CHAPTER IV

METHODOLOGY

Method Adopted
Tools and Techniques Employed for the Study
Experimental Design and Procedure Adopted
Statistical Techniques Used
CHAPTER IV

METHODOLOGY

Methodology is the procedure or technique adopted in a research study or investigation. The nature of the problem, the objectives of the study, and the kind of data necessary for the solution of the problem, will determine the method to be adopted for the study. The validity and reliability of the findings depends upon the method adopted; hence, methodology occupies a very important place in any type of research.

The present study proposes to test the ‘Effectiveness of an Instructional Material in Biological Science based on Discovery Learning Model for fostering science process skills, scientific creativity and science curiosity in higher secondary students’. The details regarding the procedure adopted for collecting the data, the tools and techniques employed, sample selected, experimental procedure and the statistical techniques adopted are given below.

4.1 METHOD ADOPTED

The investigator adopted Experimental method for the present investigation.

The details regarding the method adopted for collecting the data are given below under appropriate heads.

4.2 TOOLS AND TECHNIQUES EMPLOYED FOR THE STUDY

The following tools were adopted for collecting necessary data:

I. Instructional material in Biological Science based on Discovery Learning Model on the topic “PHYLUM MOLLUSCA”.
Methodology

(1) Identifying Features of ‘Phylum Mollusca’
(2) Class Gastropoda
(3) Class Cephalopoda
(4) Class Pelecypoda
(5) Class Scaphopoda
(6) Class Polyplacophora
(7) Class Monoplacophora
(8) Class Aplacophora

II. Achievement Test in Biological Science based on the Instructional Material.
   (a) Pre-test (Achievement) for assessing the Entry behaviour of students.
   (b) Post-test (Achievement) for assessing the Terminal behaviour of students.

III. Test of Process Skills in Biological Science
    (a) Pre-test for assessing the Entry behaviour of students.
    (b) Post-test for assessing (the effectiveness of the instructional material in
         Biological Science based on Discovery Learning Model for fostering
         science process skills) the terminal behaviour of students.

IV. Test of Creativity in Biological Science
    (a) Pre-test for assessing the Entry behaviour of students
    (b) Post-test for assessing the Terminal behaviour of students.

V. Science Curiosity Inventory
    (a) Pre-test for assessing the Entry behaviour of students
    (b) Post-test for assessing the Terminal behaviour of students.
4.2.1 Description of Tools

**Instructional Material based on Discovery Learning Model on the Topic “Phylum Mollusca”**

The investigator prepared an instructional material in Biological Science based on the topic ‘Phylum Mollusca’ for higher secondary students. For this purpose, the investigator analysed the Biology syllabus, Zoology textbook for higher secondary students, and other supplementary reading materials related to Phylum Mollusca. Apart from this, the investigator collected details about the pedagogical analysis of the content, method of processing information and method of preparation of an instructional material in Biological Science based on Discovery Learning Model.

This instructional material is based on the principles of Discovery Learning. The Discovery Learning Model has in recent years gained prominence as one of the most effective strategies in teaching learning process.

When a learner is engaged in Discovery Learning, he begins to consider success and failure as sources of information rather than as rewards or punishment. “Generalizations learned in a discovery setting are better retained and more transferable than if they were communicated as fact to the students.”

Bruner in “The Act of Discovery” claimed four advantages of discovery.

(i) increases intellectual potency

(ii) increases intrinsic motivation

(iii) teaches the students the techniques of discovery

(iv) results in better retention of what is learned.
Bruner also asserts that the environment is so diverse, and that, we human beings are able to discriminate between objects and aspects of objects. We utilise our capacity for registering the differences in things and respond to each event in a unique way. To cope with the environment, individuals engage in the process of categorizing. The categorization enables us to group together things on the basis of their traits. Categorization activity has two components, viz., concept formation and concept attainment. Direct experience is thus an unavoidable factor in the process of categorization.

An instructional material in Biological Science based on the topic PHYLUM MOLLUSCA presents some of the possible learning situations and activities for teaching at higher secondary level. The investigator provided opportunity for students to discover facts and concepts through environmental sources. The details are given below.
INSTRUCTIONAL MATERIAL
IN BIOLOGICAL SCIENCE
BASED ON DISCOVERY
LEARNING MODEL
TOPIC: PHYLUM MOLLUSCA

Prepared by: Tessy Xavier
Research Scholar,
Government College of Teacher Education,
Thycaud, University of Kerala.

Supervised by: Dr. B. Suresh
Principal,
Government Institute of Advanced Study in Education,
Thrissur, Kerala.
INSTRUCTIONAL MATERIAL IN BIOLOGICAL SCIENCE BASED ON DISCOVERY LEARNING MODEL

TOPIC: "PHYLUM MOLLUSCA"

Provide opportunity to observe different types of molluscs.

**STEP 1**

Encourage the students to observe and examine the different types of molluscs showing difference in their morphological features.

Figure representing different types of molluscs
STEP II
IDENTIFICATION

Encourage the students, to examine the molluscs and identify their special features.

Identifying special features of molluscs

1. The body is soft, unsegmented and made of four parts – visceral mass, mantle, head and foot.

2. They are generally bilaterally symmetrical (In this type, animal’s body can be divided into two similar right and left lateral sides or halves only in one plane along the longitudinal axis. Hence, main organs of the body are paired and arranged on the two sides of the body axis. Such animals have a front or anterior end and a rear or posterior end (CEPHALIZATION).
Identifying Features

3. They are triploblastic (The body wall consists of ectoderm, mesoderm and endoderm).

4. Dorso-lateral fold of the body wall forms the mantle or pallium which encloses a space known as mantle cavity.

5. Mantle secretes the calcareous shell. The shell may be external or internal or it may be absent.

Examples

- **Chiton**
- **Mytilus** (external shell)
- **Sepia** (internal shell)
Identifying Features

6. Head bears large eyes and mouth; mouth bears jaws and radula.

7. The foot is ventral, muscular and variously modified for creeping, burrowing or swimming.

8. Respiratory organs are ctenidia (gills) or lungs or both.

Examples

Helix, Sepia, Octopus

1. Fresh Water Mussel  2. Chiton

Gills – Chiton
Lungs – Helix
Identifying Features

9. Circulatory system is of open type.

9(a) The blood-vascular system consists of the heart, the veins, the arteries and the sinuses.

9(b) The pericardium, which encloses the heart is a thin-walled sac on the left side of the visceral mass immediately below the pulmonary sac.

9(c) The heart consists of two chambers, an auricle and a ventricle, the ventricle lies in front of the auricle.

10. Digestive system is well developed with salivary gland and digestive gland (liver). Buccal cavity contains a characteristic rasping organ bearing teeth – the radula.
**RADULA**

The radula is an elongated and ribbon shaped organ placed on an elevated ridge known as Odontophore, on the floor of the buccal mass of certain molluscs. It is formed of an expanded flap and a narrow strap. The strap is covered with numerous minute teeth arranged in transverse rows. Each row contains seven teeth. There are central or median tooth, two smaller lateral teeth and four marginal teeth. The posterior part of the radula lies in the radular sac. The food materials are rasped by the radula.

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**Identifying Features**

11. Excretory organs are the kidneys (nephridia), also called Organs of Bojanus.

12. Nervous system consists of paired cerebral, pleural, pedal and visceral ganglia joined by commissures and connectives.

   {Commissures - between similar ganglia
   Connectives - between dissimilar ganglia}

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**Examples**

Fresh Water Mussel – Excretory organ

Pila globosa – Nervous system
### Identifying Features

13. The sensory organs are eyes, tentacles, osphradium and the lithocyst.

### Examples

| Helix; | Pila globosa, |

Osphradium: is the comb like structure which resembles a rice grain. It is present close to the base of the left pseudopodium and attached on the left side with the roof to mantle cavity.

Osphradium acts as
1. Chemoreceptor
2. Testing organ for water
3. Olfactory sense receptor
4. Help in selection of food

14. Sexes are usually separate. Fertilization is external or internal.
In aquatic molluscs fertilization is mostly external.

Examples: Dentalium, Patella

In terrestrial forms, fertilization is internal.

Example: Pila globosa

<table>
<thead>
<tr>
<th>Identifying Features</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development is with or without a larval stage. The larval forms are trochophore, veliger and glochidium.</td>
<td>Chiton – trochophore larva, Dentalium, Teredo – veliger larva, Fresh Water mussel – glochidium larva.</td>
</tr>
</tbody>
</table>

![Trochophore larva](image1)

![Veliger larva](image2)

![Glochidium larva](image3)
**Direct development:** Development without metamorphosis.
Example: Octopus, Sepia

**Indirect development:** the egg hatches out into a larva which is entirely different from the adult.
Example: Mytilus, Pinctada, Teredo.

**FACT:** THE LARVAE IS TRANSFORMED INTO THE ADULT BY METAMORPHOSIS
Example: LARVAE $\rightarrow$ ADULT

**METAMORPHOSIS:** The change from larvae to adult generally involves a profound reorganization of the body, often involving considerable breakdown of larval tissues.

**PHYLUM: MOLLUSCA**
Soft-bodied animals
STEP III
Discovering/identifying various classes of Molluscs. (Encourage the students to examine the molluscs and classify them on the basis of morphological features.)

**G₁**
- Body is symmetrical with a mantle and shell.
- Soft-unsegmented body which is divisible into head, foot and visceral mass.
- Shell spirally coiled.
- Head is distinct bearing eyes and tentacles.
- The foot is large and flattened, which is placed just behind the head.

**G₂**
- Soft-bodied animals.
- Head distinct with well developed eyes, foot consists of sucker bearing arms and funnel.
- The shell is reduced, may be internal or absent.

