming to maximize and ways to learned more about and found one's way around the environment one was exploring. Collaboration across different fields was essential when dealing with recombination. All forms of original thought, product and service innovation, and creative problem solved adhere to these general principles.

Kraus, N., & Strait, D. L. (2015) explained there were noticeable differences in the way children and people who played music process sounded compared to those who did not. For instance, it had been found that both children and adults who were musicians had better neural encoding of speech harmonics, adaptive sounded processing, and acoustically similar sounded. These improvements could be one reasoned why musician had an advantage when it came to reading and hearing speech in noisy environments. These results had led to the hypothesis that musicians were biologically superior in terms of communication-relevant metrics because of the auditory and cognitive stimulation brought about by musical practiced. Unfortunately, cross-sectional methods that compare musicians with non-musicians had a major flaw: they could not separate the effects of training from demographic and intrinsic characteristics that could predispose guitarists. Too got around this issue, the study team had been studying the maturation of biological indicators of speech processing in kids and teens used longitudinal methods for the last several years to identified neural markers of musicianship. The author avoided used a synthetic program for the study laboratory investigation by collaborating with existing, effective community-based music initiatives. Results showed that many musicians' auditory-related physiologic improvements develop during training and could aid in language learned, even in populations that were at risk.

Graves Jr., J. L. (2015) investigated scientific determinism in biology had long historical roots. However, determinism persists even though biological researched made great strides in the 20th century. The study traces the evolution of biological determinism, looking at its many forms from its creationist roots to modern biological thought in the genomic era. Racialist conceptions of human genetic diversity were explained, and the connection between biological determinism and them was made cleared. In this context, the claimed of racial medicine (a form of contemporary biological determinism) and the revival of efforts to divide people into biological races used genetic data and clustering algorithms (like structure) were quite important. Lastly, it demonstrates how genetic, epigenetic, environmental, and chance variables all contribute to complex biological variation, which undermines the validity of biological determinism.

**Gul, S., & Sozbilir, M. (2015)** presented the results of a content analysis of 633 Ber study written by Turkish science teachers and published in journals both at home and abroad. More study on the environment, ecology, cells, and animal anatomy and physiology had been conducted, according to the results. Furthermore, as the most often study topics, learned, teaching, and attitudes take centre stage. Quantitative researched was favored, and the sample sizes ranged from 100 to 300, with the majority of study involving undergraduate and secondary school students. In addition, surveys, attitude scales, and achievement tests was widely used for gathering data, and t-tests, central tendency measures, frequency/percent tables, and ANOVA/ANCOVA analyses was typical for presenting and analyzing the results.

**Butler, J., et al., (2015)** discussed researchers in the field of scientific education were concerned about students' and teachers' misunderstandings on a global scale. These misconceptions impact students' and teachers learned and teaching processes and they impede the acquisition of accurate knowledge. A literature review of previous study addressing ecological misconceptions was included in this worked. When it came to enhancing the application of misunderstandings, diagnostic tests were one option. In ordered to teach science in a way that was corrected in terms of concepts, these were an essential part of a larger toolset of ideas. An unacceptable number of mistakes and shortcomings in the comprehension of ecological concepts was identified by analysis of the results of a diagnostic test that was taken by IRISH biology students and pre-service instructors. Misconceptions held by students and those held by pre-service teachers had a direct correlation. Here, the author went over some of the ways these results could change pre-service and ongoing teacher training.

# Research Methodology

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Overview

A research methodology is an official explanation of the procedure that will be followed during the research. To get an answer to a research question, you need to take a methodical and logical approach. A study's methodology details the procedures taken by the researcher to carry out the investigation and gather valid data for analysis. How people learn, where they find knowledge, and how they evaluate their own learning are all covered.

This section describes the procedures that will be used to conduct the planned research. The study's methodology is laid out here, covering everything from the sample size and statistical analyses to the data gathering procedures and analytic tools. An overview of the data collection process and the several tests run to assure the data's validity and reliability for use in experimentally analyzing the hypotheses obtained from the literature review and relevant to the study's aims are also provided in this chapter.

The term "research" is often used interchangeably with both creative and scientific endeavors. The purpose and rationale of the study are made clearer. This chapter discusses the study's sample, its sampling strategy, its methods of data collection, objective and hypothesis, and its methods of data analysis. Instructions on data collection, analysis, and instrument verification are provided.

## 3.2 Operational Terms

When talking about data collecting, the phrase "Operational Terms" refers to a comprehensive breakdown of the technical jargon and units of measurement employed. To ensure consistency, we must do this. There must always be a well-defined procedure for gathering data. Undefined data increases the possibility of inconsistencies and may not produce the same results when the study is duplicated. It's common practice to presume data collectors have the necessary knowledge and skills. But data gathering can be impacted by the fact that different people have different perspectives and interpretations of the same thing.

In this study, following operational definitions are used-

### 3.2.1 Evolution

Evolution is a foundational concept in biology that explains the process of change in all forms of life over generations. Charles Darwin postulated the idea of evolution in the 19th century, and it has since grown to be a fundamental component of contemporary biology and is supported by substantial empirical evidence from various scientific disciplines.

### 3.2.2 Biological Science Concepts

Biological science concepts encompass a broad range of principles and ideas that form the foundation of the study of living organisms. These concepts contribute to our understanding of the structure, function, behavior, and interactions of living things.

### 3.2.3 Secondary Level

Secondary level generally termed from class $6^{th}$ to $12^{th}$. However, it divided in three parts- class $6^{th}$ to $8^{th}$ is termed as lower secondary level, class $9^{th}$ & $10^{th}$ is secondary level where as class $11^{th}$ & $12^{th}$ is higher secondary level. This study is focused on lower secondary level which is also known as upper-primary level or middle level.

## 3.3 Need of the Study

The study of the evolution of biological science concepts among students at the secondary level is of paramount importance for several reasons. Firstly, understanding how students' comprehension of biological concepts develops over time provides valuable insights into the effectiveness of current educational approaches. It allows educators to identify potential gaps in teaching methodologies and curricular content, facilitating evidence-based improvements. Additionally, this study is crucial for curriculum designers and policymakers seeking to align secondary-level biology education with the evolving needs of students and advancements in the field. Furthermore, an exploration of the trajectory of concept evolution among students contributes to the broader discourse on science education research, offering a nuanced perspective on the challenges and successes in fostering scientific literacy. Ultimately, by delving into the evolution of biological science concepts at the secondary level, this study aims to enhance the quality of science education, promote a deeper understanding of biological principles, and empower students to engage more effectively with the dynamic world of life sciences.

### 3.4 Conceptual Framework

A conceptual framework illustrates the desired connection between your variables. It describes how your research method relevant aims work together to produce understandable results. A literature review of prior studies on your topic is frequently used to develop conceptual frameworks, which may be presented textually or graphically.

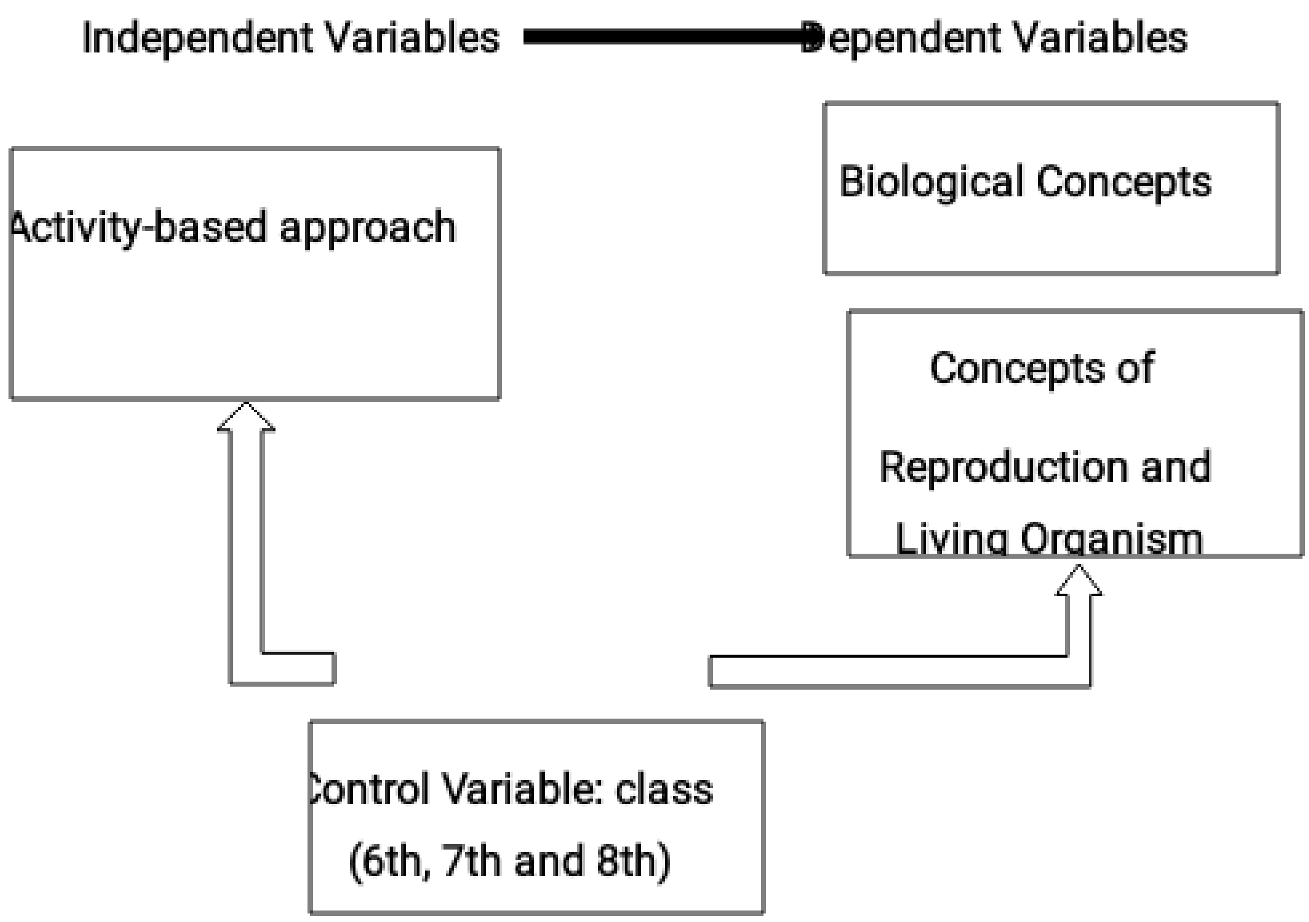


Figure 3.1: Conceptual Framework

- **Activity-based approach** - It is the variable that the researchers manipulate or categorize. The activity-based approach in education involves designing learning experiences that actively engage students in hands-on activities, experiments, and real-world applications. This approach shifts the focus from traditional teacher-centered methods to student- centered, interactive learning.

- **Biological Concepts** – In the study, biological concepts encompass a wide range of principles, ideas, and theories that form the foundation of the study of living organisms. These concepts provide the framework for understanding the structure, function, behavior, and interactions of living things.

- **Concept of Reproduction and Living Organism –** The variable reflects the concept of reproduction is fundamental to the life processes of living organisms. The biological process of reproduction ensures the survival of a species across successive generations by creating new members of the same species.

**Table 3.1: Curricular Progression of Selected Biological Concepts**

| concepts/topics | Class 6th | Class 7th | Class 8th |
|---|---|---|---|
| **Living Organisms** | Characters of living organisms, difference between living and non-living organisms, their habitat | Nutrition in plants & animals, respiration, transportation, excretion in plants & animals | Cell structure and function, from cell to tissue system, introduction about microorganisms |
| Table 3.1 (Continued) | | | |
| **Reproduction** | Flower & its structure, oviparous & viviparous animals, flowering & non-flowering plants | Reproduction in plants | Reproduction in animals |

**Control variable –** A control variable, also known as a constant variable, is a factor that is intentionally kept constant and consistent in an experiment to ensure that its effects are not confounded with the independent variable being investigated. The "class" of the students in the study that is, their grades in the sixth, seventh, and eighth is the control variable.

### 3.5 Variables of the Study

Measurements, ages, temperatures, and test scores are all examples of variables used in scientific inquiry. To examine potential causes and effects, researchers frequently employ the usage of independent and dependent variables in experimental designs.

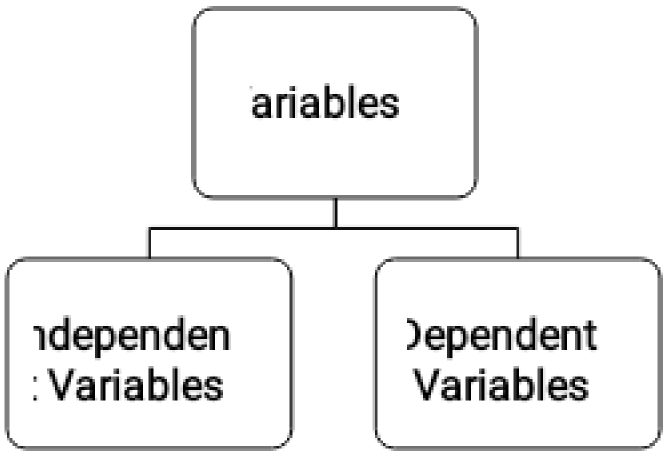


Figure 3.2: Types of Variables

### 3.5.1 Independent Variable

An independent variable is a characteristic that is unaffected by the other factors in the experiment. Furthermore, independent factors can alter other variables. Researchers typically look for evidence in studies to show if and how an independent variable impacts other variables. In the study, biological concepts & Concept of Reproduction and Living Organism depend upon Activity-based approach and the independent variable is activity-based approach. Other variables are not going to change them.

### 3.5.2 Dependent Variable

When an outside factor is altered, the dependent variable also shifts. Measurement of the outcome is important, but its relevance "depends" on the independent variable. In the study, Biological concepts & Concept of Reproduction and Living Organism depend upon on activity-based approach and the dependent variable is the Biological concepts, Concept of Reproduction and Living Organism.