**G₃**
- Soft-bodied animals.
- Soft body is protected by an external shell.
- Shell made up of 2 pieces.
- Body laterally compressed, foot wedge shaped, head not distinct.

**G₄**
- Soft bodied animals.
- Shell tubular.
- Foot conical.

### Diagram:

- **G₁**
  - 1
  - 14
  - 16
  - 17

- **G₂**
  - 4
  - 6
  - 12
  - 15

- **G₃**
  - 2
  - 3
  - 9
  - 11

- **G₄**
  - 5
G_5
Soft-bodied animals. Soft body is protected by an external shell. Shell is multivalve. Shell made of 8 pieces, body dorsoventrally flattened. Foot large and flat.

G_6
Soft-bodied animals. Soft body is protected by an external shell. Shell is univalve. Shell made of a single piece, body and foot oval.

G_7
Soft-bodied animals. Shell absent, body-worm like. Foot reduced or absent. Body is generally almost completely covered by a cuticular mantle.

Students are encouraged to suggest the basis of classification.

**Basis of Classification**  MORPHOLOGICAL FEATURES


**PART II**

**Class-1**

**STEP V**

Discovering/identifying special features (facts of gastropoda). Discovering the special features of molluscs under \( G_1 \) through observation, experimentation and discussion.

<table>
<thead>
<tr>
<th>Sl. No.</th>
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<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
</table>
| 1.      | *Pila globosa* or apple snail | 1. It is an amphibious form. 2. Herbivorous. | Spirally coiled | 1. Soft body consists of head, foot and visceral mass.  
2. Head lies on the upper side and bears two pairs of contractile tentacles and a pair of eyes.  
3. Foot is muscular and flat and serves for creeping.  
4. Visceral mass consists of the main organs of the body. It is spirally coiled and covered by mantle or pallium.  
5. Operculum is well developed and closes the aperture or the mouth of the shell.  
6. Sexes are separate.  
7. Female is oviparous.  
8. Development is direct. | 1. Used as food in certain parts of South India.  
2. Used as a medicine for sore eyes. |
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</table>
| 2.     | Patella or True limpet | Marine Herbivorous - feeding upon algae, sea weeds and diatoms | Present | 1. It is small, oval, sluggish animal.  
2. Below the shell lies the mantle.  
3. The underside of the patella shows a large foot with a broad creeping sole, with which it clings to the rocks.  
4. The head is laterally produced into a pair of small, stout, tactile tentacles.  
5. True ctenidia are absent.  
6. Processes of the mantle known as the pallial branchiae are disposed in a circle between the mantle and the foot serving respiration.  
7. Anus lies behind the head to the right side.  
8. Auricle is single.  
9. Right kidney is larger than the left.  
10. Sexes are separate.  
11. Fertilization occurs in sea water.  
12. Development includes the typical trochophore larvae, which changes into a veliger.  
13. Eyes are simple, present at the base of the tentacle |

**Economic Importance**

In France, Italy and Ireland, large quantities of limpets are collected and eaten by the poor people.
<table>
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</tr>
</thead>
</table>
| 3.     | Xancus pyrum  | Marine | Present| 1. The soft body is enclosed in a large, thick and heavy shell.  
2. The shell is univalve and is spiral.  
3. The spires form a cone with the various whorls closely applied together.  
4. The whorls are coiled round a solid central axis called columella.  
5. The lower-most whorl is the largest and through its large opening the head and the foot may be protruded out. | 1. Xancus shell is the sacred Indian chank of religious importance; the sinistral variety which is of rare occurrence is held in great reverence.  
2. The God Vishnu is represented as holding the shell in his hand.  
3. Sacred chanks are tied to bullocks and cows to protect them against the ‘evil eye’.  
4. In Bengal, bangles are carved out of them. |
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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>Helix or Garden snail</td>
<td>Terrestrial</td>
<td>Present</td>
<td>1. Body is enclosed in a shell and consists of head, foot and visceral hump.</td>
<td>It is the ‘French edible snail’ consumed in western countries</td>
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<td></td>
<td></td>
<td>Nocturnal</td>
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<td>2. Shell is thin having low conical spire and bear prominent lines of growth.</td>
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<td></td>
<td></td>
<td>Herbivorous</td>
<td></td>
<td>3. Head bears two pairs of tentacles, the first small pair bears organs of smell and the second pair is large and bears a pair of simple eyes.</td>
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<td>4. Foot possesses a flat ventral surface and serves for creeping.</td>
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<td>5. Respiration by pulmonary sac.</td>
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</tbody>
</table>
Discovering/developing facts about molluscs (1-4) through observation and discussion.

**EXAMPLE I: PILA GLOBOSA OR APPLE SNAIL**

- **F1**: Amphibious univalve molluscan living in fresh water ponds, paddy fields, etc.
- **F2**: Herbivorous
- **F3**: Body is soft and enclosed in a spirally coiled univalve shell.
- **F4**: Shell has a conical top or apex at one end, and a wide mouth at the opposite end.
- **F5**: Mouth can be closed by a lid, the operculum.
- **F6**: Operculum is attached to the muscular foot.
- **F7**: Shell consists of several whorls.
- **F8**: Externally the whorls are separated by deep lines known as sutures.
- **F9**: The surface of the shell is marked by numerous lines of growth.
- **F10**: Head bears a pair of stalked eyes and two pairs of extensible tentacles.
- **F11**: The visceral mass is spirally coiled.
- **F12**: Foot is a flat sole, used for creeping and attachment.
Sense organs consist of a pair of eyes, a pair of statocysts, two pairs of tentacles and an osphradium.

Respiratory structures are a pair of gills or ctenidium (aquatic respiration) and a lung or pulmonary cavity (for aerial respiration).

Excretion is affected by the kidney (single kidney).

Sexes are separate.

Females are larger than the males.

Female is oviparous.

**EXAMPLE II: PATELLA VULGATA OR TRUE LIMPET**

Marine in nature

Small, oval, sluggish animal.

Below the shell lies the mantle.

The underside of the patella shows a large foot with a broad creeping sole, with which it clings to the rocks.

True ctenidia are absent.

Respiratory organs are known as pallial branchiae.

Anus lies behind the head to the right side.
Auricle is single.

Respiratory organs are a pair of kidneys.

Sexes are separate.

**EXAMPLE III: XANCUS PYRUM**

Soft body is enclosed in a large thick and heavy shell.

The shell is univalve and is spiral.

The spires form a cone with the various whorls closely applied together.

The whorls are coiled round a solid central axis called columella.

The lower-most whorl is the largest and through its large opening the head and the foot may be protruded out.

Proboscis long and foot broad.

Presence of paired plume like gills or ctenidia lying enclosed in mantle cavity.

Head is distinct bearing the eyes and tentacles.

Respiratory organs are a pair of gills or ctenidia.

Excretory organs are kidneys.

Sexes are separate.
EXAMPLE IV: HELIX

- Body is enclosed in a shell.
- Body consists of head, foot and visceral hump.
- Shell is thin having low conical spire and bear prominent lines of growth.
- Head bears two pairs of tentacles.
- Second pair of tentacle is large and bears a pair of simple eyes.
- Foot possesses a flat ventral surface and serves for creeping.
- Buccal cavity contains the radula.
- Respiration by pulmonary sac.
- Hermaphrodite.
Discovering common attributes/essential features of GROUP 1 (G₁) (Fig. 1-4)

Identical Features

1. Body is symmetrical with a mantle and shell.
2. Shell shows spiral coiling.
3. Head is well developed with eyes and tentacles.
4. Mantle encloses the visceral mass.
5. Buccal cavity contains the radula.
6. Respiration by ctenidia (gills) in most forms, in many by lungs or pulmonary sacs.
7. Excretory organ is kidney.

Discovering/identifying suitable term for denoting molluscs having special features.

(Identified 1-4 through observation, discussion and reference)

CLASS- GASTROPODA
STEP VI
DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE – PILA GLOBOSA

\[ F_3 \] Body is soft and enclosed in a spirally coiled univalve shell.
\[ F_4 \] Shell has a conical top or apex at one end, and a wide mouth at the opposite end.
\[ F_7 \] Shell consists of several whorls.
\[ F_8 \] Externally the whorls are separated by deep lines known as sutures.
\[ F_9 \] The surface of the shell is marked by numerous lines of growth.
\[ F_{10} \] Head bears a pair of stalked eyes and two pairs of extensible tentacles.
\[ F_{11} \] The visceral mass is spirally coiled.
\[ F_{12} \] Foot is a flat-sole, used for creeping and attachment.
\[ F_{14} \] Respiratory structures are a pair of gills or ctenidium (aquatic respiration) and a lung or pulmonary cavity (for aerial respiration).
\[ F_{15} \] Excretion is affected by the kidney (single kidney).
All the attributes which are common to Gastropods are seen in Pila globosa. Hence Pila is a gastropod.

**STEP VII**

**CONCEPT ENLARGEMENT**

Discovering additional concepts about other molluscs.