### 3.5.3 Control variable

A control variable, also known as a constant variable, is a factor that is intentionally kept constant and consistent in an experiment to ensure that its effects are not confounded with the independent variable being investigated. Control variable is dependent on activity-based approach that is independent variable and biological concept & concept of reproduction and living organism that is dependent variable.

## 3.6 Research Questions

- How do student progress in their understanding about two biological concepts i.e., Living organisms & Reproduction from class 6$^{th}$ to 8$^{th}$?
- Is there a difference in the learning outcomes of students taught by two different pedagogical approaches?

- Is there a parallel between the progression of student conceptions about selected biological science concepts?

### 3.7 Objectives of the Study

- To find out the conceptual progression in prescribed curricular content of biological science at secondary level.
- To collate pedagogical perspectives of major biological science concepts.
- To trace the trajectory of evolution of major biological science concepts.
- To analyze and map the evolution of major biological concepts among secondary level students from field data.
- To study the effectiveness of the activity-based approach over traditional approach as two major pedagogical intervention.

### 3.8 Delimitations of the Study

In conducting a study on the evolution of biological science concepts among students at the secondary level, it is essential to delineate the delimitations that specify the scope, boundaries, and constraints of the research. First and foremost, this study is delimited to students at the secondary level, encompassing a specific age range and educational context. The focus is limited to the examination of biological science concepts, excluding other scientific disciplines. Furthermore, the study will primarily consider the curricular content prescribed at the secondary level, recognizing that variations in curricula between schools and regions may influence the findings. Delimitations also extend to the specific geographic location of the study, acknowledging that cultural and regional factors may impact the evolution of biological science concepts. Lastly, the study does not explore the influence of external factors, such as socioeconomic status or individual learning styles, on concept evolution, thus maintaining a more focused inquiry into the progression of biological science concepts among secondary- level students. These delimitations ensure a clear and manageable scope for the research, providing a foundation for a comprehensive and insightful exploration of the evolution of biological science concepts within the specified parameters.

### 3.9 Research Methodology of the Study

The word research methodology refers to the procedures and approaches utilized to find, select, process, and analyze the information on a certain subject. A research methodology outlines the investigational strategy. It is a systematic and logical technique for researching a topic. A technique describes how researchers conduct their investigation to deliver genuine, trustworthy data that achieves their objectives. A methodology is a group of techniques that combine to provide information and conclusions that are relevant to the subject of the study and the researcher's objectives. Methodology refers to the study of how to conduct research.

### 3.10 Area of the Study

A study area is a place where studies are conducted. For the research, the study is conducted in Jaunpur city (Uttar Pradesh). Because the study of the evolution of biological science lies within the field of education, more specifically in science education and curriculum development.

### 3.11 Sample of the study

The sample for the study will comprise of approximately 240 students of two schools (government) of both sexes studying in class $6^{th}$,$7^{th}$ & $8^{th}$.

### 3.12 Research Design

The problem is widely recognized, and since the facts will be utilized to examine and assess the data, the study is focused on gaining in-depth knowledge. At that point, the study would be both descriptive and analytical.

### 3.13 Sampling Design

An established method for selecting a certain number of people from a population is known as a sample design. When selecting the items for the sample, the researcher would employ this technique or strategy. Creating the sampling frame, randomizing the sample, establishing the sample size, choosing the sampling technique, gathering data from the sample, and analyzing the data are all steps in the sampling design process.

- **Stratified random sampling technique –** Is a commonly used statistical approach that divides a population into various subgroups, or strata, according to certain shared traits.

So, the researcher has utilized the Stratified random sampling technique.

### 3.14 Data Collection

The methodical collection and measurement of data on variables of interest to address research questions, test hypotheses, and assess results is referred to as data collection in research. No matter what you're studying—physical or social sciences, humanities, business, etc. You'll need to collect data. The procedures used to ensure honest and accurate collecting may change from field to field, but the importance of doing so stays constant.

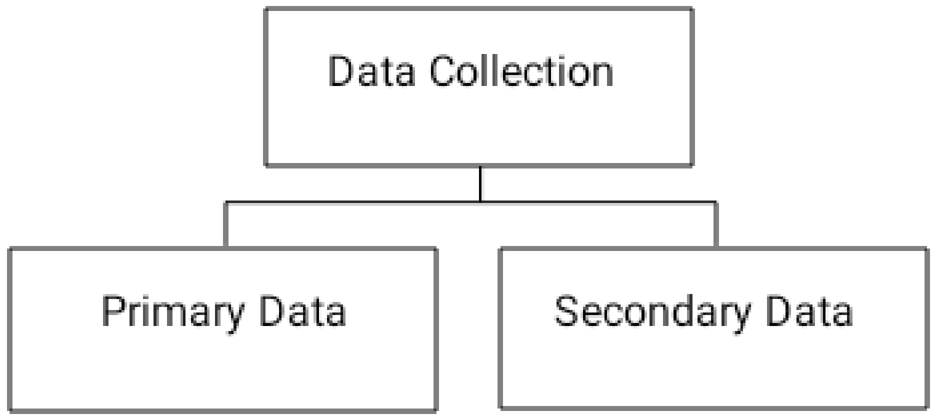


**Figure 3.3:** Types of data Collection

### 3.14.1 Primary Data

Data that has been created by the researchers themselves with the aid of tests, surveys, and interviews that have been specifically created to comprehend and address the study problem at hand.

- **Questionnaire**: The investigator creates a questionnaire or timetable using the questionnaire method that contains a list of pertinent questions. The questionnaire then records the respondent's responses. Given that the information is obtained directly from the respondents, this method is useful for gathering primary data.

### 3.14.2 Secondary Data

Secondary data is data that has already been collected and maintained by large government agencies, hospitals, and other organizations. After then, the data is pulled from a more diverse data source. Secondary data has been gathered from a variety of sources, including published works, government reports, academic studies, journal articles, libraries, the internet, and numerous organizations.

## 3.15 Statistical Tools

Statistical tools are used, among other aspects of conducting a study, in the planning, design, collection, analysis, and reporting of Research results. Using specialized commercial statistical tools like SPSS and Excel, true statistical analysis will be carried out in the study.

### 3.15.1 SPSS

A program named - SPSS (Statistical Package for the Social Sciences), often recognized as IBM SPSS Statistics is employed to do the statistical analysis of the data. Although SPSS was initially used in the field of social sciences, its application has now expanded into other data markets, which is reflected in the software's name. The SPSS provided a base for performing various tests to analyze the data.

### 3.15.2 Excel

Commonly used for checking the precision of hand-worked calculations and gaining a deeper understanding of statistical ideas that may be applied to the solution of genuine issues, Microsoft Excel is a popular piece of statistical software. Creating sophisticated quantitative research may be sped up with the help of the Analysis Tool Pak, a collection of data analysis methodologies.

## 3.16 Statistical Techniques

When examining research data, math is used to apply statistics, computations, models, and methods. Researchers can use statistical methods to extract information from their data and perform various reliability analyses on their findings. There were numerous statistical techniques to choose from but going by the objectives and hypothesis the chosen statistical techniques are - ANOVA, t-test, Mean, Standard Deviation.

### 3.16.1 Mean

The mean is calculated by dividing the total value of all the data points in a dataset by the total number of data points. This is the same thing as the arithmetic means. The term "mean" is used to describe the numerical value obtained by taking the average of two or more integers. Several methods are used to calculate the average of a collection of numbers. The arithmetic mean method, in which the mean is determined by adding all the numbers in the series, and the geometric mean approach, in which the mean is determined by calculating the average of a collection of products. In most cases, the outcomes of the most popular approaches of calculating a simple average are comparable.

### 3.16.2 Standard Deviation

The standard deviation is a measure of the typical spread of data. How far each value is from the average is displayed. When the standard deviation is high, the values are widely scattered about the mean, but when it's low, the numbers tend to cluster together around the center.

### 3.16.3 ANOVA

ANOVA, often known as the analysis of variance, to determine the statistical significance of your results and/or conclusions. Determine whether your independent factors have an effect on your dependent variable by running an analysis of variance (ANOVA).

### 3.16.4 t-test

To compare the means of the two groups, a t-test is utilized as a statistical test. This method is frequently used in hypothesis testing to see whether therapy or treatment influences the population of interest or whether two groups differ from one another.

# Data Analysis & Interpretation

# CHAPTER 4

# DATA ANALYSIS & INTERPRETATION

## 4.1 Student Profile

| Table 4.1: Class of Student | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | 6th | 80 | 33.3 | 33.3 | 33.3 |
| | 7th | 80 | 33.3 | 33.3 | 66.7 |
| | 8th | 80 | 33.3 | 33.3 | 100 |
| | Total | 240 | 100 | 100 | |

The table- 4.1 describes the demographic variable wise frequency, percent, valid percent and cumulative percent. When it comes to —Valid demographic variable out of 240 students, 80 are of $6^{th}$, 80 are of $7^{th}$ class and 80 are of $8^{th}$ class.

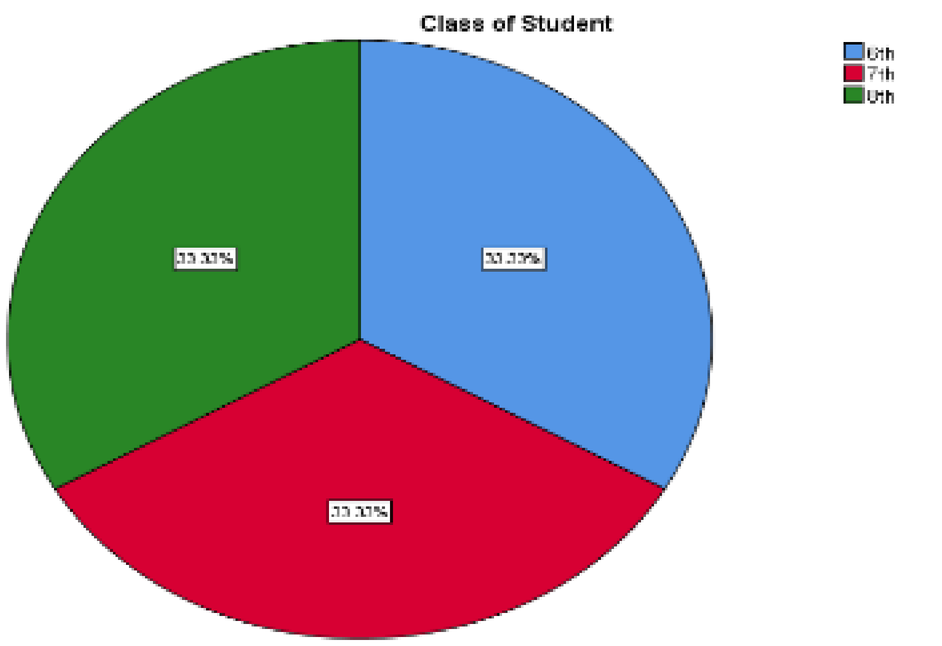


Figure 4.1: Class of Student

The above pie chart shows the data of table-4.1, this shows the percentage of students in each class relative to the total number of students. It shows the proportion of the total student population each class represents. In this case, each class represents approximately 33.3% of the total.

| Table 4.2: Name of School | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | Composite School, Adarsh Kerakat | 120 | 50 | 50 | 50 |
| | Composite School, Saroj badewar | 120 | 50 | 50 | 100 |
| | Total | 240 | 100 | 100 | |

Table-4.2 provides a summary of the distribution of students across two different schools, along with the percentage each school represents, both individually and cumulatively. It helps to understand the distribution of school within the group, with 120 students from Composite school, Adarsh Kerakat and 120 students from Composite School, Saroj Badewar.

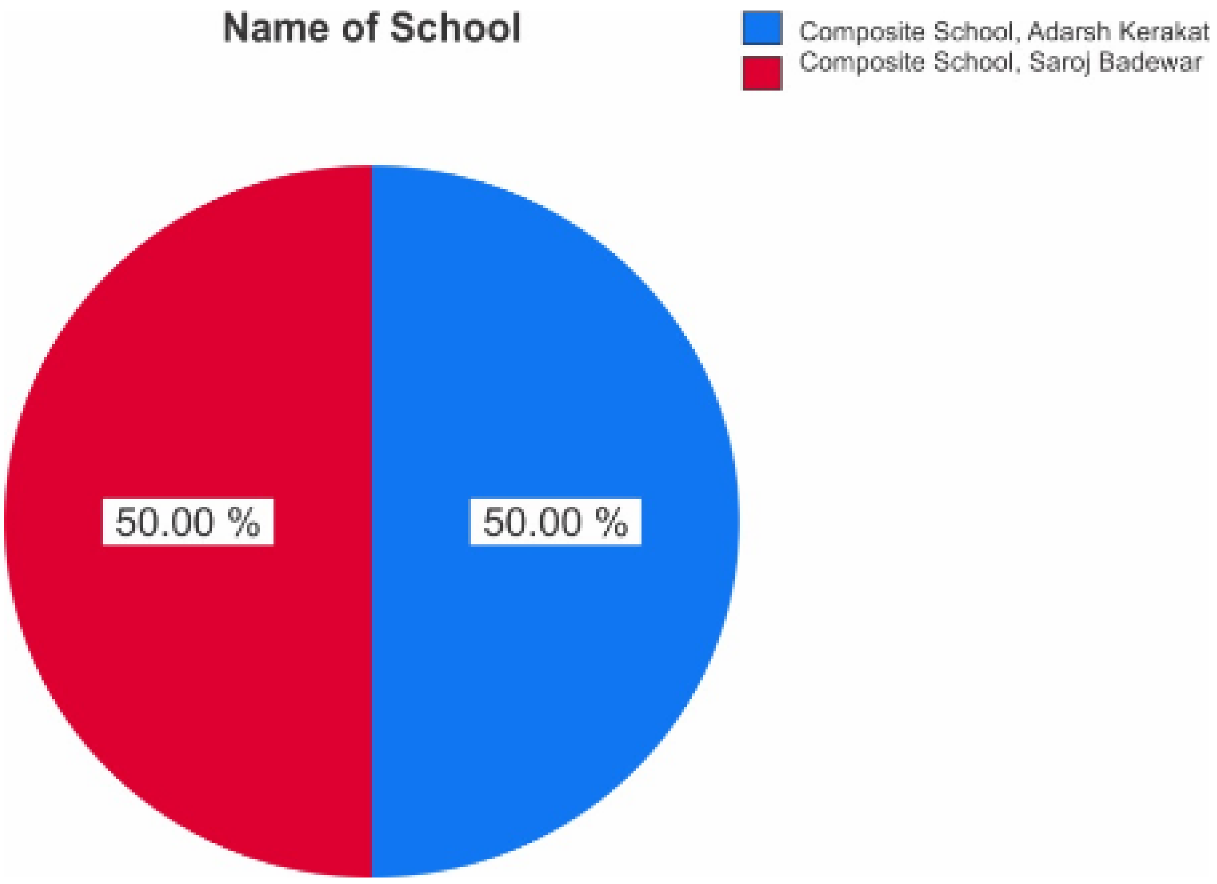


Figure 4.2: Name of School

Above chart shows that 50.00% of students belongs to Composite School, Adarsh Kerakat and 50.00% of students belongs to Composite School, Saroj badewar.