- **C2** PATELLA IS A GASTROPOD
- **C3** XANCUS IS A GASTROPOD
- **C4** HELIX IS A GASTROPOD
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>5.</td>
<td>Sepia or Cuttle Fish</td>
<td>1. Marine</td>
<td>Outer shell is absent.</td>
<td>1. The body is fleshy, bilaterally symmetrical and dorso-ventrally flattened.</td>
<td>1. It is useful as a food, provides sepia ink for artists, their shells are source of calcium.</td>
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<td></td>
<td></td>
<td>2. Good swimmer</td>
<td>Shell is internal</td>
<td>2. Distinct head, shield shaped trunk and narrow neck is present.</td>
<td>2. The internal calcareous shell of sepia, the ‘cuttle-bone’ is used as medicine (as well as for other purpose).</td>
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<td></td>
<td></td>
<td>3. Carnivorous in nutrition</td>
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<td>3. Lateral fins are present in trunk region.</td>
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<td>4. Head bears a pair of large eyes and ten arms.</td>
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<td>5. Two arms are elongated and termed as tentacular arms having suckers on the tips only.</td>
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<td>7. Internal cartilaginous skeleton is also found.</td>
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<td>8. An ink gland is present which secrets coloured fluid.</td>
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<td>9. Sexes are separate.</td>
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</tbody>
</table>
| 6.     | Octopus or Devil fish     | 1. Marine               | Shell is reduced (shell is represented by a pair of vestiges). | 1. Body is oval shaped.  
2. Head is large, flexible and bearing a pair of eyes and 8 arms.  
3. Each arm carries a double row of adhesive suckers which are sessile.  
4. A funnel is present on the ventral side.  
5. Buccal cavity contains a pair of jaws.  
6. Gills and kidneys are present in a single pair.  
7. Fins are absent.  
8. Ink gland present. | 1. It is used in Canada and Alaska on many occasions.  
2. Small Octopuses are used as bait by the line fishermen of Palk Bay. |

**CLASS- CEPHALOPODA**
<table>
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</table>
| 7.     | Loligo or squid     | Marine | Shell is a thin transparent plate which is internal. | 1. Body is spindle or torpedo shaped.  
2. Body is divisible into head, foot and visceral hump.  
3. Head bears a pair of large eyes.  
4. Foot is modified into funnel and ten arms.  
5. 8 arms are short and non-retractile, while two are long and retractile tentacles.  
6. Arms and tentacles are provided with suckers.  
7. Visceral hump is long and pointed and bears two dorsolateral triangular fins.  
8. Shell is a thin transparent plate which is internal and feather shaped.  
9. Sexes are separate.  
10. The 3\textsuperscript{rd} right arm in male is hectocotylised, i.e., it is specially modified as an intromittent organ during copulation to transfer the spermatophores. | 1. Squids make an excellent bait for marine fishes especially Cod in United States.  
2. They are split, sun dried and preserved for later use. |

**CLASS-CEPHALOPODA**
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| 8.     | Nautilus | 1. Marine    | Present | 1. It is found on the bottom in deep sea waters.  
2. The shell is external, spirally coiled made up of calcareous material.  
3. Shell is divided into large number of chambers by series of septa; innermost chamber is smallest and outermost is largest which is known as animal chamber.  
4. A tube siphuncle runs through all the chambers. It is made up of calcareous wall.  
5. Prolongation of visceral mass runs through the siphuncle and finally attached to the septa of innermost chamber. When animal feels any danger, it gets immediately withdrawn in the body chamber with the help of visceral prolongation.  
6. Head is well-developed bearing years. | 1. Is much prized as food by Pacific islanders.  
2. Shell is much used for decoration, art and for many other useful purposes. |
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<td>7. Trunk is rounded sac-like.</td>
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<td>8. Mouth is situated at the tip of head having a pair of calcified jaws.</td>
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<td>9. Tentacles present which are without suckers.</td>
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<td>10. Funnel lies on the posterior side of the head.</td>
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<td>11. Ink gland absent.</td>
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<td>12. Osphradium is present.</td>
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<td></td>
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<td></td>
<td></td>
<td>13. Sexes are separate.</td>
<td></td>
</tr>
</tbody>
</table>

**CLASS- CEPHALOPODA**
Developing/Discovering facts about molluscs (5-8) G2 through observation and discussion.

**EXAMPLE V - SEPIA OR CUTTLE FISH**

- Marine mollusc.
- A good swimmer and carnivorous in nutrition.
- Body is differentiated into 2 parts: head and trunk.
- Head has one pair of eyes, 8 sucker-bearing arms and 2 long tentacles surrounding the mouth.
- Trunk bears one pair of lateral fins for swimming.
- Each arm bears 11 rows of stalked suckers.
- On the ventral side of junction of head and trunk, it has a funnel or siphon for backward darting.
- Internal cartilaginous skeleton is also found.
- An ink gland is present which secretes coloured fluid.
- Sexes are separate.
EXAMPLE VI – OCTOPUS

F₅₉  Marine mollusc.
F₆₀  A good swimmer and carnivorous in nutrition.
F₆₁  Body is oval shaped.
F₆₂  Head is large, flexible bearing a pair of eyes and 8 arms.
F₆₃  Each arm carries a double row of adhesive suckers which are sessile.
F₆₄  A funnel is present on the ventral side.
F₆₅  Buccal cavity contains a pair of jaws.
F₆₆  Gills and kidneys are present in a single pair.
F₆₇  Fins are absent.
F₆₈  Ink gland present.
EXAMPLE VII – LOLIGO OR SQUID

- Marine
- A good swimmer and carnivorous in nutrition.
- Body is simple or torpedo shaped.
- Body is divisible into head, foot and visceral hump.
- Head bears a pair of large eyes.
- Foot is modified into funnel and ten arms.
- 8 arms are short and non-retractile, while two are long and retractile tentacles.
- Arms and tentacles are provided with suckers.
- Visceral hump is long and pointed and bears two dorsolateral triangular fins.
- Shell is a thin transparent plate which internal and feather shaped.
- Sexes are separate.
<table>
<thead>
<tr>
<th>Example VIII – Nautilus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F80</strong> Marine</td>
</tr>
<tr>
<td><strong>F81</strong> The shell is external, spirally coiled made up of calcareous material.</td>
</tr>
<tr>
<td><strong>F82</strong> Shell is divided into large number of chambers by series of septa.</td>
</tr>
<tr>
<td><strong>F83</strong> A tube siphuncle runs through all the chambers.</td>
</tr>
<tr>
<td><strong>F84</strong> Prolongation of visceral mass runs through the siphuncle and finally attached to the septa of innermost chamber.</td>
</tr>
<tr>
<td><strong>F85</strong> Head is well developed and bears eyes.</td>
</tr>
<tr>
<td><strong>F86</strong> Trunk is rounded and sac-like.</td>
</tr>
<tr>
<td><strong>F87</strong> Mouth is situated at the tip of head having a pair of calcified jaws.</td>
</tr>
<tr>
<td><strong>F88</strong> Tentacles are present which are without suckers.</td>
</tr>
<tr>
<td><strong>F89</strong> Funnel lies on the posterior side of the head.</td>
</tr>
<tr>
<td><strong>F90</strong> Osphradium is present.</td>
</tr>
<tr>
<td><strong>F91</strong> Sexes are separate.</td>
</tr>
</tbody>
</table>
Discovering common attributes/essential features of GROUP II (G₂) (Fig. 5-8)

Identical Features

1. Marine
2. Body is bilaterally symmetrical.
3. Head distinct with well developed eyes.
4. The foot is displaced over the head and divides into series of arms.
5. The shell may be rudimentary or absent.
6. Ctenidia or gills are either two or four in numbers.
7. Sexes are separate.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identified 5-8 through observation, discussion and reference)

CLASS- CEPHALOPODA
STEP VIII

DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE - SEPIA

- Marine mollusc
- A good swimmer and carnivorous in nutrition.
- Body is differentiated into 2 parts – head and trunk.
- Head has one pair of eyes and 8 sucker bearing arms and 2 long tentacles surrounding the mouth.
- On the ventral side of junction of head and trunk, it has a funnel or siphon for backward darting.
- Internal cartilagenous skeleton is also found.
- Sexes are separate.

\[
F_{49} + F_{50} + F_{51} + F_{52} + F_{55} + F_{56} + F_{58} = C_5
\]

C_5  SEPIA IS A CEPHALOPOD
All the attributes which are common to Cephalopods are seen in Sepia. Hence Sepia is a Cephalopod.

STEP IX
CONCEPT ENLARGEMENT

Discovering additional concepts about other molluscs (6-8).

- **C₆**: OCTOPUS IS A CEPHALOPOD
- **C₇**: LOLIGO IS A CEPHALOPOD
- **C₈**: NAUTILUS IS A CEPHALOPOD
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>Pinctada or Indian Pearl Oyster</td>
<td>Marine</td>
<td>Present</td>
<td>1. The surface of the shell is coarse, irregular and ruffled.</td>
<td>1. Pearls are used as ornaments. Pearl buttons are largely manufactured from the shells of the pearl oyster.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. The left shell valve is large convex and permanently attached to the rocks.</td>
<td>2. Oyster shells are used as food for poultry.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. The right shell valve is smaller and thinner and covers the viscera.</td>
<td>3. Shells of oysters are mixed with tar for making roads.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. There is a single adductor muscle.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. The right and left mantle lobes are quite free.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. Its shell secrets pearls, whenever any organism enters the shell and causes irritation.</td>
<td></td>
</tr>
</tbody>
</table>

CLASS-PELECYPODA
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td><em>Unio</em>—Fresh water mussel</td>
<td>It is a fresh water mollusc.</td>
<td>Present</td>
<td>1. It is characterised by 2-valvular shell joined dorsally by hinge ligament.</td>
<td>1. Used as food.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omnivorous and Filter feeder</td>
<td></td>
<td>2. Each shell valve has a whitish raised umbo at anterior end and crescentic lines of growth.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Body has a plough share-shaped foot on anteroventral side and two tubular siphons – lower broader inhalant siphon and upper narrower exhalent siphon.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Sexes are separate.</td>
<td>2. Act as scavenger</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Fertilization is internal in the enlarged water tubes of the gill.</td>
<td>3. Shells are a source of lime, so is used as poultry food.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. Development includes a glochidium larva.</td>
<td>4. Shells are used in the pearl button industry.</td>
</tr>
</tbody>
</table>