4.2Based on the Objectives of the Study

★ Introduction to Life Sciences in Class 6

- Students learn the fundamentals of the life sciences in the sixth grade.
- They gain knowledge of the wide variety of living things, such as plants, animals, and microorganisms.
- The structure of cells, tissues, and organs, as well as other elements of basic plant and animal anatomy and physiology, are described.
- It introduces the idea of ecosystems and food chains, which gives a basic knowledge of how interdependent nature is.

★ Life Processes and Adaptations in Class 7

- Students learn more about life cycles and adaptations in the seventh grade.
- They gain knowledge of vital life processes in both plants and animals, such as respiration, digestion, and circulation.
- It is possible to present the ideas of adaptation, evolution, and natural selection to clarify how organisms gradually adapt to their circumstances.
- The division of creatures into kingdoms, such as plants, mammals, fungi, and protists, may be studied by students.

★ Advanced Biology Concepts for Class 8

- Students continue to expand their biological understanding in the eighth grade.
- They gain knowledge of more intricate systems like the human reproductive system and how plants reproduce.
- More research is done on cellular biology, including meiosis and mitosis.
- There may include an introduction to environmental science subjects including pollution, conservation, and the effects of human activity on ecosystems.
- With the discussion of subjects like Punnett squares and the inheritance of traits, the concept of genetics becomes increasingly complex.

It's vital to remember that different educational systems and geographical areas can have different specialized curricula and levels of coverage. Additionally, over time, instructional methods and new breakthroughs in the field of biology may be included into educational standards.

The progression of biological science topics from sixth to eighth grade seeks to give pupils a fundamental knowledge of the life sciences, laying the groundwork for more in-depth biology studies in subsequent grades. Building a solid foundation of biological knowledge and scientific inquiry abilities during these years is essential.

1. **To find out the conceptual progression in prescribed curricular content of Biological science at secondary level.**

The research objective under scrutiny pertains to a comprehensive examination of the prescribed curriculum for biological science at the secondary level. Specifically, it seeks to elucidate the manner in which critical biological science concepts progress and evolve throughout the educational journey of secondary-level students. This objective embodies a profound quest for understanding how the intricacies of biological science education are structured, sequenced, and developed over time, aiming to offer insights into the trajectory of students' learning.

The analysis commences in Class 6, where students are introduced to the fundamental building blocks of biological science. This stage sets the foundation for the more advanced concepts that students will encounter in subsequent years. Class 6 typically involves the exploration of characteristics exhibited by living organisms, a critical introduction to the subject. The curriculum also delves into the habitats in which these organisms exist. These early lessons likely lay the groundwork for students to grasp the very essence of life and the interplay between organisms and their surroundings. This stage is the initial step in a student's biological science education, akin to building the base of a pyramid.

In Class 6 (Joints and Movements), students are introduced to the concept of joints and movements. This serves as an entry point into understanding the structural aspects of the human body and the mechanics that enable mobility. The curriculum in this grade typically focuses on the different types of joints and the movements they facilitate. From a pedagogical perspective, this stage may involve interactive lessons, visual aids, and basic hands-on activities to help students grasp the foundational principles of skeletal and muscular systems. The emphasis is on building the basic knowledge necessary for further exploration knowledge will be constructed.

Moving on to Class 7, the curriculum takes a step forward in complexity. Students delve into the fascinating concept of adaptation. Adaptation is a pivotal biological concept that underpins the survival and thriving of living organisms in a constantly changing world. In this stage, students are expected to explore the diverse ways in which living organisms adapt to their environments. This involves studying how various species have evolved to cope with their specific ecological niches, from physical adaptations to behavioral changes. The introduction of adaptation in Class 7 represents a logical progression from the foundational knowledge acquired in Class 6. Students are now ready to contemplate the intricate mechanisms that govern life and the remarkable ways in which species adapt to ensure their survival.

In Class 7 (Animal Nutrition and Respiration) represents a significant step forward in the journey of biological science education. At this stage, students transition from a primarily structural focus to a more functional one. They explore two crucial aspects of life: nutrition and respiration in animals. This shift in content demonstrates the progression in the curriculum. Students delve into the processes that sustain life, examining how organisms acquire and utilize nutrients and oxygen. The pedagogical approach likely becomes more complex, introducing students to concepts like digestion and cellular respiration. Students are encouraged to think critically about how these processes are essential for life.

students are expected to explore the diverse ways in which living organisms adapt to their environments. This involves studying how various species have evolved to cope with their specific ecological niches, from physical adaptations to behavioral changes. The introduction of adaptation in Class 7 represents a logical progression from the foundational knowledge acquired in Class 6. Students are now ready to contemplate the intricate mechanisms that govern life and the remarkable ways in which species adapt to ensure their survival.

As students advance to Class 8, the curriculum takes a more profound dive into the world of biological science. At this stage, students are exposed to complex topics, including cell structure and function, as well as the realm of microorganisms. Cell biology is a cornerstone of biological science, as cells are the fundamental structural and functional units of life. Understanding cell structure and function provides students with insights into the mechanisms of life itself, from cellular processes to cellular organization. Simultaneously, the exploration of microorganisms introduces students to a world of minuscule yet profoundly impactful life forms. Microorganisms are involved in various essential biological processes, from decomposition to disease, and studying them further enriches students' comprehension of the living world.

In Class 8 (Reproduction in Animals and Growth in Humans with Hormones) represents the apex of the secondary-level biological science curriculum. Here, students explore the intricate processes of reproduction in animals and the mechanisms governing human growth, particularly focusing on hormones. The progression from Class 6, which dealt with the structural aspects of the body, to Class 8, which addresses complex biological functions, is striking. In the traditional curriculum, students learn about the reproductive systems of animals, including internal and external fertilization, and gain insights into the role of hormones in human growth and development. From a pedagogical perspective, this level likely involves in-depth discussions, laboratory experiments, and advanced visual aids to explain complex biological mechanisms.

The research objective, at its core, seeks to unravel the intricate patterns that govern the sequencing and presentation of these concepts in the secondary-level biological science curriculum. By delving into the detailed progression of these concepts, it aims to provide valuable insights into the educational development of biological science knowledge. This information is not only valuable for educators but also for curriculum designers and policymakers, as it can aid in optimizing the curriculum structure, improving teaching methods, and ultimately enhancing the learning experience for students.

In conclusion, the research objective is a journey into the heart of secondary-level biological science education. It investigates how key concepts progress and evolve as students advance through their studies. It starts with a foundational understanding of living organisms and their habitats in Class 6, moves on to the concept of adaptation in Class 7, and delves into the intricacies of cell biology and microorganisms in Class 8. This research objective's findings have the potential to shape the future of biological science education, ensuring that students receive a robust and well-structured education in this vital field of science.

**Table 4.3: Conceptual progression of prescribed curricular content of biological concepts**

| Topic | Class | N | Mean | Std. Deviation | Minimum marks | Maximum marks |
|---|---|---|---|---|---|---|
| Living Organism | 6th | 80 | 4.51 | 1.71 | 1.00 | 8.00 |
| | 7th | 80 | 5.17 | 1.97 | 1.00 | 10.00 |
| | 8th | 80 | 9.60 | 1.36 | 3.00 | 10.00 |
| | Total | 240 | 6.43 | 2.82 | 1.00 | 10.00 |
| Reproduction | 6th | 80 | 4.97 | 1.85 | 1.00 | 8.00 |
| | 7th | 80 | 4.94 | 1.83 | 1.00 | 8.00 |
| | 8th | 80 | 9.66 | 1.43 | 3.00 | 10.00 |
| | Total | 240 | 6.52 | 2.80 | 1.00 | 10.00 |

Table 4.3 show descriptive statistics for "Living Organism" variables across different categories (6th, 7th, 8th, and Total). This number of columns shows the total number of responses or observations for each variable. In this there are 80

observations in each category (6th, 7th & 8th), and a total of 240 observations across all categories. Mean shows the average value of the variable in each category.

| Table 4.4: ANOVA OF LIVING ORGANISM & REPRODUCTION | | | | | | |
|---|---|---|---|---|---|---|
| | | Sum of Squares | df | Mean Square | F | Result |
| Living Organism | Between Groups | 68.27 | 2 | 34.13 | 4.64 | Significant |
| | Within Groups | 1984.50 | 237 | 7.35 | | |
| | Total | 2052.77 | 239 | | | |
| Reproduction | Between Groups | 67.52 | 2 | 33.76 | 4.12 | Significant |
| | Within Groups | 1941.35 | 237 | 8.19 | | |
| | Total | 2008.87 | 239 | | | |

The ANOVA table 4.4 indicates that there is a statistically significant difference between the living organism and reproduction. The F-static and associated significance level (p=0.000) suggest that there are significant differences between the groups.

2. **To collate pedagogical perspectives of major biological science concepts.**

The research objective at hand is focused on the collection and analysis of pedagogical perspectives concerning major biological science concepts. This objective, in essence, seeks to create a comprehensive understanding of how these key biological science concepts are approached in the educational context. It encompasses an in-depth exploration of the pedagogical methods, strategies, and philosophies employed by educators to impart knowledge and foster understanding of these concepts among students. The major biological science concepts under examination are drawn from the curricular content typically taught in secondary-level education. These concepts are distributed across different grades and represent a progressive and interconnected approach to teaching biological science. Let's delve into each of these major concepts and understand how they are approached from a pedagogical perspective:

In Class 6 (Characteristics of Living Organisms and Habitat), students are introduced to the very foundations of biological science. This stage serves as a platform for building a robust understanding of life and the living world. Educators are tasked with instilling in their students an awareness of what characterizes living organisms and the ecosystems or habitats in which they exist. From a pedagogical perspective, this may involve interactive and experiential learning, such as field trips to observe various ecosystems or hands-on experiments with living organisms. The emphasis is likely on sparking curiosity and observation skills among students.

Joints and Movements marks the beginning of a student's exploration into the intricacies of biological science. The concept introduced at this stage is "Joints and Movements." In this context, students are initiated into understanding the structural components of the human body and the mechanisms that underlie physical mobility. From a pedagogical standpoint, educators aim to impart this foundational knowledge using various methods. Traditional pedagogical perspectives may involve classroom lectures, textbooks, and visual aids to illustrate the different types of joints and their functions. On the other hand, progressive pedagogical perspectives may employ more interactive approaches, such as hands- on demonstrations, anatomical models, or even digital simulations, to actively engage students in the learning process

In Class 7 (Adaptation) is a central concept in biology. In Class 7, educators dive deeper into this concept, explaining how living organisms evolve and change to suit their environments. The pedagogical perspective here may involve case studies of specific adaptations, interactive lessons on the evolution of species, and discussions on how these adaptations impact the survival and reproduction of organisms. Teachers may use real-life examples to make the concept relatable and engage students in critical thinking about the natural world.

(Animal Nutrition and Respiration) represents a significant step forward in the journey of biological science education. At this stage, students transition from a primarily structural focus to a more functional one. They explore two crucial aspects of life: nutrition and respiration in animals. This shift in content demonstrates the progression in the curriculum. Students delve into the processes that sustain life, examining how organisms acquire and utilize nutrients and oxygen. The pedagogical approach likely becomes more complex, introducing students to concepts like digestion and cellular respiration. Students are encouraged to think critically about how these processes are essential for life.

Class 8 (Cell Structure and Function, Microorganisms) represents a pivotal stage in the journey of biological science education. Students are introduced to the microscopic world of cells and microorganisms. Pedagogically, this can be a challenging but immensely rewarding phase. Educators may employ advanced teaching tools, such as microscopes, to allow students to observe cells and microorganisms firsthand. Visual aids, models, and interactive experiments may be integral to the teaching approach. Understanding cell structure and function is essential for comprehending the basis of life itself, and the study of microorganisms has wide-ranging implications, from health and medicine to environmental science.

Reproduction in Animals and Growth in Humans with Hormones represents the apex of the secondary-level biological science curriculum. Here, students explore the intricate processes of reproduction in animals and the mechanisms governing human growth, particularly focusing on hormones. The progression from Class 6, which dealt with the structural aspects of the body, to Class 8, which addresses complex biological functions, is striking. In the traditional curriculum, students learn about the reproductive systems of animals, including internal and external fertilization, and gain insights into the role of hormones in human growth and development. From a pedagogical perspective, this level likely involves in-depth discussions, laboratory experiments, and advanced visual aids to explain complex biological mechanisms.

The research objective's core focus is to gather insights into how these major biological science concepts are taught and the strategies employed by educators to facilitate learning. It's a journey into the world of teaching methods, classroom dynamics, and instructional materials used in the context of biological science education. Furthermore, this research aims to be a valuable resource for educators, curriculum designers, and policymakers. By collating diverse pedagogical perspectives, it can help identify effective teaching practices and areas that might Require improvement. This, in turn, can lead to the refinement of curricula and the development of more engaging and effective teaching approaches.
In summary, the research objective's pursuit of pedagogical perspectives on major biological science concepts is an endeavor to understand how the fundamentals of life and biology are imparted to students. It underscores the importance of effective teaching strategies, engaging educational materials, and the nurturing of curiosity and critical thinking among students. Ultimately, it contributes to the ongoing enhancement of the educational experience and the promotion of scientific literacy among future generations.

Collating pedagogical perspectives for teaching reproduction and living organisms to students in grades 6 to 8 requires a student-centered and engaging approach. Here's an analysis of pedagogical strategies for these topics in this age group:

★**Living Organisms:**

- Classification: Teach students about biological classification, starting with the broad categories (kingdoms) and gradually moving to more specific classifications (phylum, class, etc.). Use mnemonic devices to aid memory.
- Observation: Encourage students to observe and document living organisms in their surroundings. Provide journals or worksheets for

recording their observations.

- Interactive Technology: Incorporate interactive educational software and apps that allow students to explore the diversity of living organisms virtually. Virtual dissections and interactive field guides can be useful.
- Field Trips: Organize field trips to local parks, nature reserves, or botanical gardens to observe and study living organisms in their natural habitats.
- Hands-On Projects: Assign projects where students collect and classify specimens they find in their environment. These projects can include creating a mini-ecosystem in the classroom or starting a small garden.
- Food Webs and Ecosystems: Explore food webs and ecosystems to help students understand the interdependence of living organisms in different environments.
- Case Studies: Introduce case studies that showcase unique adaptations and behaviors in living organisms, such as animal migrations or plant adaptations to extreme environments.
- Assessment: Use a variety of assessment methods, including quizzes, presentations, and project-based assessments, to gauge students' understanding of living organisms and their ability to classify them.

When collating pedagogical perspectives for these topics, consider the developmental stage of students in grades 6 to 8. They are curious and benefit from active, inquiry-based learning experiences. Additionally, connecting biological concepts to real-life examples and applications can help make the material more relevant and engaging for them.

Table 4.5: Paired Samples Statistics for pedagogical perspectives of Class $6^{th}$

| Pedagogical Perspectives | | | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|---|
| Living Organism | Pair 1 | Living Organism | 80 | 4.51 | 1.70 | .19 |
| | | Teaching Approaches | 80 | 10.37 | 2.46 | .27 |
| | Pair 2 | Living Organism | 80 | 4.51 | 1.70 | .19 |
| | | Technology and Digital Resources | 80 | 6.30 | 2.14 | .24 |
| | Pair 3 | Living Organism | 80 | 4.51 | 1.70 | .19 |
| | | Cross-Curricular Connections | 80 | 6.82 | 1.96 | .22 |
| Reproductio | Pair 1 | Reproduction | 80 | 4.97 | 1.85 | .20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| n | | Teaching Approaches | 80 | 10.37 | 2.46 | .27 |
| Table 4.5 (Continued) | | | | | | |
| | Pair 2 | Reproduction | 80 | 4.97 | 1.85 | .20 |
| | | Technology and Digital Resources | 80 | 6.30 | 2.14 | .24 |
| | Pair 3 | Reproduction | 80 | 4.97 | 1.85 | .20 |
| | | Cross-Curricular Connections | 80 | 6.82 | 1.96 | .22 |

**Table 4.6: Paired Samples Statistics for pedagogical perspectives of Class 7th**

| Pedagogical Perspectives | | | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|---|
| Living Organism | Pair 1 | Living Organism | 80 | 5.17 | 1.96 | .21 |
| | | Teaching Approaches | 80 | 9.48 | 2.69 | .30 |
| | Pair 2 | Living Organism | 80 | 5.17 | 1.96 | .21 |
| | | Technology and Digital Resources | 80 | 7.31 | 1.74 | .19 |
| | Pair 3 | Living Organism | 80 | 5.17 | 1.96 | .21 |
| | | Cross-Curricular Connections | 80 | 6.58 | 2.29 | .25 |
| Reproduction | Pair 1 | Reproduction | 80 | 4.93 | 1.82 | .20 |
| | | Teaching Approaches | 80 | 9.48 | 2.69 | .30 |
| | Pair 2 | Reproduction | 80 | 4.93 | 1.82 | .20 |
| | | Technology and Digital Resources | 80 | 7.31 | 1.74 | .19 |
| | Pair 3 | Reproduction | 80 | 4.93 | 1.82 | .20 |
| | | Cross-Curricular Connections | 80 | 6.58 | 2.29 | .25 |

| Table 4.7: Paired Samples Statistics for pedagogical perspectives of Class 8th | | | | | | |
|---|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Mean | Std. Deviation | Std. Error Mean |
| Living Organism | Pair 1 | Living Organism | 80 | 9.60 | 1.36 | .15 |
| | | Teaching Approaches | 80 | 8.77 | 3.22 | .36 |
| | Pair 2 | Living Organism | 80 | 9.60 | 1.36 | .15 |
| | | Technology and Digital Resources | 80 | 6.75 | 2.22 | .24 |
| | Pair 3 | Living Organism | 80 | 9.60 | 1.36 | .15 |
| | | Cross-Curricular Connections | 80 | 6.95 | 2.34 | .26 |
| Reproduction | Pair 1 | Reproduction | 80 | 9.66 | 1.43 | .16 |
| | | Teaching Approaches | 80 | 8.77 | 3.22 | .36 |
| | Pair 2 | Reproduction | 80 | 9.66 | 1.43 | .16 |
| | | Technology and Digital Resources | 80 | 6.75 | 2.22 | .24 |
| | Pair 3 | Reproduction | 80 | 9.66 | 1.43 | .16 |
| | | Cross-Curricular Connections | 80 | 6.95 | 2.34 | .26 |

Table-4.5,4.6 & 4.7 shows paired samples statistics for class of students organized by grade level, which is divided into three pairs. Within each pair, students are assessed on different subjects or topics. The "Mean" values indicate the average scores for each subject or topic within each pair and grade level. For example, in the 6th grade, for Pair 1, the mean score for "Living Organism" is 4.51, and the mean score for "Teaching Approaches" is 10.37. The standard deviation values show how much the scores vary or spread out from the mean. For instance, in 6th grade Pair 1, "Living Organism" has a standard deviation of 1.71, and "Teaching Approaches" has a standard deviation of 2.46. A smaller standard error mean indicates greater precision in the sample mean estimates. For example, in 6th grade Pair 1, "Living Organism" has a standard error mean of 0.19, and "Teaching

Approaches" has a standard error mean of 0.27.

| Table 4.8 Paired Samples Correlations for pedagogical perspectives of class 6th | | | | | |
|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Correlation | Sig. |
| Living Organism | Pair 1 | Living Organism & Teaching approaches | 80 | -.007 | .95 |
| | Pair 2 | Living Organism & Technology and Digital Resources | 80 | -.036 | .75 |
| | Pair 3 | Living Organism & Cross-Curricular Connections | 80 | .129 | .25 |
| Reproduction | Pair 1 | Reproduction & Teaching approaches | 80 | .049 | .66 |
| | Pair 2 | Reproduction & technology and digital resources | 80 | .015 | .89 |
| | Pair 3 | Reproduction & Cross-Curricular Connections | 80 | .033 | .76 |

| Table 4.9 Paired Samples Correlations for pedagogical perspectives of class 7th | | | | | |
|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Correlation | Sig. |
| Living Organism | Pair 1 | Living Organism & Teaching approaches | 80 | -.007 | .95 |
| | Pair 2 | Living Organism & Technology and Digital Resources | 80 | -.001 | .99 |
| | Pair 3 | Living Organism & Cross-Curricular Connections | 80 | .025 | .82 |
| Reproduction | Pair 1 | Reproduction & Teaching approaches | 80 | -.050 | .65 |
| | Pair 2 | Reproduction & technology and digital resources | 80 | -.184 | .10 |
| | Pair 3 | Reproduction & Cross-Curricular Connections | 80 | -.136 | .22 |

| Table 4.10 Paired Samples Correlations for pedagogical perspectives of class 8th | | | | | |
|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Correlation | Sig. |
| Living Organism | Pair 1 | Living Organism & Teaching approaches | 80 | -.067 | .55 |
| | Pair 2 | Living Organism & Technology and Digital Resources | 80 | -.008 | .94 |
| | Pair 3 | Living Organism & Cross-Curricular Connections | 80 | .077 | .49 |
| Reproduction | Pair 1 | Reproduction & Teaching approaches | 80 | -.017 | .88 |
| | Pair 2 | Reproduction & technology and digital resources | 80 | -.011 | .92 |
| | Pair 3 | Reproduction & Cross-Curricular Connections | 80 | .093 | .41 |

Table-4.8,4.9 & 4.10 shows paired samples correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. The table is organized by grade level, which is divided into three pairs. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair. For example, in the 6th grade Pair 1, the correlation between "Living Organism" and "Teaching Approaches" is - 0.007, which suggests a very weak and almost no linear relationship between these two subjects. The "Sig." values represent the p-value associated with the correlation. A p-value less than a predefined significance level (usually 0.05) indicates that the correlation is statistically significant. If the p-value is less than 0.05, the observed correlation is unlikely to have occurred by chance.

| Table 4.11 Paired Sample Test for Pedagogical Perspectives of class 6th | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Mean | Standard Deviation | Standard Error | t | Result (Sig.) at 0.05 level |
| Living Organism | Pair 1 | Living Organism- Teaching Approaches | 80 | -5.86 | 3.00 | .33 | -17.42 | significant |
| | Pair 2 | Living Organism - Technology and Digital Resources | 80 | -1.78 | 2.79 | .31 | -5.73 | significant |
| | Pair 3 | Living Organism - Cross Curricular Connections | 80 | -2.31 | 2.43 | .27 | -8.50 | significant |
| Reproduction | Pair 1 | Reproduction- Teaching approaches | 80 | -5.40 | 3.01 | .34 | -16.03 | significant |
| | Pair 2 | Reproduction- Technology and Digital Resources | 80 | -1.32 | 2.82 | .32 | -4.20 | significant |
| | Pair 3 | Reproduction- Cross Curricular Connections | 80 | -1.85 | 2.66 | .29 | -6.22 | significant |

| Table 4.12 Paired Sample Test for Pedagogical Perspectives of class 7th | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Mean | Standard Deviation | Standard Error | t | Result (Sig.) at 0.05 level |
| Living Organism | Pair 1 | Living Organism-Teaching Approaches | 80 | -4.31 | 3.35 | .37 | -11.52 | significant |
| | Pair 2 | Living Organism - Technology and Digital Resources | 80 | -2.13 | 2.63 | .29 | -7.26 | significant |
| | Pair 3 | Living Organism - Cross Curricular Connections | 80 | -1.41 | 2.99 | .33 | -4.23 | significant |
| Reproduction | Pair 1 | Reproduction - Teaching approaches | 80 | -4.55 | 3.33 | .37 | -12.22 | significant |
| | Pair 2 | Reproduction - Technology and Digital Resources | 80 | -2.37 | 2.74 | .31 | -7.12 | significant |
| | Pair 3 | Reproduction - Cross Curricular Connections | 80 | -1.65 | 3.12 | .35 | -4.73 | significant |

| Table 4.13 Paired Sample Test for Pedagogical Perspectives of class 8th | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pedagogical Perspectives | | | N | Mean | Standard Deviation | Standard Error | t | Result (Sig.) at 0.05 level |
| Living Organism | Pair 1 | Living Organism- Teaching Approaches | 80 | .82 | 3.59 | .40 | 2.06 | significant |
| | Pair 2 | Living Organism - Technology and Digital Resources | 80 | 2.85 | 2.60 | .29 | 9.80 | significant |
| | Pair 3 | Living Organism - Cross Curricular Connections | 80 | 2.65 | 2.62 | .29 | 9.03 | significant |
| Reproduction | Pair 1 | Reproduction- Teaching approaches | 80 | .88 | 3.55 | .39 | 2.23 | significant |
| | Pair 2 | Reproduction- Technology and Digital Resources | 80 | 2.91 | 2.65 | .30 | 9.79 | significant |
| | Pair 3 | Reproduction- Cross Curricular Connections | 80 | 2.71 | 2.63 | .29 | 9.20 | significant |

The table- 4.11, 4.12 & 4.13 contains paired samples test results for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. the mean differences between the two subjects or topics within each pair. For example, in the 6th grade Pair 1, the mean difference between "Living Organism" and "Teaching Approaches" is -5.86. This means that, on average, students scored 5.86 units lower in "Living Organism" compared to "Teaching Approaches." In the 6th grade, Pair 1, the mean difference between "Living Organism" and "Teaching

Approaches" is -5.86. This difference is highly significant with a p-value of 0.00, indicating that students, on average, scored significantly lower in "Living Organism" compared to "Teaching Approaches." In the 8th grade, Pair 1, the mean difference between "Living Organism" and "Teaching Approaches" is 0.82. The p-value is 0.04, suggesting that this difference is statistically significant. These paired samples test results are important for understanding whether there are significant differences in student performance between the paired subjects.

### 3.To trace the trajectory of evolution of major biological science concepts.

The research objective before us is a compelling exploration into the evolutionary path of major biological science concepts as they unfold within the educational context. This objective is akin to a journey through the annals of pedagogy, where we trace the historical and conceptual progression of these pivotal biological science themes across different levels of education. The major biological science concepts under scrutiny, derived from the secondary- level curriculum, form the foundation of our exploration. These concepts are strategically dispersed across various grade levels, presenting a comprehensive and interconnected approach to the teaching of biological science. Let's embark on this educational journey and understand how these concepts evolve over the years.

Class 6 (Characteristics of Living Organisms and Habitat) serves as the introductory chapter in a student's biological science education. At this stage, students are introduced to the fundamental building blocks of life. This includes understanding what distinguishes living organisms from non-living entities and delving into the varied habitats in which these organisms thrive. The pedagogical approach at this level emphasizes foundational knowledge. Students are encouraged to explore the living world through observation, classification, and the basic understanding of ecosystems. The aim is to ignite their curiosity and foster a sense of wonder about the diversity of life on Earth.