**CLASS- PELECEYPoda**
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Perna virdis or Mytilus or Green Mussel</td>
<td>1. Marine&lt;br&gt;2. Sedentary form&lt;br&gt;3. Cosmopolitan in distribution.</td>
<td>Bivalve</td>
<td>1. Body is bilaterally symmetrical enclosed in bivalve shell. &lt;br&gt;2. Mantle lobes are two which are fused posteriorly. &lt;br&gt;3. The foot is cylindrical having ventral groove, continuous with byssus pit. &lt;br&gt;4. The gills are lamelliform. &lt;br&gt;5. The adductor muscles are present, anterior one somewhat smaller. &lt;br&gt;6. There are byssus threads for attachment. &lt;br&gt;7. A pair of simple eyes present. &lt;br&gt;8. Sexes are separate. &lt;br&gt;9. Gonads develop in the mantle. &lt;br&gt;10. Eggs develop outside the body of the mother.</td>
<td>1. Widely used as food by man. &lt;br&gt;2. It is used in chowder.</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Name</td>
<td>Nature</td>
<td>Shell</td>
<td>Special Features</td>
<td>Economic Importance</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
<td>--------</td>
<td>---------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
</tbody>
</table>
| 12.    | *Teredo* or *Ship Worm* | Marine | Two shell valves present | 1. Vermiform having two shell valves which are small and weak.  
2. Anterior end of the body is enclosed in movable shell valves.  
3. Presence of paired basket shaped gills with their gill filaments.  
4. Two equal sized adductor muscles are well developed.  
5. Foot is very small.  
6. The siphons are prolonged into distinct muscular tubes and both are united for most of their length.  
7. Two calcareous pallets are present behind the siphonal region and these act as operculum to close the burrow.  
8. Sexes are separate.  
9. Development is indirect, producing veliger larva. | It causes serious damage to ships with wooden hulls, piers and piles. |

**CLASS- PELECYPODA**
EXAMPLE IX – PINCATA OR INDIAN PEARL OYSTER

F92 Marine.
F93 Sedentary forms
F94 Feeding on minute planktonic organisms (filter feeders).
F95 Shell is composed of two pieces (valves) which are hinged together along the dorsal side by a hinge ligament.
F96 The surface of the shell is coarse, irregular and ruffled.
F97 Mantle’s right and left lobes secrete a bivalved shell.
F98 The left shell valve is large convex and permanently attached to the rocks.
F99 The right shell valve is smaller and thinner and covers the viscera.
F100 It has a single adductor muscle.
F101 The right and left mantle lobes are quite free.
F102 Head, eyes, tentacles and radula absent.
F103 Foot wedge shaped.
F104 Respiratory organs are a pair of ctenidia or gills.
F105 Sexes are separate.
EXAMPLE X – UNIO OR FRESH WATER MUSSEL

- **F_{106}** Fresh water mollusc
- **F_{107}** Sedentary form.
- **F_{108}** Omnivorous and filter feeder.
- **F_{109}** It is characterised by 2-valvular shell joined dorsally by hinge ligament.
- **F_{110}** Each shell valve has a whitish raised umbo at anterior end and crescentic lines of growth.
- **F_{111}** Head, eyes, tentacles and radula absent.
- **F_{112}** Body has a plough share-shaped foot.
- **F_{113}** It has a single adductor muscle.
- **F_{114}** Respiration is by gills hanging in the mantle cavity.
- **F_{115}** Sexes are separate.
EXAMPLE XI – PERNA VIRDIS OR MYTILUS

- Marine.
- Sedentary form.
- Omnivorous and filter feeder.
- Body is bilaterally symmetrical enclosed in bivalve shell.
- Mantle lobes are two which are fused posteriorly.
- Each shell valve has a umbo at anterior end and crescentic lines of growth.
- Head, tentacles and radula absent.
- Foot is cylindrical and long.
- Respiration is by gills.
- Adductor muscles are present.
- There are byssus threads for attachment.
- A pair of simple eyes present.
- Sexes are separate.
EXAMPLE XII – TEREDO OR SHIPWORM

- Marine.
- Two shell valves present.
- Anterior end of the body is enclosed in movable shell valves.
- The shell valves are used for boring the wood.
- The body has a worm like appearance and attains 30 cm in length.
- Mantle is tube like and open anteriorly.
- Two equal sized adductor muscles are well developed.
- The foot is much reduced.
- Shell is small and is restricted to anterior region only.
- The siphons are prolonged into distinct muscular tubes and both are united most of their length.
- A pair of elongated gills are present inside the mantle cavity.
- Sexes are separate.
Discovering common attributes/essential features of GROUP III (G₃) (Fig. 9-12)

Identical Features

1. They are marine or fresh water forms.
2. Body bilaterally symmetrical and laterally compressed.
3. Mantle’s right and left lobes secrete a bivalved shell.
4. Head, eyes, tentacles and radula absent.
5. Foot is median and muscular.
6. Presence of two gills.
7. Shell made up of two pieces.
8. Shell consists of two lateral valves hinged together mid-dorsally.
9. Respiratory organs are a pair of ctenidia.
10. Sexes are separate.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identified 9-12 through observation, discussion and references)

CLASS- PELECYPODA
### STEP X

#### DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

### EXAMPLE – PINCTADA

<table>
<thead>
<tr>
<th>F₀₂</th>
<th>Marine.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F₀₃</td>
<td>Sedentary forms.</td>
</tr>
<tr>
<td>F₀₄</td>
<td>Feeding on minute planktonic organisms.</td>
</tr>
<tr>
<td>F₀₅</td>
<td>Shell is composed of two pieces (valves) which are hinged together along the dorsal side by a hinge ligament.</td>
</tr>
<tr>
<td>F₀₇</td>
<td>Mantle’s right and left lobes secretes a bivalved shell.</td>
</tr>
<tr>
<td>F₁₀₀</td>
<td>It has a single adductor muscle.</td>
</tr>
<tr>
<td>F₁₀₁</td>
<td>The right and left mantle lobes are quite free.</td>
</tr>
<tr>
<td>F₁₀₂</td>
<td>Head, eyes, tentacles and radula absent.</td>
</tr>
<tr>
<td>F₁₀₃</td>
<td>Foot wedge shaped.</td>
</tr>
<tr>
<td>F₁₀₄</td>
<td>Respiratory organs are a pair of ctenidia or gills.</td>
</tr>
<tr>
<td>F₁₀₅</td>
<td>Sexes are separate.</td>
</tr>
</tbody>
</table>
PINCTADA IS A PELECYPOD
All the attributes which are common to Pelecypods are seen in Pinctada. Hence Pinctada is a pelecypod.

STEP XI
CONCEPT ENLARGEMENT

Discovering additional concepts about other molluscs (10-12).

<p>| ( C_{10} ) | UNIO IS A PELECYPOD |
| ( C_{11} ) | MYTILUS IS A PELECYPOD |
| ( C_{12} ) | TEREDO IS A PELECYPOD |</p>
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
</table>
| 13     | **Dentalium or Elephant** Tusk Shell | Marine | Present | 1. Body is cylindrical, elongated and is enclosed by a tubular shell open at both ends.  
2. Mantle is tubular and completely encloses the body.  
3. Head has no eyes or tentacles.  
4. Mouth is surrounded by tubular outgrowths or cephalic filaments called 'Captacula'.  
5. Foot is spade-like and is used for digging.  
6. Gills are absent.  
7. Respiration is by exchange of gases through the mantle surface.  
8. Circulatory system is simple.  
9. Nervous system has a pair of cerebral and pleural ganglia.  
10. Sexes are separate | Shells of dentalium are used as money by Red Indians in America and certain tribes in Africa. |
Developing/discovering facts about molluscs (13) G4 through observation and discussion.

**EXAMPLE XIII – DENTALIUM OR ELEPHANT TUSK SHELL**

- **F_{141}** Marine.
- **F_{142}** Body is cylindrical, elongated and is enclosed by a tubular shell open at both ends.
- **F_{143}** Mantle is tubular and completely encloses the body.
- **F_{144}** Head has no eyes and no tentacles.
- **F_{145}** Mouth is surrounded by tubular outgrowths or cephalic filaments called ‘Captacula’.
- **F_{146}** Foot is spade-like.
- **F_{147}** Gills are absent.
- **F_{148}** Respiration is by exchange of gases through the mantle surface.
- **F_{149}** Circulatory system is simple.
- **F_{150}** Sexes are separate.
Discovering common attributes/essential features of GROUP IV (G₄) (Ads 13)

Identical Features

1. They are marine, burrowing and bilaterally symmetrical.
2. Shell tubular.
3. Foot conical.
4. The body is headless, elongated, worm like which is enclosed in a shell.
5. Eyes, tentacles and gills absent.
6. Mouth is surrounded by tubular outgrowth and bears two groups of sensory retractile filaments called captacula.
7. Dioecious and development is indirect.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identified 13 through observation, discussion and reference)

CLASS- SCAPHOPODA
STEP XIV
DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE – DENTALIUM

- F141: Marine.
- F142: Body is cylindrical, elongated and is enclosed by a tubular shell open at both ends.
- F143: Mantle is tubular.
- F144: Head has no eyes or tentacles.
- F145: Mouth is surrounded by tubular outgrowths called ‘Captacula’.
- F146: Foot is spade-like.
- F147: Gills are absent.
- F150: Sexes are separate.
All the attributes which are common to Scaphopods are seen in Dentalium. Hence Dentalium is a Scaphopod.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
</table>
| 14.    | **Chiton or Coat of Mail Shell** | 1. It is marine. 2. Nocturnal in activity. 3. Herbivorous in nutrition. | Present | 1. Body is covered by a shell formed of 8 plates.  
2. The body of the animal is bilaterally symmetrical, elliptical and dorsoventrally flattened with convex surface.  
3. The head is inconspicuous without tentacles and eyes.  
4. The mouth is anteriorly placed and anus at the posterior side.  
5. The mantle covers a great part of the body.  
6. There is a large elliptical, muscular, broad, flat and ventral foot which is used for creeping and also acts as a sucker when the animal attaches to the surface of the rock.  
7. The buccal cavity bears a radula – the horny rasping organ.  
8. At the sides of the body, there are numerous pairs of gills which are lodged in the grooves of the mantle cavity on the lateral sides.  
9. Sexes are separate. | In America, chitons were taken as food by the Red Indians. Some large chitons are extensively eaten and are commonly called as 'Sea beef'. |
Discovering common attributes/essential features of GROUP V (G₃) (Ads 14)

Identical Features

1. Marine.
2. Bilaterally symmetrical.
3. Body is dorsoventrally flattened.
4. Shell made up of 8 pieces.
5. Foot large and flat.
6. Head is not distinct (reduced).
7. Buccal cavity bears a radula.
8. Respiration by gills.
9. Sexes are separate.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identify 14 through observation, discussion and reference)

CLASS-POLYPLACOPHORA
Developing/discovering facts about molluscs (14) Gs through observation and discussion.