In Class 6 (Joints and Movements), students embark on their journey into the realm of biological science. Here, they are introduced to the concept of "Joints and Movements." This represents the foundational phase of the educational trajectory. At this stage, students are familiarized with the structural aspects of the human body, particularly the skeletal system and the role of joints in facilitating movement. The pedagogical approach at this level typically involves introductory lessons, including classroom instruction, textbook readings, and perhaps some basic hands-on activities to help students grasp the fundamental principles of the skeletal and muscular systems.

In Class 7 (Adaptation), the journey takes a significant step forward as students dive into the concept of adaptation. This theme builds upon the introductory knowledge acquired in Class 6 and delves into the dynamic world of evolutionary biology. Students learn how living organisms adapt to their ever-changing environments through biological and behavioral changes. The pedagogical approach at this stage might involve real-life examples of adaptation, interactive lessons, and discussions about how these adaptations contribute to species' survival and evolution. Students are encouraged to think critically and engage in discussions about the intricacies of the natural world.

Class 7 (Animal Nutrition and Respiration) signifies a pivotal step in the journey of biological science education. Students transition from structural aspects to more functional ones, delving into the dynamic processes of "Animal Nutrition and Respiration." This shift reflects the evolution of the curriculum. In Class 7, students explore how living organisms acquire and utilize nutrients and oxygen. The pedagogical approach likely becomes more complex, introducing students to concepts like digestion and cellular respiration. Lessons may involve a blend of classroom instruction, laboratory experiments, and interactive discussions, encouraging students to think critically about how these processes are essential for life.

Class 8 (Cell Structure and Function, Microorganisms) marks a pivotal point in the evolution of biological science concepts within the curriculum. Students are introduced to the microscopic realm of biology, with a focus on cell structure and function. Understanding cells is fundamental, as they are the basic units of life. The pedagogical approach may involve advanced teaching tools like microscopes, visual aids, and interactive experiments to enable students to observe and comprehend the intricacies of cells. Additionally, students explore the world of microorganisms. This phase introduces students to the unseen yet profoundly influential microcosm of life, with lessons extending into various areas such as health, medicine, and environmental science.

Class 8 (Reproduction in Animals and Growth in Humans with Hormones) marks the pinnacle of the secondary-level biological science curriculum. In this phase, students tackle complex and intricate concepts, such as "Reproduction in Animals" and "Growth in Humans with Hormones." The progression from Class 6 to Class 8 is evident as students move from structural knowledge to the mechanisms governing reproduction and growth. In Class 8, students delve into the reproductive systems of animals and the role of hormones in human growth and development. The pedagogical approach at this level likely involves advanced lessons and discussions. Students may engage in laboratory experiments, in-depth case studies, and explore the complexities of biological mechanisms, reflecting the evolution of their knowledge and understanding.

Now, to trace the trajectory of evolution of these major biological science concepts: The journey begins in Class 6 with foundational knowledge about living organisms and their habitats. This stage is characterized by an emphasis on observation and classification, laying the groundwork for subsequent learning. Class 7 represents a significant step in evolution, where students delve into the fascinating concept of adaptation. The shift in focus from the characteristics of living organisms to the mechanisms of adaptation showcases the dynamic nature of biology. Finally, in Class 8, the trajectory reaches its zenith as students are introduced to the microscopic world of cell biology and microorganisms. This phase represents a culmination of the students' journey, providing them with the tools and knowledge to comprehend the intricate workings of life itself.

This research objective, in its quest to trace the trajectory of evolution of these major biological science concepts, seeks to unravel the patterns, progressions, and connections within the curriculum. It aims to provide valuable insights into how students' understanding of biology evolves throughout their educational journey. This knowledge can be invaluable for educators, curriculum designers, and policymakers in refining the educational experience, enhancing teaching methods, and shaping the future of biological science education. In conclusion, the research objective is a voyage through the educational landscape, tracking how fundamental biological science concepts progress and mature over time. It underscores the importance of building a strong foundation and progressively deepening students' understanding of biology, ultimately contributing to a well-rounded and robust biological science education.

Tracing the trajectory of major biological science concepts like living organisms for students in classes 6 to 8 involves presenting the concepts progressively and building on their existing knowledge. Here's a simplified trajectory for these concepts:

Class 6: Introduction to Living Organisms

★ Introduction to Life:.

- Start by discussing what constitutes a living organism.
- Explore characteristics of living things (e.g., growth, reproduction, response to stimuli).

★ Cell Introduction:

- Introduce the concept of cells as the basic units of life.
- Discuss the differences between plant and animal cells.

Class 7: Reproduction and Heredity

★ Heredity and Traits:

- Introduce genetics by explaining how traits are inherited from parents.

- Discuss dominant and recessive traits.

★ Variation:

- Explain that variation in traits occurs due to genetic differences.
- Use simple Punnett squares to demonstrate genetic inheritance.

Class 8: Evolution and Advanced Concepts

★ Introduction to Evolution:

- Introduce the concept of evolution as changes in living organisms over time.
- Explain that variation and adaptation are essential components of evolution.

★ Darwin and Natural Selection:

- Discuss Charles Darwin's theory of natural selection.
- Explain how natural selection leads to the adaptation of species to their environments.

★ Ecosystems and Interactions:

- Explore ecosystems as communities of living organisms interacting with their environment.
- Discuss how organisms depend on each other for survival.

★ Health and Hygiene:

- Discuss the importance of personal hygiene and health in maintaining the well- being of living organisms.
- Introduce concepts like nutrition and disease prevention.

★ Environmental Conservation:

- Highlight the importance of conserving living organisms and their habitats for biodiversity and a balanced ecosystem.
- Discuss the impact of human activities on the environment.

★ Biological Classification:

- Introduce basic principles of biological classification, such as grouping organisms based on similarities and differences.

★ Ethical Considerations:

- Discuss ethical issues related to living organisms, such as animal rights, conservation, and responsible use of biotechnology (in a simplified manner).

Table 4.14: Descriptive Analysis for trajectory of evolution of biological concepts

| | | Class 6th | Class 7th | Class 8th |
|---|---|---|---|---|
| Living Organism | Mean | 4.51 | 5.17 | 9.60 |
| | Standard Deviation | 1.71 | 1.97 | 1.36 |
| Reproduction | Mean | 4.97 | 4.93 | 9.66 |
| | Standard Deviation | 1.85 | 1.82 | 1.43 |

Table-4.14 shows three grade levels: Class 6th, Class 7th, and Class 8th. For Class 6th, the mean value is 4.51, for Class 7th, the mean value is 5.17, and for Class 8th, the mean value is 9.60. The standard deviation for each grade level, which tells how much the values within each grade level vary. For Class 6th, the standard deviation is 1.71, for Class 7th, the standard deviation is 1.97, suggesting slightly more variability in the data compared to Class 6th. For Class 8th, the standard deviation is 1.36, which is the lowest among the three grade levels.

4.To analyze and map the evolution of major biological concepts among secondary level students from field data.

The research objective at hand presents a captivating journey into the realm of biological science education, focusing on the analysis and mapping of the evolutionary trajectory of major biological concepts as they are understood and learned by secondary level students. This objective is rooted in the collection and examination of field data, which offers valuable insights into how these concepts evolve and are comprehended by students as they progress through their education. The major biological science concepts that serve as the foundation of this research have been derived from the secondary-level curriculum, specifically from Class 6, 7, and 8. These concepts form a structured and interconnected framework for teaching biology, reflecting the progression of complexity and depth as students advance through their education.

In Class 6 (Characteristics of Living Organisms and Habitat), students embark on their biological science journey. This initial stage serves as the foundation upon which their understanding of life is built. It involves the exploration of the fundamental characteristics that define living organisms and their respective habitats. From a pedagogical perspective, this level may emphasize observation, classification, and the establishment of basic knowledge about the diversity of life.

The aim is to spark students' curiosity and encourage them to appreciate the intricate relationships between organisms and their environments.

In Class 6 (Joints and Movements), students are introduced to fundamental concepts related to the human body's structure and function. The focus here is on "Joints and Movements," which provides insights into the skeletal system and how it enables mobility. The curriculum at this stage likely covers the different types of joints and their role in facilitating various movements. Students typically encounter these concepts in traditional classroom settings, and teachers often employ a mix of theoretical instruction, textbook readings, and simple hands-on activities to foster understanding. This foundational knowledge serves as the starting point for the study.

Class 7 (Adaptation) represents a significant milestone in a student's biological science education. This stage builds upon the foundational knowledge acquired in Class 6 by delving into the captivating concept of adaptation. Students begin to explore how living organisms evolve and adapt to their changing environments, both biologically and behaviorally. From a pedagogical standpoint, this level may involve the use of real-life examples and case studies to illustrate the concept of adaptation, encouraging critical thinking and fostering a deeper understanding of evolutionary biology. In Class 7 (Animal Nutrition and Respiration) represents a significant shift as student's transition from the structural aspects of biology to the functional. In this phase, they dive into the "Animal Nutrition and Respiration" concepts, delving into the processes that sustain life. This includes how animals acquire and utilize nutrients and oxygen, fundamental for survival. The pedagogical approach at this stage becomes more complex, and students are encouraged to think critically. Traditional methods may involve classroom lectures and textbook-based learning, while more progressive approaches may integrate laboratory experiments, case studies, and interactive discussions to make the subject matter more engaging and relatable.

Class 8 (Cell Structure and Function, Microorganisms) represents the culmination of a student's journey through the major biological science concepts. At this stage, students are introduced to the microscopic world of biology, with a specific focus on cell structure and function. Understanding the complexities of cells is crucial, as they are the fundamental units of life. The curriculum may include advanced teaching tools such as microscopes, hands-on experiments, and visual aids to help students explore the intricacies of cells. Additionally, students delve into the world of microorganisms, which play a pivotal role in various biological processes, from human health to environmental sustainability.

In Class 8 (Reproduction in Animals and Growth in Humans with Hormones) represents the pinnacle of the secondary-level biological science curriculum, focusing on the "Reproduction in Animals" and "Growth in Humans with

Hormones." This phase marks a considerable shift towards intricate biological concepts. Students explore the reproductive systems of animals and delve into the role of hormones in human growth and development. At this level, the pedagogical perspective tends to be more in-depth, reflecting the complexity of the subjects. Traditional approaches may include detailed lectures, comprehensive textbooks, and assessments. In contrast, more progressive methodologies can involve advanced teaching tools, hands-on experiments in reproductive biology, and interactive discussions about the role of hormones. These approaches aim to facilitate a deeper understanding of complex biological mechanisms.

The research objective aims to provide a comprehensive analysis of how these major biological concepts are absorbed, understood, and internalized by secondary level students. It seeks to map the evolution of their knowledge and comprehension over time. To accomplish this, field data will be collected, allowing researchers to gain a real-world perspective on how students engage with and progress through these concepts. The field data collection process may involve a variety of research methods, including surveys, interviews, classroom observations, and assessments. Researchers may interact directly with students, educators, and other stakeholders to gather insights into the learning experience. The collected data will offer valuable information on the challenges students may face in grasping these concepts, the teaching methods that prove most effective, and the potential areas for improvement in the educational process. The mapping aspect of the research objective involves creating a visual representation of the evolution of students' understanding of these major biological concepts. This can take the form of concept maps, knowledge progression timelines, or other visual aids that showcase how students' comprehension deepens and evolves as they progress through their secondary level education.

In conclusion, the research objective embodies a deep dive into the realm of secondary-level biological science education. It aims to shed light on how students' understanding of major biological concepts transforms over time and how effective pedagogical methods contribute to this evolution. The analysis of field data and the mapping of knowledge progression will provide valuable insights for educators, curriculum designers, and policymakers, ultimately enhancing the educational experience and fostering a deeper appreciation for the wonders of the living world among secondary level students.

**5.To study the effectiveness of the activity-based approach over traditional approach as two major pedagogical intervention.**

The research objective at hand offers an intriguing exploration into the realm of biological science education by comparing the effectiveness of two major pedagogical interventions: the activity-based approach and the traditional approach. This study seeks to analyze and discern which of these two teaching methods proves more efficacious in imparting knowledge and understanding of major biological science concepts among students. The major biological science concepts selected for this comparative analysis are drawn from the secondary-level curriculum, spanning Class 6, 7, and 8. These concepts serve as the foundation for a student's understanding of biology, representing a structured progression from basic knowledge to more complex subjects.

In Class 6 (Characteristics of Living Organisms and Habitat) marks the beginning of a student's journey into the world of biological science. Here, students are introduced to the fundamental characteristics that distinguish living organisms from non-living entities and the ecosystems or habitats they inhabit. In the traditional approach, this stage is typically characterized by lectures, textbook readings, and theoretical instruction. Students learn about the characteristics and habitats of living organisms through passive learning. In contrast, the activity-based approach in Class 6 may involve hands-on activities, field trips to observe organisms in their natural habitats, and interactive experiments. For instance, students might collect and classify local plant specimens, examine soil samples, or study the adaptation of organisms in various ecosystems. This approach encourages students to engage with the subject matter actively, fostering curiosity and a deeper appreciation for the natural world. In Class 6 (Joints and Movements), students are introduced to the fundamental concept of "Joints and Movements." This is the first stepping stone in their biological science education. At this stage, students learn about the structural aspects of the human body, focusing on the skeletal system and the mechanics of movement. In a traditional classroom setting, this would typically involve lectures, textbook readings, and theoretical instruction. Students acquire knowledge about different types of joints and their functions primarily through passive learning. In contrast, the activity-based approach in Class 6 could involve more engaging methods. Students might participate in hands-on activities, explore models of joints, or even take part in interactive demonstrations to actively engage with the subject matter. This approach aims to spark curiosity, foster understanding, and make learning a more dynamic and interactive process.

In Class 7 (Adaptation) represents a transitional phase in a student's biological science education. Here, the traditional approach would likely involve in-depth theoretical lessons, textbook readings, and discussions about the concept of adaptation. Students may learn about how living organisms evolve to fit their environments primarily through passive engagement. In the activity-based approach, Class 7 becomes an opportunity to reinforce understanding through practical examples and experiments. Students may explore case studies of specific adaptations, conduct experiments to observe adaptations in action, and engage in discussions about the evolutionary mechanisms underlying adaptation. This hands-on approach provides students with a more immersive and interactive learning experience.