EXAMPLE XIV - CHITON or COAT OF MAIL SHELL

- **F151** Marine.
- **F152** Herbivorous in nutrition.
- **F153** Body is covered by a shell made of 8 plates.
- **F154** The body of the animal is bilaterally symmetrical and dorsoventrally flattened.
- **F155** Foot large and flat.
- **F156** Head is inconspicuous without tentacles and eyes.
- **F157** The mouth is anteriorly placed and anus at the posterior side.
- **F158** The mantle covers great part of the body.
- **F159** The buccal cavity bears a radula.
- **F160** Numerous bipectinate gills occur on either side of the body in the mantle groove.
- **F161** Sexes are separate.
STEP XV
DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE – CHITON

- Marine.
- Herbivorous in nutrition.
- Body is covered by a shell made of 8 plates.
- Body is bilaterally symmetrical and dorsoventrally flattened.
- Foot large and flat.
- Head is inconspicuous without tentacles and eyes.
- The mantle covers great part of the body.
- The buccal cavity bears a radula.
- Numerous bipectinate gills occur on either side of the body in the mantle groove.
- Sexes are separate.
All the attributes which are common to Polyplacophores are seen in Chiton. Hence Chiton is a Polyplacophor.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Neopilina galatheae</td>
<td>1. Marine.</td>
<td>Shell is made of a single piece.</td>
<td>1. Body is oval and bilaterally symmetrical.</td>
<td>1. It acts as a connecting link between Annelida (metameric segmentation, nephridia for excretion and trochophore larva) and Mollusca (radula, mantle, shell, etc.). It is also an example of ‘living fossil’.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Creeping type locomotion</td>
<td></td>
<td>2. It is characterised by a cup-shaped shell.</td>
<td>2. The presence of spiral cleavage, appearance of trochophore larva and annelid characters in Neopilina prove that molluscs and annelids had a common coelomate ancestor and annelids are evolutionary precursors of molluscs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Carnivorous</td>
<td></td>
<td>3. Foot is flat and sole-like.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Head without eyes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Mantle encircles the body as a circular fold of the body wall.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. Gills are external and serially arranged (5 or 6 pairs).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. Sexes are separate.</td>
<td></td>
</tr>
</tbody>
</table>

**CLASS-MONOPLACOPHORA**
Developing/discovering facts about molluscs (15) G6 through observation and discussion.

EXAMPLE XV – NEOPILINA GALATHEAE

- Marine.
- Body is oval and bilaterally symmetrical.
- Shell is made of a single piece.
- Foot is flat sole-like.
- Head without eyes.
- Mantle encircles the body as a circular fold of the body wall.
- Gills are external and serially arranged.
- Sexes are separate.
Discovering common attributes/essential features of GROUP VI (G₆) (Ads 15)

Identical Features

1. Marine.
2. Body oval and bilaterally symmetrical.
4. Foot is ventral with a flat creeping sole.
5. Eyes and tentacles absent.
6. Mantle encircles the body as a circular fold of the body wall.
7. Gills are external.
8. Sexes are separate.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identified 15 through observation, discussion and reference)

CLASS-MONOPLACOPHORA
STEP XVI
DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE – NEOPILINA GALATHEAE

- Marine.
- Body is oval and bilaterally symmetrical.
- Shell is made of a single piece.
- Foot is flat sole-like.
- Head without eyes.
- Mantle encircles the body as a circular fold of the body wall.
- Gills are external and serially arranged.
- Sexes are separate.
Neopilina is a Monoplacophor.

All the attributes which are common to Monoplacophores are seen in Neopilina. Hence Neopilina is a Monoplacophor.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
</table>
2. Shell is completely absent  
3. Body is generally almost completely covered by a cuticular mantle in which are embedded calcareous spicules and papillae.  
4. It possesses a longitudinal ventral groove with a slight, ciliated ridge which represents the foot.  
5. The mantle cavity is represented only by a deep posterio-ventral depression or cloaca into which open the anus and renopericardial ducts.  
6. The cloacal wall often contains a series of folds used for respiratory interchange.  
7. Ctenidial structures are absent.  
8. Hermaphrodite. | It is a primitive mollusc. |
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name</th>
<th>Nature</th>
<th>Shell</th>
<th>Special Features</th>
<th>Economic Importance</th>
</tr>
</thead>
</table>
| 17.    | Chaetoderma nitidulum | Marine | Absent| 1. Worm-like body.                                                                                              2. Shell is completely absent.  
3. Body is generally almost completely covered by a cuticular mantle in which are embedded calcareous spicules and papillae.  
4. The cloaca is a discrete bell-like mantle cavity at the posterior end of the animal.  
5. The cloaca contains a pair or a series of ctenidia.  
6. Dioecious.                                                                 | It is a primitive mollusc.             |

**CLASS-APLACOPHORA**
Developing/discovering facts about (16-17) G7 through observation and discussion.

**EXAMPLE XVI – PRONEOMENIA**

- $F_{170}$ Marine.
- $F_{171}$ Carnivorous
- $F_{172}$ Short, thick worm-like body.
- $F_{173}$ Shell is completely absent.
- $F_{174}$ Body is generally almost completely covered by a cuticular mantle in which are embedded calcareous spicules and papillae.
- $F_{175}$ It possesses a longitudinal ventral groove with a slight, ciliated ridge which represents the foot.
- $F_{176}$ Ctenidial structures are absent.
- $F_{177}$ Hermaphrodite.
EXAMPLE XVII – CHAETODERMA NITIDULUM

- Marine.
- Carnivorous
- Worm-like body.
- Shell is completely absent.
- Body is generally almost completely covered by a cuticular mantle.
- The cloaca is a discrete bell-like mantle cavity at the posterior end of the animal.
- The cloaca contains a pair or a series of ctenidia.
- Dioecious.
Discovering common attributes/essential features of GROUP VII (G7) (Ads 16-17)

Identical Features
1. Marine.
2. Carnivorous
3. Worm-like body.
4. Shell is completely absent.
5. Foot reduced or absent.

Discovering/identifying suitable term for denoting molluscs having special features.
(Identified 16-17 through observation, discussion and reference)

CLASS-APLACOPHORA
STEP XVII
DISCOVERING CONCEPTS

Discovering concepts by combining previously acquired facts.

EXAMPLE – PRONEOMENIA

- F170: Marine
- F171: Carnivorous
- F172: Short, thick, worm-like body
- F173: Shell is completely absent
- F174: Body is generally almost completely covered by a cuticular mantle in which are embedded calcareous spicules and papillae

\[ F_{170} + F_{171} + F_{172} + F_{173} + F_{174} = C_{16} \]

C16 PRONEOMENIA IS AN APLACOPHOR
All the attributes which are common to Aplacophores are seen in Proneomenia. Hence Proneomenia is an aplacophore.

STEP XVIII
CONCEPT ENLARGEMENT
Discovering additional concepts about other molluscs (16-17).

\[ C_{17} \quad \text{CHAETODERMA IS AN APLACOPHOR} \]
**STEP XIX**

Encourage students to examine external features and classify the molluscs on the basis of

**PRESENCE OR ABSENCE & NATURE OF SHELL**

- **PILA**
- **MYTILUS**
- **SEPIA**
- **LOLIGO**
- **HELIX**
- **DENTALIUM**
- **CHITON**
- **NEOPILINA**

**POSSIBLE CLASSIFICATION MAY BE AS FOLLOWS:**

- **Name of Molluscs showing spirally coiled shell.**
  - Examples: 1. PILA
  - 2. HELIX

- **Name of Molluscs having internal shell.**
  - Examples: 1. SEPIA
  - 2. LOLIGO

- **Name of Molluscs showing bivalved shell.**
  - Examples: 1. MYTILUS
  - 2. FRESH WATER MUSSEL

- **Name of Molluscs showing tubular shell.**
  - Example: DENTALIUM

- **Name of Molluscs showing multi-plated shell.**
  - Example: CHITON

- **Name of Molluscs showing single shell.**
  - Example: NEOPILINA

- **Name of Molluscs without shell.**
  - Example: PRONEOMENIA
STEP XX

PROBLEM SOLVING

Solving problems with the help of previously learned concepts and rules.

I. Solving problems by identifying the class of molluscs. Name of shell and morphological features with scientific names.

(Example: Provide opportunity to examine the following organisms showing different types of morphological features and encourage students to classify the given organisms on the basis of the nature of shell.)

Application of acquired knowledge to new situations.

Classifying the given organisms into different classes on the basis of the nature of shell and suggesting relevant details regarding the organisms.
<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>SCIENTIFIC NAME OF THE ORGANISM</th>
<th>CLASS OF MOLLUSCS</th>
<th>NATURE OF SHELL</th>
<th>SPECIAL FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>PILA GLOBOSA</td>
<td>GASTROPODA</td>
<td>Spirally coiled.</td>
<td>1. Soft body consists of head, foot and visceral mass.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Head lies on the upper side and bears two pairs of contractile tentacles and a pair of eyes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Foot is muscular and flat and serves for creeping.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Visceral mass consists of the main organs of the body. It is spirally coiled and covered by mantle or pallium.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Operculum is well developed and closes the aperture or the mouth of the shell.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. Sexes are separate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. Female is oviparous.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8. Development is direct.</td>
</tr>
<tr>
<td>Sl.No.</td>
<td>SCIENTIFIC NAME OF THE ORGANISM</td>
<td>CLASS OF MOLLUSCS</td>
<td>NATURE OF SHELL</td>
<td>SPECIAL FEATURES</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>2.</td>
<td>SEPIA</td>
<td>CEPHALOPODA</td>
<td>Shell is internal.</td>
<td>1. The body is fleshy, bilaterally symmetrical and dorso-ventrally flattened.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Distinct head, shield shaped trunk and narrow neck is present.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. Lateral fins are present in trunk region.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. Head bears a pair of large eyes and ten arms.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. Two arms are elongated and termed as tentacular arms having suckers on the tips only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. Internal cartilaginous skeleton is also found.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8. An ink gland is present which secretes coloured fluid.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9. Sexes are separate.</td>
</tr>
<tr>
<td>Sl.No.</td>
<td>SCIENTIFIC NAME OF THE ORGANISM</td>
<td>CLASS OF MOLLUSCS</td>
<td>NATURE OF SHELL</td>
<td>SPECIAL FEATURES</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>3.</td>
<td>PERNA VIRDIS</td>
<td>PELECYPODA</td>
<td>Bivalved shell</td>
<td>1. Body is bilaterally symmetrical and enclosed in bivalved shell.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2. Mantle lobes are two which are fused posteriorly.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3. The foot is cylindrical having ventral groove, continuous with byssus pit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4. The gills are lamelliform.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5. The adductor muscles are present, anterior one somewhat smaller.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6. There are byssus threads for attachment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7. A pair of simple eyes present.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8. Sexes are separate.</td>
</tr>
</tbody>
</table>
4.2.2 ACHIEVEMENT TEST IN BIOLOGICAL SCIENCE

The investigator prepared an achievement test in Biological Science based on the topic 'PHYLUM MOLLUSCA' (for higher secondary school students) to obtain evidence as to the relative effectiveness of the instruction through Discovery Learning Method and Lecture Method. Details regarding the Achievement Test are given below under appropriate heads (The details regarding the Blueprint of the Achievement Test in Zoology at Higher Secondary level prepared by the investigator are given below in tables 4.1 to 4.5).

Table 4.1
Weightage to Objectives

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Objectives</th>
<th>Marks</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Knowledge</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Understanding</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>3.</td>
<td>Application</td>
<td>19</td>
<td>38</td>
</tr>
<tr>
<td>4.</td>
<td>Skill</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4.2
Weightage to Content

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Sub-Unit</th>
<th>Marks</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Identifying features of Phylum Mollusca</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>2.</td>
<td>Class Gastropoda</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>3.</td>
<td>Class Cephalopoda</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>4.</td>
<td>Class Pelecypoda</td>
<td>13</td>
<td>26</td>
</tr>
<tr>
<td>5.</td>
<td>Class Scaphopoda</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td>Class Polyplacophora</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>7.</td>
<td>Class Monoplacophora</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>8.</td>
<td>Class Aplacophora</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 4.3

Weightage to Form of Questions

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Form of Questions</th>
<th>No. of Questions</th>
<th>Marks</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Objective type</td>
<td>30</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>2.</td>
<td>Short answer type</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>3.</td>
<td>Essay type</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>37</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4.4

Weightage to Difficulty Level

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Level of Difficulty</th>
<th>Marks</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Easy questions</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>2.</td>
<td>Average questions</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td>3.</td>
<td>Difficult questions</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

Blueprint of the Achievement Test

Blueprint is a three-dimensional chart showing the content, objectives and form of questions. The blueprint of the achievement test used is given in Table 4.5. The figures in the bracket indicate the mark for each question and those outside, the number of questions.
Table 4.5
Blueprint of the Achievement Test

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Objectives</th>
<th>Knowledge</th>
<th>Understanding</th>
<th>Application</th>
<th>Skill</th>
<th>Total Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of Questions</td>
<td>O</td>
<td>SA</td>
<td>E</td>
<td>O</td>
<td>SA</td>
</tr>
<tr>
<td></td>
<td>Identifying features of Phylum Mollusca</td>
<td>1(^{(1)})</td>
<td>1(^{(2)})</td>
<td>2(^{(1)})</td>
<td>2(^{(1)})</td>
<td>2(^{(1)})</td>
</tr>
<tr>
<td></td>
<td>Class Gastropoda</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td>2(^{(1)})</td>
<td>1(^{(5)})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Cephalopoda</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td>1(^{(2)})</td>
<td>1(^{(1)})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Pelecypoda</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td>1(^{(2)})</td>
<td>3(^{(1)})</td>
<td>1(^{(5)})</td>
</tr>
<tr>
<td></td>
<td>Class Scaphopoda</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td>1(^{(2)})</td>
<td>2(^{(1)})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Polyplacophora</td>
<td>1(^{(1)})</td>
<td>2(^{(1)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Monoplacophora</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class Aplacophora</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td>1(^{(1)})</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(O\) – Objective Type  \(SA\) – Short Answer Type  \(E\) – Essay Type
PRE-TEST (To assess the Entry behaviour of students)

POST-TEST (To assess the Terminal behaviour of students)

The test was conducted to assess the achievement of the students and duration was two hours. Total mark is 50 and included 37 questions. Thirty questions are of objective type, five are of short answer type and the remaining are of essay type questions (Appendix T).

4.2.3 TEST OF PROCESS SKILLS IN BIOLOGICAL SCIENCE

The Science Process skills of the students for the present study were measured using a tool developed and standardised by the investigator in collaboration with the supervising teacher. This test entitled “Test of Process Skills in Biological Science” was developed for the use of higher secondary school students on the basis of Botany and Zoology syllabus.

For preparing this test, the investigator adopted appropriate modifications on the scheme prepared by Klopfer et al. (1971). The following theoretical construct was adopted. Major components of Science Process Skills,

- Process I – Initiation
- Process II – Manipulation
- Process III – Open-endedness

Each of the above science process skills has seven major process categories as indicated below.

1. **Initiation**: Major process categories: Initiation and hypothesis

2. **Manipulation**: Major process categories: Gathering of data and processing of data
3. **Open-endedness**: **Major process categories**: Conceptualisation, generalization and open-endedness.

The other details in the first stage in which the student faces a problem situation and thinks of the method of its solution. This consists of two major processes.

A  - Initiation

B  - Hypothesising

The process ‘Initiation’ is the stage in which the student is aware of the problem situation and he starts to solve it. The sub-categories of initiation are:

A₁  - Recognition of the problem

A₂  - Observation of objects and phenomena.

If the student is able to recognise what actually the problem is, then the process ‘Recognition of the problem’ is attained.

If the student purposely observes the object or phenomena of the problem correctly then the process ‘Observation of objects and phenomena’ is attained.

The process ‘Hypothesizing’ is the stage in which the student seeks different ways of attacking the problem. The sub-categories of hypothesising are:

B₁  - Formulation of a working hypothesis

B₂  - Selection of a suitable test of hypothesis

B₃  - Design of appropriate procedure for experimental

If the student formulates a hypothesis which can work out the problem, then the process ‘Formulation of hypothesis’ is attained.

If the student designs an appropriate procedure for experimental test, then the process design of appropriate procedure for experimental test is attained.
Process II: Manipulation

Manipulation is the stage in which the student actually plunges into the problem for solution. This consists of 2 major categories:

C – Gathering of data
D – Processing of data

The process ‘Gathering of data’ is the stage in which the student is collecting all the details regarding the problem to solve it.

The three sub-categories of gathering data are:

C₁ – Selection of proper instrument or material
C₂ – Measuring of objects and changes
C₃ – Estimation of measurement

If the student selects a proper instrument or material for investigation, then the process ‘Selection of proper instrument or material’ is attained.

If the student is able to measure the particulars of the object or changes which is useful for investigation, then the process ‘Measuring of objects and changes’ is attained.

If the student estimates measurement, then the process ‘Estimation of measurement’ is attained.

The three sub-categories of processing of data are:

D₁ – Organization and manipulation of data
D₂ – Preparation of graphs
D₃ – Interpolation and extrapolation
If the student organises and manipulates the data he collected for the solution of the investigation, then the process ‘Organisation and manipulation of data’ is obtained.

If the student is able to prepare graphs from the data, then the process ‘Preparation of graph’ is attained.

If the student can interpolate (in between the data) or extrapolate (outside the data), then the process ‘Interpolation and extrapolation’ is attained.

**Process III – Open-endedness**

Open-endedness is the stage in which the result of the investigation is put open to the human society. The three major categories of this process are:

- **E – Conceptualisation**
- **F – Generalization**
- **G – Open-endedness**

The major process component ‘conceptualisation’ is the stage in which the student gets the full concept of what he has solved, i.e., he can explain the implications and verify the hypothesis he formulated. The sub-categories of conceptualisation are:

- **E₁ – Interpreting experimental data**
- **E₂ – Evaluation of hypothesis**

If the student interprets experimental data or he can explain the implications of each data, then the process ‘Interpreting experimental data’ is attained.