In Class 7 (Animal Nutrition and Respiration) represents a transition from the structural to the functional aspects of biology. Students explore two vital biological processes: "Animal Nutrition and Respiration." In the traditional approach, students are taught about these processes primarily through lectures, textbook-based learning, and theoretical explanations. They gain insights into how animals acquire and utilize nutrients and oxygen, critical for life. However, this method may not always provide a tangible and relatable understanding of these concepts. The activity-based approach in Class 7 takes a different route. It introduces more hands-on experiences, like laboratory experiments that allow students to observe digestion processes, interactive case studies that challenge them to apply their knowledge, and engaging discussions about the importance of nutrition and respiration. This approach aims to provide a more immersive and engaging learning experience, making the subject matter more accessible and relatable.

Class 8 (Cell Structure and Function, Microorganisms) marks a significant phase in a student's journey through major biological science concepts. In the traditional approach, students would typically delve into the microscopic world of cells, studying their structure and function. This stage may involve textbook-based learning, lectures, and perhaps minimal hands-on activities. In Class 8 (Reproduction in Animals and Growth in Humans with Hormones) represents the zenith of secondary-level biological science education. Students encounter complex topics, including "Reproduction in Animals" and "Growth in Humans with Hormones." In the traditional approach, these subjects are typically taught through detailed lectures, comprehensive textbooks, and assessments that evaluate students' understanding. While these methods are comprehensive, they may not always foster an in-depth, practical understanding of these intricate biological mechanisms.

In the activity-based approach, Class 8 becomes an opportunity to explore the microscopic world more profoundly. Students may have access to microscopes and engage in practical experiments to observe cells and microorganisms. This approach encourages students to actively investigate and explore the subject matter, leading to a deeper understanding of cell biology and microorganisms. The research objective aims to systematically study and compare the effectiveness of these two major pedagogical interventions—activity-based and traditional approaches—across the aforementioned biological science concepts and grade levels. The study will involve data collection, including student performance assessments, surveys, and feedback from educators, to evaluate the impact of these teaching methods on students' knowledge retention, comprehension, and engagement.

The activity-based approach in Class 8 aims to provide students with a more experiential understanding. It involves advanced teaching tools, such as laboratory experiments in reproductive biology, interactive discussions about the role of hormones in human growth and development, and hands-on exploration of complex concepts. This approach encourages students to actively investigate and apply their knowledge, fostering a deeper comprehension of these intricate topics. The research objective sets out to systematically study and compare the effectiveness of these two major pedagogical interventions—traditional and activity-based approaches—across the mentioned biological science concepts and grade levels. The research process includes data collection through student performance assessments, surveys, and feedback from educators. By analyzing the data, the objective aims to determine which approach, whether traditional or activity-based, is more successful in enhancing students' comprehension, knowledge retention, and overall engagement with the major biological science concepts.

By conducting a comprehensive analysis, this research seeks to determine which approach, whether traditional or activity-based, proves more effective in enhancing students' understanding of biological science concepts. The findings of this study can have significant implications for the field of education, guiding educators and curriculum designers in selecting the most suitable pedagogical interventions to foster a deeper appreciation for the living world and biological science concepts among students. In conclusion, the research objective is a pivotal exploration into the effectiveness of pedagogical interventions in the context of major biological science concepts at the secondary level. It highlights the importance of engaging and interactive approaches in education, aiming to enhance students' comprehension and appreciation of the intricate world of biology. Ultimately, this research aims to contribute to the advancement of science education by providing evidence-based insights into the most effective teaching methods for nurturing the next generation of biological scientist.

# Findings and Suggestions

# CHAPTER 5

# FINDINGS AND SUGGESTIONS

## 5.1Conclusion

The study focuses on examining the development and evolution of biological science concepts among secondary-level students. It aims to investigate how students' understanding of biological science evolves over time as they progress through their education. By analyzing the changes in their comprehension of various biological concepts, the research aims to provide insights into the effectiveness of science education at the secondary level and identify areas where improvements may be needed. This study contributes to our understanding of the learning process in the field of biology and can inform educational strategies to enhance students' knowledge and conceptual growth in biological science.

The study explores how students' understanding and application of biological science concepts change over time, and what factors influence their learning process. The study also seeks to identify the challenges and opportunities for improving the teaching and learning of biological science in secondary schools. The study uses a mixed-methods approach, combining quantitative and qualitative data collection and analysis. The study involves a sample of students from different grades, schools, and backgrounds, who are assessed on their knowledge, skills, and attitudes towards biological science concepts. The study also involves interviews and observations of teachers and students to gain insights into their experiences and perspectives on biological science education. The study contributes to the existing literature on science education, and provides implications for curriculum development, teacher training, and student assessment.

## 5.2Findings of the Study

The findings of the study are:

### 5.2.1 Findings based on the Demographics of the Client

i. According to the Class of Student of the Respondents, describes the demographic variable wise frequency, percent, valid percent, and cumulative percent. When it comes to -Valid demographic variable out of 240 students, 80 are of 6th class, 80 are of 7th class and 80 are of 8th class.

ii. According to the Name of School, a summary of the distribution of students across two different schools, along with the percentage each school represents, both individually and cumulatively. It helps to understand the distribution of school within the group, with 120 students from Composite Adarsh Kerakat and 120 students from Composite School Saroj Badewar.

### 5.2.2 Findings based on the Objectives.

Findings based on the objective are divided into two concepts.

★ **Characteristics of Living Organisms**

**1 To find out the conceptual progression in prescribed curricular content of biological science at secondary level.**

- The findings show descriptive statistics for "Living Organism" variables across different categories (6th, 7th, 8th, and Total). This number of columns shows the total number of responses or observations for each variable. In this there are 80 observations in each category (6th, 7th, and 8th), and a total of 240 observations across all categories. Mean shows the average value of the variable in each category.

- The findings indicate that there is a statistically significant difference between the living organism and reproduction. The F-static and associated significance level suggest that there are significant differences between the groups.

**2 To collate pedagogical perspectives of major biological science concepts.**

- The findings describe statistics display paired samples data for students categorized by grade level, with each grade level consisting of three pairs. Within each pair, students are evaluated on different subjects or topics. The "Mean" values represent the average scores for each subject or topic in each pair and grade level. For instance, in 6th grade Pair 1, the mean score for "Living Organism" is 4.51, and for "Teaching Approaches," it is 10.37. The standard deviation values indicate the extent to which scores deviate or spread from the mean.

- The findings show paired samples correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. The table is organized by grade level, which is divided into three pairs. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair.

- The findings provided contain paired samples test results for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. The meaning differences between the two subjects or topics within each pair.

**3To trace the trajectory of evolution of major biological science concepts.**

- The findings show three grade levels: Class 6th, Class 7th, and Class 8th. For Class 6th, the mean value is 4.51, for Class 7th, the mean value is 5.17, and for Class 8th, the mean value is 9.60. The standard deviation for each grade level, which tells how much the values within each grade level vary. For Class 6th, the standard deviation is 1.70, for Class 7th, the standard deviation is 1.96, suggesting slightly more variability in the data compared to Class 6th. For Class 8th, the standard deviation is 1.36, which is the lowest among the three grade levels.

**4To analyze and map the evolution of major biological concepts among secondary level students from field data.**

- The findings indicate that class of students organized by grade level, which is divided into two pairs. Within each pair, students are assessed on different subjects or topics. The "Mean" values indicate the average scores for each subject or topic within each pair and grade level. The standard deviation values show how much the scores vary or spread out from the mean. A smaller standard error indicates greater precision in the sample mean estimates.

- The findings show correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair.

- The findings described contains paired samples for different classes of students (6th, 7th, and 8th grades) for various pairs of assessments, including "Living Organism-Biological Concepts," "Living Organism-Concepts of Reproduction," within each class and in each case, the "Living Organism - Biological Concepts" assessments have lower scores than the "Living Organism- Concepts of Reproduction" assessments.

5To study the effectiveness of the activity-based approach over traditional approach as two major pedagogical intervention.

- The finding objective is a pivotal exploration into the effectiveness of pedagogical interventions in the context of major biological science concepts at the secondary level. It highlights the importance of engaging and interactive approaches in education, aiming to enhance students' comprehension and appreciation of the intricate world of biology. Ultimately, this research aims to contribute to the advancement of science education by providing evidence-based insights into the most effective teaching methods for nurturing the next generation of biological scientists.

★ Reproduction in Animals

1.To find out the conceptual progression in prescribed curricular content of biological science at secondary level.

- The findings show descriptive statistics for "Reproduction" variables across different categories (6th, 7th, 8th, and Total). This number of columns shows the total number of responses or observations for each variable. In this there are 80 observations in each category (6th, 7th, and 8th), and a total of 240 observations across all categories. Mean shows the average value of the variable in each category.

- The findings indicate that there is a statistically significant difference between the living organism and reproduction. The F-static and associated significance level suggest that there are significant differences between the groups.

2. To collate pedagogical perspectives of major biological science concepts.

- The findings provided contain paired samples statistics for different classes of students in 6th, 7th, and 8th grades, with various assessment types. The "Mean" column provides the average score for the given assessment type within each pair and grade. For example, in 6th grade, Pair 1 for "Reproduction" has a mean score of 4.97. The standard deviation measures the variability or spread of the data points. It tells you how much individual scores or performances differ from the meaning. The standard error of the mean provides an estimate of how much the sample mean might vary from the true population mean. It accounts for the sample size.

- The findings show paired samples correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. The table is organized by grade level, which is divided into three pairs. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair.

- The findings describe contains paired samples test for different classes of students (6th, 7th, and 8th grades) for various pairs of assessments, including "Reproduction & Teaching Approaches," "Reproduction & Technology and Digital Resources," and "Reproduction & Cross-Curricular Connections." These correlations are used to assess the relationships between these pairs of assessments within each class.

3. To trace the trajectory of evolution of major biological science concepts

- The findings show three grade levels: Class 6th, Class 7th, and Class 8th. For Class 6th, the mean value is 4.97, for Class 7th, the mean value is 4.93, and for Class 8th, the mean value is 9.66. The standard deviation for each grade level, which tells how much the values within each grade level vary. For Class 6th, the standard deviation is 1.85, for Class 7th, the standard deviation is 1.82, suggesting slightly more variability in the data compared to Class 6th. For Class 8th, the standard deviation is 1.43, which is the lowest among the three grade levels.

4. To analyze and map the evolution of major biological concepts among secondary level students from field data.

- The findings show that class of students organized by grade level, which is divided into two pairs. Within each pair, students are assessed on different subjects or topics. The "Mean" values indicate the average scores for each subject or topic within each pair and grade level.

- The findings explain correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair.

- The findings present paired sample for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. Paired differences provide the differences in scores between the two paired assessments within each class. The results indicate that there are statistically significant differences in scores between the paired assessments in all three classes, and in each case, the "Reproduction - Biological Concepts" assessments have lower scores than the "Reproduction - Concepts of Reproduction" assessments.

5. **To study the effectiveness of the activity-based approach over traditional approach as two major pedagogical intervention.**

    - The finding objective is a journey into the realm of pedagogical effectiveness in teaching major biological science concepts at the secondary level. It underscores the significance of engaging and interactive approaches in education, aiming to enhance students' comprehension and appreciation for the wonders of biology. By comparing traditional and activity-based approaches, this research seeks to provide evidence-based insights into the most effective teaching methods for nurturing the next generation of biological scientists and fostering their deep understanding of biological science concepts.

## 5.3 Educational Implication

The implications of a study on the evolution of biological science concepts among secondary- level students are significant for both educators and policymakers. These implications can help shape the future of science education and student development:

- **Informed Curriculum Revisions:** The study's findings can inform curriculum designers and educational institutions about the effectiveness of current teaching methods and the need for revisions. It can lead to a more informed, structured, and progressive curriculum that better aligns with students' evolving cognitive abilities.

- **Enhanced Teaching Strategies:** Understanding how students' understanding of biological science evolves can guide educators in implementing more effective teaching strategies. Teachers can tailor their approaches to match the developmental stages of their students, making learning more engaging and impactful.

- **Targeted Remediation:** Identifying common misconceptions and areas of difficulty in biological science concepts allows for targeted remediation. Teachers and educational systems can focus on addressing specific challenges and helping students overcome conceptual hurdles.

- **Early Intervention:** Early identification of students who may struggle with certain concepts can lead to early intervention and additional support. This can prevent the accumulation of knowledge gaps that may hinder future learning.

- **Educational Resource Allocation:** Policymakers can allocate resources more effectively by focusing on areas where the study identifies the greatest need for improvement. This could include investments in teacher training, classroom materials, and technology.

- **Enhanced Science Literacy:** The study's implications can contribute to a more scientifically literate society. When students develop a stronger understanding of biological science, they are better equipped to engage with real-world issues, make informed decisions, and potentially pursue careers in science.

- **Increased Interest in STEM Fields:** As students' comprehension of biological science concepts improves, they may develop a greater interest in science, technology, engineering, and mathematics (STEM) fields. This can have long-term implications for the STEM workforce and innovation.

- **Global Competitiveness:** A well-rounded science education can enhance a country's global competitiveness by producing a skilled workforce capable of contributing to scientific advancements and innovation.

- **Scientific Exploration:** Students who grasp fundamental biological concepts are more likely to explore and contribute to scientific research and discovery, fostering a culture of inquiry and innovation.

- **Cultural and Environmental Awareness:** A better understanding of biological science can lead to increased awareness of environmental issues and cultural appreciation for the natural world. This can have implications for conservation efforts and sustainability.

In summary, the implications of a study on the evolution of biological science concepts among secondary-level students have far-reaching effects on education, policy, and society. They provide valuable insights for improving science education, enhancing scientific literacy, and preparing students for the challenges and opportunities of the future.

### 5.4. Suggestion and Recommendations

- **Early Exposure to Fundamental Concepts:** To ensure a solid foundation in biological science, it is advisable to introduce students to fundamental concepts at an early stage. This can help build a strong base upon which more complex ideas can be developed as they progress through secondary education.

- **Progressive Curriculum Design:** Curriculum designers and educators should consider the gradual progression of biological concepts, ensuring that students are exposed to increasingly advanced topics as they move through secondary school. This approach can help students grasp complex ideas more effectively.

- **Interactive and Practical Learning:** Incorporating hands-on and interactive learning experiences, such as laboratory experiments and field trips, can greatly enhance students' understanding of biological science. Practical applications of theoretical knowledge can make the subject matter more engaging and memorable.

- **Use of Technology:** Utilize technology, such as multimedia presentations and online resources, to make learning more engaging and accessible. Visual aids, simulations, and digital platforms can supplement traditional teaching methods.

- **Regular Assessment and Feedback:** Implement frequent assessments and provide timely feedback to students. This can help identify areas where students are struggling and allow for tailored interventions to address their specific needs.

- **Teacher Training and Professional Development:** Support teachers with ongoing training and professional development opportunities to keep them updated on the latest teaching techniques and content knowledge in the field of biology.

- **Promote Critical Thinking:** Encourage students to think critically and question biological concepts. This can foster a deeper understanding and a more active engagement with the subject.

- **Cross-Disciplinary Integration:** Encourage cross-disciplinary learning by relating biological science concepts to other subjects like chemistry and environmental science. This approach can provide a holistic understanding of the natural world.

- **Community and Industry Engagement:** Foster partnerships with local scientific communities and industries to expose students to real-world applications of biological science concepts. This can inspire them and provide insights into potential career paths.
- **Regular Research and Updates:** Continuously conduct research and evaluations of science education methods and curricula to adapt to evolving educational needs and incorporate the latest scientific discoveries.

## 5.5 Discussion

The study of the evolution of biological science concepts among students at the secondary level is crucial for understanding how students develop their knowledge and comprehension of complex biological ideas. In this discussion, we will explore key findings from research in this field and highlight the significance of understanding the evolution of students' biological science concepts.

**Conceptual Progression and Cognitive Development:** Research has shown that students' understanding of biological concepts evolves as they progress through secondary education. As Vygotsky (1978) argued, cognitive development is a dynamic process influenced by social interaction and cultural factors. When it comes to biological science, students initially have a basic understanding of concepts, such as cells and ecosystems, which becomes increasingly sophisticated as they advance through grade levels (Smith, 2016).

**Influence of Pedagogical Approaches:** The way biological science is taught significantly impacts the evolution of students' concepts. Research by Tanner and Allen (2004) emphasized those active learning strategies, problem-based learning, and hands-on experiences can promote deeper understanding and conceptual change. Therefore, educators must employ effective teaching strategies that encourage students to actively engage with the subject matter (Linder, 2013).

**Misconceptions and Conceptual Change:** The development of students' biological concepts often involves confronting and resolving misconceptions. These misconceptions can be remarkably resilient, as noted by Posner et al. (1982). Hence, teachers need to be aware of common misconceptions and address them explicitly in their instruction. Creating opportunities for students to revise and update their mental models is essential for conceptual development (Driver et al., 2000).

**Age and Conceptual Development:** Research by Carey (1985) suggests that the age at which students acquires certain biological concepts varies, reflecting the developmental appropriateness of specific ideas. For example, younger students might have difficulty comprehending complex genetic concepts, while older students can grasp them more readily. This highlights the importance of aligning the curriculum with students' cognitive development stages.

**Assessment and Feedback:** Accurate assessment is a critical component of understanding the evolution of students' biological science concepts. Utilizing both formative and summative assessments, such as concept maps, quizzes, and written assignments, can provide valuable insights into students' learning trajectories (Bissell and Lemons, 2006). Moreover, timely feedback enables students to correct their misconceptions and refine their understanding.

**Curricular Adaptations:** The findings of this study have practical implications for curriculum development. It suggests that curricula should be designed in a way that allows for the gradual progression of complex biological concepts over the secondary school years. Furthermore, educators should be given the flexibility to adapt their teaching methods to align with the evolving needs of their students.

In conclusion, the evolution of biological science concepts among students at the secondary level is a dynamic process influenced by a combination of cognitive development, pedagogical approaches, and assessment practices. Understanding this process is crucial for educators and curriculum developers to design more effective and targeted science education programs. Moreover, addressing misconceptions and fostering conceptual change should be a primary focus of biology instruction. By incorporating these insights into practice, we can better equip students to navigate the complex world of biological science.

# Summary

## SUMMARY OF THE STUDY

**Chapter-1 (Introduction)** introduced the topic **A Study of The Evolution of Biological Science Concepts Among Students at The Secondary Level**. and brought attention to the topic's importance. Scientific and technological development in recent times has and will continue to transform the lives of humanity. The role of biological science in the modern technological world needs no deliberation.

Biological science is an extensive covering the minute workings of chemical substances inside the living cells, to the broad scale concepts of ecosystems and global environmental changes. It is also concerned with physical characters and behavior of organisms. Biological science education inculcates the knowledge of facts, the spirit of enquiry, the technique of assumption, the power of observation and value of judgement in the students. It helps in developing logical thinking, reasoning, analysis, and creativity in the students. Advances in medicine, agriculture, biotechnology, and many other areas of biology have brought improvement in the quality of life.

NABT is a national association of biology teachers which empowers educators to provide the best possible biology and life sciences education for all students. Biologists recognize that knowledge based upon experimental results and accurate observations is gained through a variety of experiences. Thus, the role of laboratory and field learning becomes a key component in understanding biology. Laboratory and field activities and enquiry provide students with opportunities to question, observe, sample, experience, and experiment with scientific phenomena.

**Chapter-2 (Review of Literature)** created on the theme of "**A Study of The Evolution of Biological Science Concepts Among Students at The Secondary Level**". To highlight the significance of that subject. Finding, assessing, and appreciating the corpus of documented work that professionals and scholars are currently producing are the objectives of literature research. Pertinent literature provides critical information on difficulties, evaluations of modern practices, and empirical research in addition to providing the historical context for important ideas, concepts, and theories. The kinds of questions that have been posed and the areas that have been looked at can be clarified by reviewing earlier studies on the same subject. It was necessary to read the laws and regulations covered in the pertinent academic literature and research since they set forth the guidelines that must be adhered to. "Literature" in academic circles starts with the first written work on a subject that critically analyzes information gathered from primary sources to further previous research. The process of evaluating the worth of diverse sources (including dictionaries, academic studies, research journals, articles, periodicals, and internet resources) created by specialists in each topic is referred to as a "literature review". The literature review highlights the significance of the new research and offers context for comprehending the state of the art now. Knowing literature can not only help you avoid repeating the mistakes of others, but it can also prevent you from copying their efforts. The author of the paper also addresses potential conclusions and areas that might require more research.

Banet, E., & Ayuso, G. E. (2003) aimed to identify some approaches to improving secondary school instruction on biological inheritance and the evolution of living things. Here, the author studied the students' knowledge growth over time (pre-test, post-test, and retention test) using a teaching tool that took a constructionist approach to learning. Analyses of both the qualitative and quantitative data demonstrated that the program successfully imparted knowledge that was at least sufficiently advanced for this level of schooling. The author next suggested some disciplinary criteria for choosing and sequencing the content to be taught, and the author talked about the educational conditions that were most conducive to the development of students' understanding of these subjects.

Tidon, R., & Lewontin, R. C. (2004) explained that evolutionary Biology was interdisciplinary in nature, requiring knowledge from many different fields for a comprehensive understanding. Since this knowledge was sometimes inaccessible to most specialist professionals, including instructors, the author gave some reflections to inspire debates aimed at the improvement of the conditions of education in this field. Using data from the ―National Institute for Educational Studied and Research‖ and information gathered from educators in different parts of Brazil, the author analyzed the makeup of evolutionary education in the country. To facilitate conversations aimed at enhancing the teaching of evolutionary biology, the study addressed concerns relating to biological misconceptions, curriculum, and didactic material, and presented some proposals in this area.

Chapter-3 (Research Methodology) This chapter describes the framework of the study, for example, the Objectives of the study, Hypotheses of the study, size of the sample, description of the Tools used in the study etc. The current study's results and findings are subsequently used to assess understanding statements. As a result, the techniques are defined by the research's viewpoints on approaching the issue. This study uses a variety of questionnaires and fact-gathering questions to conduct both exploratory and descriptive research. Our evolving comprehension of how secondary students acquire domain-specific knowledge in the field of biological sciences holds valuable insights for the design and organization of biological science curricula. While this study does not aim to solely develop Biological Science concepts, it does underscore the importance of fostering conceptual understanding as a key objective within the curriculum. Additionally, it suggests that supporting and supplementary courses should be strategically planned, drawing upon a sound understanding of how the comprehension of Biological Science Concepts is generated.

## Operational Terms

When talking about data collecting, the phrase "Operational Terms" refers to a comprehensive breakdown of the technical jargon and units of measurement employed. To ensure consistency, we must do this. There must always be a well-defined procedure for gathering data. Undefined data increases the possibility of inconsistencies and may not produce the same results when the study is duplicated. It's common practice to presume data collectors have the necessary knowledge and skills. But data gathering can be impacted by the fact that different people have different perspectives and interpretations of the same thing.

In this study, following operational definitions are used-

### Evolution

Evolution is a foundational concept in biology that explains the process of change in all forms of life over generations. Charles Darwin postulated the idea of evolution in the 19th century, and it has since grown to be a fundamental component of contemporary biology and is supported by substantial empirical evidence from various scientific disciplines.

### Biological Science Concepts

Biological science concepts encompass a broad range of principles and ideas that form the foundation of the study of living organisms. These concepts contribute to our understanding of the structure, function, behavior, and interactions of living things.

### Secondary Level

Secondary level generally termed from class $6^{th}$ to $12^{th}$. However, it divided in three parts- class $6^{th}$ to $8^{th}$ is termed as lower secondary level, class $9^{th}$ & $10^{th}$ is secondary level where as class $11^{th}$ & $12^{th}$ is higher secondary level. This study is focused on lower secondary level which is also known as upper-primary level or middle level.

## Need of the Study

The study of the evolution of biological science concepts among students at the secondary level is of paramount importance for several reasons. Firstly, understanding how students' comprehension of biological concepts develops over time provides valuable insights into the effectiveness of current educational approaches. It allows educators to identify potential gaps in teaching methodologies and curricular content, facilitating evidence-based improvements. Additionally, this study is crucial for curriculum designers and policymakers seeking to align secondary-level biology education with the evolving needs of students and advancements in the field. Furthermore, an exploration of the trajectory of concept evolution among students contributes to the broader discourse on science education research, offering a nuanced perspective on the challenges and successes in fostering scientific literacy. Ultimately, by delving into the evolution of biological science concepts at the secondary level, this study aims to enhance the quality of science education, promote a deeper understanding of biological principles, and empower students to engage more effectively with the dynamic world of life sciences.

## Research Questions

- How do student progress in their understanding about two biological concepts i.e., Living organisms & Reproduction from class $6^{th}$ to $8^{th}$?
- Is there a difference in the learning outcomes of students taught by two different pedagogical approaches?
- Is there a parallel between the progression of student conceptions about selected biological science concepts?

## Objectives of the Study

- To find out the conceptual progression in prescribed curricular content of biological science at secondary level.
- To collate pedagogical perspectives of major biological science concepts.
- To trace the trajectory of evolution of major biological science concepts.
- To analyze and map the evolution of major biological concepts among secondary level students from field data.
- To study the effectiveness of the activity-based approach over traditional approach as two major pedagogical intervention.

## Delimitations of the Study

- The scope of this study is limited to the entire field of evolution of biological science concepts; however, it is possible to concentrate on other science concepts in the future study.

- The study was limited to 240 respondents.
- Research is limited to the secondary school (government) students of class 6th, 7th & 8th. It should also investigate private schools in future study.
- The study was bound to concepts of living organisms & reproduction.
- The study only covers Uttar Pradesh government schools, it has the potential to be expanded to include other state schools in the future study.

## Area of the Study

A study area is a place where studies are conducted. For the research, the study is conducted in Jaunpur city (Uttar Pradesh). Because the study of the evolution of biological science lies within the field of education, more specifically in science education and curriculum development.

## Sample of the study

The sample for the study will comprise of approximately 240 students of two schools (government) of both sexes studying in class $6^{th}$,$7^{th}$ & $8^{th}$.

- **Stratified random sampling technique –** Is a commonly used statistical approach that divides a population into various subgroups, or strata, according to certain shared traits.

So, the researcher has utilized the Stratified random sampling technique.

## Primary Data

Data that has been created by the researchers themselves with the aid of tests, surveys, and interviews that have been specifically created to comprehend and address the study problem at hand.

- **Questionnaire**: The investigator creates a questionnaire or timetable using the questionnaire method that contains a list of pertinent questions. The questionnaire then records the respondent's responses. Given that the information is obtained directly from the respondents, this method is useful for gathering primary data.

## Secondary Data

Secondary data is data that has already been collected and maintained by large government agencies, hospitals, and other organizations. After then, the data is pulled from a more diverse data source. Secondary data has been gathered from a variety of sources, including published works, government reports, academic studies, journal articles, libraries, the internet, and numerous organizations.

SPSS

A program named - SPSS (Statistical Package for the Social Sciences), often recognized as IBM SPSS Statistics is employed to do the statistical analysis of the data. Although SPSS was initially used in the field of social sciences, its application has now expanded into other data markets, which is reflected in the software's name. The SPSS provided a base for performing various tests to analyze the data.

In shaping the curriculum for biological science courses in schools, numerous factors, including social and cultural considerations, play a pivotal role in decision-making. Biological science, as a discipline, is not merely a repository of knowledge; it is the outcome of human endeavor, demanding both original thought and systematic data collection and analysis. Its existence is deeply rooted in a rich intellectual and social history, built on empirical, theoretical, and practical understanding of the natural world.

Chapter-4 (Data Analysis and Interpretation) included a presentation, analysis, and interpretation of the study's objectives. It addresses the findings and conclusions from the qualitative approach, the compilation of the questionnaire, and the quantitative research analysis results to identify similarities and differences between this study and other studies and literature. If necessary, the observations are also examined in the context of pertinent prior research as well as relevant literature. Full explanations of the research methodologies are provided. The analysis of the data is descriptive, as was mentioned in the previous chapter.