If the student evaluates the hypothesis or he verifies whether the hypothesis tested is correct or not, then he attains the process evaluation of hypothesis.
The major category ‘Generalisation’ is the state in which the specific problem situation is generalized. The sub-categories of generalization are:

\[ F_1 \] – Formulation of generalization

\[ F_2 \] – Developing a mental model that can be defined operationally.

If the student is able to formulate generalization from the specific facts he studied, then the process ‘Formulation of generalization’ is attained.

If the student develops a mental model, in which he formulates a theoretical model to accommodate known phenomena and principles, then the process, ‘Developing a mental model’ is attained.

The major process category ‘Open-endedness’ is the state in which the result of the investigation can be utilised for other purposes. The sub-categories of open-endedness are:

\[ G_1 \] – Application of discovered knowledge

\[ G_2 \] – Identification of a new problem for investigation

If the student applies the discovered knowledge to solve further problem, then the process ‘Application of discovered knowledge’ is attained.

After the result of the investigation, if the student can identify a new problem for investigation, then the process ‘Identification of a new problem for investigation’ is attained.

Thus there are seven major categories and 17 sub-categories in the process of scientific investigation.
Developing a Draft Test

The procedure for developing the Test of Process Skill in Biological Science are summarised below.

The first step in the construction of the test was to define the content area in Biological Science of higher secondary school syllabus (XI and XII) and to analyse the areas in terms of the measurable processes to be achieved as outcomes. Suitable items relating to each of the process outcomes were formulated. The blueprint of the draft test showing the process category and the number of items in each category selected from Biological Science are presented in Table 4.6.

Table 4.6
Item Numbers in the Test of Science Process Skills
Classified into 17 Process Skills Sub-Categories

<table>
<thead>
<tr>
<th>Main Process Skills</th>
<th>Process Skill Sub-category</th>
<th>Item No. in the Draft Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Botany</td>
</tr>
<tr>
<td>I. Initiation</td>
<td>A₁ – Recognition of the problem</td>
<td>1, 3</td>
</tr>
<tr>
<td></td>
<td>A₂ – Observation of objects and phenomena</td>
<td>5,</td>
</tr>
<tr>
<td>II. Hypothesising</td>
<td>B₁ – Formulation of hypothesis</td>
<td>8, 10</td>
</tr>
<tr>
<td></td>
<td>B₂ – Selection of suitable test of hypothesis</td>
<td>12, 15</td>
</tr>
<tr>
<td></td>
<td>B₃ – Design of appropriate procedure for experimental test</td>
<td>16</td>
</tr>
<tr>
<td>III. Manipulation</td>
<td>C₁ – Selection of proper instrument</td>
<td>20</td>
</tr>
<tr>
<td>Gathering Data</td>
<td>C₂ – Measuring of objects and changes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C₃ – Estimation of measurement</td>
<td>24</td>
</tr>
<tr>
<td>Main Process Skills</td>
<td>Process Skill Sub-category</td>
<td>Item No. in the Draft Test</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Botany</td>
</tr>
<tr>
<td>IV. Processing Data</td>
<td>$D_1$ – Organisation and manipulation of data</td>
<td>27, 28</td>
</tr>
<tr>
<td></td>
<td>$D_2$ – Preparation of graphs</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$D_3$ – Interpolation and extrapolation</td>
<td>0</td>
</tr>
<tr>
<td>V. Conceptualisation</td>
<td>$E_1$ – Interpreting experimental data</td>
<td>33, 34</td>
</tr>
<tr>
<td></td>
<td>$E_2$ – Evaluation of hypothesis</td>
<td>36, 37, 38</td>
</tr>
<tr>
<td>VI. Generalization</td>
<td>$F_1$ – Formulation of generalization</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>$F_2$ – Developing a mental model</td>
<td>46</td>
</tr>
<tr>
<td>VII. Open-endedness</td>
<td>$G_1$ – Application of discovered knowledge</td>
<td>47, 48</td>
</tr>
<tr>
<td></td>
<td>$G_2$ – Identification of a new problem</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

It is evident from the table that seven major process skills consisting of seventeen sub-process skills were included in the ‘Test of Process Skills in Biological Science’. The draft form of the test contained 50 multiple choice items with four alternatives each.

The draft test was subjected to expert criticism. Modifications were made on the basis of suggestions given by experts. The items were arranged in the order of process skill category. The ‘Test of Process Skills in Biological Science’ (Draft form) containing 50 items with directions to the candidates is given as Appendix A. The scoring sheet for the Test of Process Skills in Biological Science (Draft form) is given as Appendix B. The scoring key is also given as Appendix C.
Administration of the Draft Test

The ‘Test of Process Skill in Biological Science’ (Draft form) was administered to 100 higher secondary school students. This pre-test was administered by the investigator. The test was administered without time limit. All the students completed the test in about one hour.

Scoring and Item Analysis

The response sheets were collected and one point credit was given for each correct answer. The aggregate scores for each student was entered at the top of the response sheet.

For item analysis, the answer sheets were arranged in the descending order of the aggregate scores obtained in the test. Then the top 27 percent of the answer sheets were classified as the upper group and the bottom 27 percent of the answer sheets were classified as the lower group. The number of correct responses for each item was identified for both the upper group and lower group. The difficulty index and discriminating power of each item was calculated by using the formulae:

Difficulty index \[= \frac{U + L}{2N}\]

Discriminating power \[= \frac{U - L}{N}\] where

U – Number of correct responses in the upper group
L – Number of correct responses in the lower group
N – Number of students in the upper or lower group
For item selection, the following guidelines proposed by Garrett (1973) were used. Other things being equal, item of moderate difficulty (40-50-60% passing) are to be preferred to those which are much easier or much harder. As a general rule, items with validity indicates 20 percent or more are regarded as satisfactory, but items with lower indicates will often serve if the test is long.

Items having difficulty index between 0.4 and 0.7 and discriminating power above 0.6 were selected for the final test. The details regarding the item analysis are given in Table 4.7.

Table 4.7

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Upper Class</th>
<th>Lower Class</th>
<th>Difficulty index</th>
<th>Discriminating power</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>22</td>
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<tr>
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<tr>
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<td>6</td>
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<td>0.259</td>
<td>accepted</td>
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<td>7</td>
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<td>0.462</td>
<td>0.703</td>
<td>accepted</td>
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<tr>
<td>8</td>
<td>25</td>
<td>10</td>
<td>0.648</td>
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<tr>
<td>9</td>
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<td>0.444</td>
<td>0.666</td>
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<tr>
<td>10</td>
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<td>0.333</td>
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<tr>
<td>11</td>
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<td>0.703</td>
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<tr>
<td>12</td>
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<td>0.703</td>
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<td>16</td>
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<td>17</td>
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<td>accepted</td>
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<tr>
<td>Item No.</td>
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<td>Lower Class</td>
<td>Difficulty index</td>
<td>Discriminating power</td>
<td>Remarks</td>
</tr>
<tr>
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<tr>
<td>18</td>
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<td>23</td>
<td>0.907</td>
<td>0.111</td>
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<td>19</td>
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<td>0.611</td>
<td>0.777</td>
<td>accepted</td>
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<td>20</td>
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<td>0.278</td>
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<td>32</td>
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<td>0.185</td>
<td>0.145</td>
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<td>0.462</td>
<td>0.777</td>
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<td>0.518</td>
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<td>0.777</td>
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<td>0.333</td>
<td>discarded</td>
</tr>
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<td>42</td>
<td>22</td>
<td>4</td>
<td>0.481</td>
<td>0.666</td>
<td>accepted</td>
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<td>43</td>
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<td>0.425</td>
<td>0.333</td>
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</tr>
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</tr>
<tr>
<td>45</td>
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<td>0.537</td>
<td>0.777</td>
<td>accepted</td>
</tr>
<tr>
<td>46</td>
<td>9</td>
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<td>0.203</td>
<td>0.259</td>
<td>discarded</td>
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<td>47</td>
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<td>0.444</td>
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<td>0.592</td>
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<td>0.185</td>
<td>discarded</td>
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<tr>
<td>50</td>
<td>22</td>
<td>3</td>
<td>0.463</td>
<td>0.703</td>
<td>accepted</td>
</tr>
</tbody>
</table>
Preparation of the Final Test

Out of the 50 items included in the tryout, 26 items were selected for the final test and is named as ‘Test of Process Skills in Biological Science’. The selected items were arranged in the order of difficulty. The duration for the final test was fixed as 35 minutes. The final test, viz., ‘Test of Process Skills in Biological Science’ was printed in the form of a booklet with necessary directions. A specimen test is given as Appendix D. The scoring sheet for the ‘Test of Process Skill in Biological Science’ is given as Appendix E. The scoring key is given as Appendix F.

Item numbers in the final ‘Test of Process Skills in Biological Science’ classified into 17 process skills sub-categories from the two areas of Biological Science, viz., Botany and Zoology is presented as Appendix G.

Illustrative Test Items

Some representative items of the test are presented below. Seven items from each major process (skill) category are presented together with the essential behavioural details.

Example 1

Main process – Process I (Initiation)

Major process skill category – Initiation

Process skill subcategory – Recognition of the problem

Operational definition – The student is able to recognise the actual problem implied in a situation.
Item

If a person lives exclusively on a diet of milk, eggs and bread, he is likely to suffer from scurvy. The problem here is

(a) Deficiency of Vitamin K
(b) Deficiency of Vitamin C
(c) Deficiency of Vitamin E
(d) Deficiency of Vitamin A

Example 2

Main process – Process I (Initiation)

Major process skill category – Hypothesising

Process skill subcategory – Formulation of hypothesis

Operational definition – The student is able to suggest a hypothesis that would give direction to the investigation.

Item

Some cells contain a large number of mitochondria. What is the most reasonable hypothesis that can be made for this?