The research objective under scrutiny pertains to a comprehensive examination of the prescribed curriculum for biological science at the secondary level. Specifically, it seeks to elucidate the manner in which critical biological science concepts progress and evolve throughout the educational journey of secondary-level students. This objective embodies a profound quest for understanding how the intricacies of biological science education are structured, sequenced, and developed over time, aiming to offer insights into the trajectory of students' learning.

Collating pedagogical perspectives for teaching reproduction and living organisms to students in grades 6 to 8 requires a student-centered and engaging approach. Here's an analysis of pedagogical strategies for these topics in this age group:

★Living Organisms & Reproduction:

- Classification: Teach students about biological classification, starting with the broad categories (kingdoms) and gradually moving to more specific classifications (phylum, class, etc.). Use mnemonic devices to aid memory.
- Observation: Encourage students to observe and document living

organisms in their surroundings. Provide journals or worksheets for recording their observations.

- Interactive Technology: Incorporate interactive educational software and apps that allow students to explore the diversity of living organisms virtually. Virtual dissections and interactive field guides can be useful.
- Field Trips: Organize field trips to local parks, nature reserves, or botanical gardens to observe and study living organisms in their natural habitats.
- Hands-On Projects: Assign projects where students collect and classify specimens they find in their environment. These projects can include creating a mini-ecosystem in the classroom or starting a small garden.
- Food Webs and Ecosystems: Explore food webs and ecosystems to help students understand the interdependence of living organisms in different environments.
- Case Studies: Introduce case studies that showcase unique adaptations and behaviors in living organisms, such as animal migrations or plant adaptations to extreme environments.
- Assessment: Use a variety of assessment methods, including quizzes, presentations, and project-based assessments, to gauge students' understanding of living organisms and their ability to classify them.

## Chapter-5 (Findings & Suggestions)

The results and conclusions of the study are discussed in this chapter. It will be followed by a discussion of the research's shortcomings and the potential for further study based on the thesis.

### Findings based on the Demographics of the Client

i. According to the Class of Student of the Respondents, describes the demographic variable wise frequency, percent, valid percent, and cumulative percent. When it comes to -Valid demographic variable out of 240 students, 80 are of 6th class, 80 are of 7th class and 80 are of 8th class.

ii. According to the Name of School, a summary of the distribution of students across two different schools, along with the percentage each school represents, both individually and cumulatively. It helps to understand the distribution of school within the group, with 120 students from Composite Adarsh Kerakat and 120 students from Composite School Saroj Badewar.

### Findings based on Objectives

Table 4.3 show descriptive statistics for "Living Organism" variables across different categories (6th, 7th, 8th, and Total). This number of columns shows the total number of responses or observations for each variable. In this there are 80 observations in each category (6th, 7th & 8th), and a total of 240 observations across all categories. Mean shows the average value of the variable in each category.

The ANOVA table 4.4 indicates that there is a statistically significant difference between the living organism and reproduction. The F-static and associated significance level  suggest that there are significant differences between the groups.

Table-4.5,4.6 & 4.7 shows paired samples statistics for class of students organized by grade level, which is divided into three pairs. Within each pair, students are assessed on different subjects or topics. The "Mean" values indicate the average scores for each subject or topic within each pair and grade level. For example, in the 6th grade, for Pair 1, the mean score for "Living Organism" is 4.51, and the mean score for "Teaching Approaches" is 10.37. The standard deviation values show how much the scores vary or spread out from the mean. For instance, in 6th grade Pair 1, "Living Organism" has a standard deviation of 1.71, and "Teaching Approaches" has a standard deviation of 2.46. A smaller standard error mean indicates greater precision in the sample mean estimates. For example, in 6th grade Pair 1, "Living Organism" has a standard error mean of 0.19, and "Teaching Approaches" has a standard error mean of 0.27.

Table-4.8,4.9 & 4.10 shows paired samples correlations for different classes of students (6th, 7th, and 8th grade) across various pairs of subjects. The table is organized by grade level, which is divided into three pairs. Within each pair, correlations are calculated between different subjects based on student performance. The correlation values indicate the strength and direction of the relationship between the two subjects or topics within each pair. For example, in the 6th grade Pair 1, the correlation between "Living Organism" and "Teaching Approaches" is - 0.007, which suggests a very weak and almost no linear relationship between these two subjects. The "Sig." values represent the p-value associated with the correlation. A p-value less than a predefined significance level indicates that the correlation is statistically significant. If the p-value is less than 0.05, the observed correlation is unlikely to have occurred by chance.

In the activity-based approach, Class 8 becomes an opportunity to explore the microscopic world more profoundly. Students may have access to microscopes and engage in practical experiments to observe cells and microorganisms. This approach encourages students to actively investigate and explore the subject matter, leading to a deeper understanding of cell biology and microorganisms. The research objective aims to systematically study and compare the effectiveness of these two major pedagogical interventions—activity-based and traditional approaches—across the aforementioned biological science concepts and grade levels. The study will involve data collection, including student performance assessments, surveys, and feedback from educators, to evaluate the impact of these teaching methods on students' knowledge retention, comprehension, and engagement.

Traditionally, living organism & reproduction are the topics that are not addressed in much. depth at the lower secondary school level and part of the reluctance to introduce children to the microscopic worldview is based on a long standing belief that children are essentially concrete thinkers. Understanding the microscopic world requires acts of imagination. A recent developmental literature by Metz (1995) suggested that children are capable of fairly complex and abstract scientific reasoning, especially in appropriately supportive instructional contexts. Conceptual change in this area has been historically difficult for scientists, and will be difficult for students as well.

### Scope for Further Study

- The model of progression presents scope for curriculum change.
- Major Biological science concepts in science curriculum from (primary till secondary or senior secondary) can be compiled and their historical evolution of those Biological science concepts may be collated.
- The study of evolution of Biological science disciplines may help the curriculum planners and teachers to arrive at strategic procedures to develop progression maps for each Biological science concept.
- Stakeholders can develop a model for curriculum change at a conceptual level. Strategies may be developed taking consideration of the scientific path in emerging understanding of a science concept.
- Textbook writers can reflect scientific evolution and communicate to science teacher community Biological Science teacher community as a part of the operational curriculum has an immense role to help the students tread the path to scientific knowledge.
- Research into the process of scaffolding and its location along the trajectory of students' learning Biological science concepts may throw light on critical class room practices.

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# Appendices

# APPENDIX I (Class 6th)

Name :

Class :

Section :

Roll Number:

School :

Date :

This question paper is on the topics- living organisms and reproduction. Each question has four options. Choose the most correct one according to you. Read carefully and answer as directed.

## (A) LIVING ORGANISMS

1.Study the list of items given below & answer the questions as living/non-living.

| organisms | Living/non-living |
|---|---|
| Insect | |
| Table | |
| Fan | |
| Plant | |

2.Food has important role in our body. Why do we need food?

a)For growth, good health and energy b) only for good health

C)To satisfy hunger d)for growth

3.Which is not the character of living organisms?

a)Digestion b) Reproduction

c)Excretion d) no movement

4.Which comes under category of autotrophs?

a)Dogb) Cat

c)Plant d) animal

5.Basic unit of body of living organisms is-

a)Bone b) Musscle

c)Cell d)Tissue

6. Unicellular organism is-

a)Paramoecium b) Chimpanzee

c)Earthworm d) Leech

7.Example of largest cell is-

a)Euglena b) egg of ostrich

c)Yeast d) Chlamydomonas

8.Name an animal that can perform process of photosynthesis-

a)Amoeba b) Paramecium

c)Euglena d) Star-fish

9.Which one is sensitive for stimulus?

a)Wood b) Duster

c)School d) Plant

10.Part of the plant that involve in Respiration-

a)Root b) Stem

c)Leaf d) Stomata

## (B) REPRODUCTION

1. Reproduction is-

   a)Increase in height of plant by giving water

   b)formation of food by plants

   c)Formation of food by animals

   d)produce their offspring by animal

2. In the following, tick the one which is different from other-

   a) Birdb) Dog

   c) Cat d) elephant

3. Reproductive part of a plant-

   a)Flower b)Root

   c) Stemd) Leaf

4. Tick the one that can produce their baby among the following?

   a)Cow b) parrot

   c)Crow d) owl

5. Which one is an example of non-flowering plant?

   a)Rose b) algae

   c)Genda d) hibiscus

6. Name the system of human body that is helpful in producing their babies.

    a)Skeletal system b) Digestive system

    c)Reproductive system d)Excretory system

7. Viviparous animal is-

    a)Human b) Fish

    c)Frog d) snake

8. Example of oviparous organism is-

    a)Human b) Snake

    c)Rat d) Rabbit

9. Frog lay their eggs in-

    a)Land b) Sand

    c)Water d) Leaf

10. Animal that gives direct birth to their babies, are known as-

    a) Oviparousb) Viviparous

    c) Herbivores d) Omnivores

## APPENDIX II (CLASS-7$^{th}$)

Name :
Class :
Section :
Roll Number:
School :
Date :

This question paper is on the topics – Living Organisms and Reproduction. Each question has four options. Choose the most correct one according to you. Read carefully and answer as directed.

### (A) LIVING ORGANISMS

1. Green plants make their food by the process of-

    A)Respiration B) Photosynthesis
    C)Digestion D) Transportation

2. Plants form their food in form of-

A)Sucrose B)Maltose
C)Glucose D) Lactose

3. How many steps are there in the process of human digestion?

A)Two B) Four
C)Five D) Seven

4. During rest, Respiration rate in human beings-

A)15-18 times/minute B) 30 times/minute
C)40 times/minute D) 45 times/minute

5. Process of respiration in green plants takes place in-

A)Xylem B) Phloem
C)StomataD) Guard cells

6. Respiratory organs in fishes are-

A)Gills B) Fins
C)Pelvic D) Skin

7. Transportation of blood in human beings is done by-

A)Lungs B) Heart
C)Hands D) Brain

8. Pigment that is responsible for red colour of blood-

A)Chlorophyll B) Serotonin
C)Hemoglobin D) Plasma

9. Waste substances of body are come outside the body, process named is-

A)Respiration B) Excretion
C)Digestion D) Transportation

10.Number of kidneys in human body –

A)Three B) two
C)Four D) One

## (B) REPRODUCTION

1. Transfer of pollen grains to stigma, is called-

A)Pollination B) Reproduction
C)FertilizationD) Vegetative Propagation

2. Reproduction in sugar cane, by-

A)Vegetative reproduction B) Budding
C)Fragmentation D) Spore formation

3. Spirogyra reproduces with the help of-

A)Vegetative propagation B) Budding
C)Fragmentation D) By leaf

4. Fruit is a mature-

A)Zygote B) Ovary
C)Gynoecium D) Androecium

5. Reproductive organs of a plant are-

A)Root B) Stem
C)Leaf D) Flower

6. Male reproductive part of a flower, is known as-

A)Androecium B) Gynoecium
C)Petals D) Sepals

7. Which part is female reproductive part of a flower?

A)Androecium B) Gynoecium
C)Petals D) Sepals

8. In which organism, reproduction is takes place by process of budding-

A)Spirogyra B) Yeast
C)Algae D)Rhizopus

9. Most attractive part of a flower is-

A)Calyx B) Corolla
C)Androecium D) Gynoecium

10. Part of a flower that is also helpful in process of photosynthesis-

A)Calyx B)Androecium
C)Gynoecium D) Corolla

APPENDIX III (CLASS-8$^{th}$)

Name :
Class :
Section :
Roll number:
School :
Date :

This question paper is on the topics- Living Organisms & Reproduction. Each question has four options. Choose the most correct one according to you. Read carefully and answer as directed.

## (A) LIVING ORGANISMS

1. Which organism is a connecting link between living and non-living?

A)Bacteria B) Virus
C)Algae D) Fungi

2. Microorganisms are present in-

A)Air B) Water
C)Soil D) Everywhere

3. Structural and functional unit of body is-

A)Tissue B) Organ
C)Cell D) Organ-system

4. Which one is an example of unicellular organism?

A)Dog B) Cat
C)Amoeba D) Gorilla

5. Animal that can perform the process of photosynthesis-

A)Amoeba B) Paramecium
C)Sponge D) Euglena

6. Tissue that is not act as connective tissue-

A)Bone B) Blood
C)Cartilage D) Epithelial tissue

7. Presence of nervous system was first seen in-

A)Hydra B) Amoeba
C)Sponge D) Ascaris

8. 'Power House' of the cell is-

A)Ribosome B) Mitochondria
C)Chloroplast D) Nucleus

9. Tissue that can form outer layer of body and organs-

A)Connective tissue B) Muscular tissue
C)Epithelial tissue D) Nervous tissue

10. Discovery of the nucleus is done by-

A)Robert Hook B) Galeleo
C)Robert Brown D) Aristotle

## (B) REPRODUCTION

1. Process that is required for continuity in animals and plants-

   A)Digestion B) Respiration
   C)Reproduction D) Excretion

2. External fertilization takes place in –

   A)Frog B) Cow
   C)Human D) Goat

3. Internal fertilization occur –

   A)Outside male body B) Outside female body
   C)Inside male body D) Inside female body

4. Female reproductive organs are –

   A)Testis B) Ovary
   C)Penis D) Vas deferens

5. Male gamete is termed as –

   A)Sperm B) Ovum
   B)Zygote D)Embryo

6. Structure that is formed due to fusion of male and female gamete –

   A)Zygote B) Embryo

   B)Sperm D) Ovum

7. Ovum are formed in which part –

   A)Ovary B) Penis

   B)Placenta D) Cow

8. The process of fusion of male and female gamete, is known as-

   A)Fertilization B) Binary Fission

   B)Pregnancy D) Embryo

9. Asexual reproduction does not take place in –

   A)Hydra B) Human

   B)Amoeba D) Spirogyra

10.Fertilized ovum is known as-

A)Zygote B) Embryo

B)Sperm D) Male gamete