(a) The size of the cell is large
(b) The size of the mitochondria is small
(c) The cells need more energy
(d) The cells need less energy

Example 3

Main process – Process II (Manipulation)

Major process skill category – Gathering of data
Methodology

Process skill subcategory – Measuring of objects and changes

Operational definition – The student is able to measure the particulars of the object or changes which is useful for investigation.

**Item**

Average pulse rate of an adult is

(a) 72 per minute
(b) 70 per minute
(c) 100 per minute
(d) 75 per minute

**Example 4**

Main process – Process II (Manipulation)

Major process skill category – Processing data

Process skill subcategory – Interpolation and extrapolation

Operational definition – The student is able to interpolate and extrapolate from the given data after finding out the functional relationship of the variable.

(If he is able to find out the missing data between two observations, it is called interpolation. If he can find out the data beyond the actual observation, it is called extrapolation).
Item

The height and weight of six boys are given below.

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>35</td>
</tr>
<tr>
<td>135</td>
<td>40</td>
</tr>
<tr>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>165</td>
<td>60</td>
</tr>
<tr>
<td>180</td>
<td>80</td>
</tr>
<tr>
<td>195</td>
<td>85</td>
</tr>
</tbody>
</table>

What will be the weight of a boy having a height of 160 centimetres?
(a) 50 Kg    (b) 55 Kg    (c) 65 Kg    (d) 70 Kg

Example 5

Main process – Process III (Open-endedness)

Major process skill category – Conceptualisation

Process skill subcategory – Interpreting experimental data

Operational definition – The student is able to interpret the data he obtained from the experiment.

Item

Euglena synthesises its food with the help of chloroplasts. If a jar containing Euglena in a rich nutrient solution is kept in a dark room, what do you infer from this?

(a) Synthesis of food will stop and the animal will die of starvation.
(b) Synthesis of food will continue through chloroplasts
(c) Chloroplasts and pyrenoids will disappear and the animal will derive its nourishment from the surrounding solution.
(d) Synthesis will continue but pyrenoids will disappear.

Example 6

Main process – Process III (Open-endedness)

Major process skill category – Generalization

Process skill subcategory – Formulation of generalization

Operational definition – The student is able to arrive at a general conclusion from observed facts.

Item

Evidences from the fossils show that living organisms in the past had simple structures. But they have complex structures today. What can you generalize from this?

(a) Living organisms in the past are not seen today.

(b) Complex forms of organisms evolved from simpler forms which existed in the past.

(c) Living organisms in the past were changed to fossils.

(d) There is similarity between living organisms in the past and the present.

Example 7

Main process – Process III (Open-endedness)

Major process skill category – Open-endedness

Process skill subcategory – Identification of a new problem

Operational definition – The student identifies a new problem situation which is to be investigated.
Methodology

Item

The wastes from factories cause water pollution in rivers and ponds. If so, the new problem scientists have to face is

(a) How to reuse these wastes after purifying
(b) How to dispose these wastes off
(c) How to prevent the discharge of wastes to ponds and rivers
(d) How to prevent the formation of wastes in factories.

Validity and Reliability of the Test of Process Skills in Biological Science

Validity

The procedure adopted for developing a test is a clear evidence of its validity. The Test of Process Skills in Biological Science was prepared very carefully following all the principles of test construction. Moreover, the coherence of the items in the test was assured through item analysis. The item selection procedure may be interpreted as proof of internal validity of the test. The face validity of the test was ascertained by showing the prepared test to experts for their assessment. Moreover, the obtained reliability coefficients give ample indication of the validity of the test. All these factors show that the test is a reasonably valid one.

Reliability

The reliability of the present test was established using the Test-retest method. The test-retest time interval was three weeks. The sample used for validation also was the one used for estimating the reliability ($N = 50$).
The test-retest reliability coefficients were estimated separately for each of the major processes as well as for the total process outcomes. The correlation coefficients (r’s) are presented in Table 4.8.

**Table 4.8**

**Test-retest Reliability Coefficients of the Test of Process Skills in Biological Science**

<table>
<thead>
<tr>
<th>Test Component</th>
<th>Test-retest reliability coefficient (N = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>0.82</td>
</tr>
<tr>
<td>Manipulation</td>
<td>0.75</td>
</tr>
<tr>
<td>Open-endedness</td>
<td>0.76</td>
</tr>
<tr>
<td>Process Total</td>
<td>0.78</td>
</tr>
</tbody>
</table>

The reliability of the test was also established using the split-half method. In split-half method, the test scores were divided into two halves, one for even numbers and other for odd numbers. The obtained correlations are presented in Table 4.9.

**Table 4.9**

**Split-half Reliability Coefficients of the Test of Process Skills in Biological Science**

<table>
<thead>
<tr>
<th>Test Component</th>
<th>Split-half Reliability Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>0.86</td>
</tr>
<tr>
<td>Manipulation</td>
<td>0.78</td>
</tr>
<tr>
<td>Open-endedness</td>
<td>0.79</td>
</tr>
</tbody>
</table>

The validity and reliability indicate that the test is a valid and reliable measure of Process Skills in Biological Science.
Scoring Scheme

The test is scored mainly for the major process skill categories such as Initiation, Hypothesising, Manipulation, Processing of data, Conceptualization, Generalization and Open-endedness. A score of one was assigned to each item. The sum of the scores of the seven major process skills is termed as the total scores on Test of Process Skills in Biological Science.

4.2.4 TEST OF CREATIVITY IN BIOLOGICAL SCIENCE

According to Guilford, the comprehensive test of scientific creativity consists of five major parts. They are:

1. Part A – Fluency
2. Part B – Flexibility
3. Part C – Originality
4. Part D – Elaboration and Redefinition
5. Part E – Sensitivity to problems

Each part consists of different subcategories. Based on this, the investigator prepared a standardised Test of Creativity in Biological Science for finding the effectiveness of the Instructional material in Biological Science based on Discovery Learning Model for fostering Scientific Creativity in higher secondary students.

(a) Preparation of Draft Test

First of all, items meant for measuring creativity (general) were examined. Their utility for scientific creativity was visualised by the investigator and a number of sample items were constructed in order to judge the suitability in local conditions. The test consists of the following five major categories:
Methodology

1. Fluency
2. Flexibility
3. Originality
4. Sensitivity to problems
5. Elaboration and redefinition

The sample categories were discussed with the supervising teacher. As a result of discussion, a few categories were included in the test.

Table 4.10
Components and Subcategories of Scientific Creativity

<table>
<thead>
<tr>
<th>Components</th>
<th>Subcategory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fluency</td>
<td>1. Word fluency</td>
</tr>
<tr>
<td></td>
<td>2. Ideational fluency</td>
</tr>
<tr>
<td></td>
<td>3. Associational fluency</td>
</tr>
<tr>
<td>2. Flexibility</td>
<td>1. Unusual tests</td>
</tr>
<tr>
<td>3. Originality</td>
<td>1. Remote consequences</td>
</tr>
<tr>
<td></td>
<td>2. Picture completion</td>
</tr>
<tr>
<td>4. Sensitivity to problems</td>
<td>1. Product improvement</td>
</tr>
<tr>
<td>5. Elaboration and redefinition</td>
<td>1. Figural definition</td>
</tr>
<tr>
<td></td>
<td>2. Symbolic redefinition</td>
</tr>
</tbody>
</table>

The investigator was very particular to avoid factual statements which could be interpreted in more than one way. Some of the statements were deleted and some were modified after a careful scrutiny of the items with regard to language, accuracy and clarity of ideas. With the help of the supervising teacher, some dimensions were dropped in view of their apparent difficulty level. A preamble with directions for
responding to these statements was also prepared and examples were given for each test. The number of items included in the draft test were as follows:

**Table 4.11**

<table>
<thead>
<tr>
<th>Component</th>
<th>Subcategory</th>
<th>Number of items</th>
<th>Time</th>
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<td>1. Word fluency</td>
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<td>4 mts</td>
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<td>3. Associational fluency</td>
<td>4</td>
<td>8 mts</td>
</tr>
<tr>
<td>2. Flexibility</td>
<td>1. Unusual uses tests</td>
<td>4</td>
<td>6 mts</td>
</tr>
<tr>
<td>3. Originality</td>
<td>1. Remote consequences</td>
<td>2</td>
<td>4 mts</td>
</tr>
<tr>
<td></td>
<td>2. Picture completion</td>
<td>3</td>
<td>6 mts</td>
</tr>
<tr>
<td>4. Sensitivity to problems</td>
<td>1. product improvement</td>
<td>4</td>
<td>8 mts</td>
</tr>
<tr>
<td>5. Elaboration and redefinition</td>
<td>1. Figural definition</td>
<td>4</td>
<td>4 mts</td>
</tr>
<tr>
<td></td>
<td>2. Symbolic redefinition</td>
<td>1</td>
<td>5 mts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>51 minutes</td>
</tr>
</tbody>
</table>

**Pilot Testing**

The success or failure of any test depends mainly on the critical study of every aspect of the test, namely, its meaning, item construction for the test, nature of instruction, time, method of answering, etc. Such a critical study is possible by administering the test of a sample. For this, the investigator randomly selected 100 students of Standard XI. Besides, the directions given in the test booklet and instructions also were given to the students. They were provided with separate response sheets. Time limit for each of the item was set and was strictly observed. The investigator noted as well as explained the difficulties expressed by the students.
Careful supervision was done to avoid copying of other students’ responses. No student was allowed to write after the expiry of the scheduled time limit.

After pilot testing, the test was again edited and the draft scale was prepared along with instructions. The draft test is given as Appendix H.

**Item Analysis**

Item analysis is one of the important and essential steps in the development of psychological tests. Guilford (1956), Garrett (1982) and Edwards (1969) have favoured employing item analysis for improving the reliability and validity of the tests. Item analysis primarily concerns with the item difficulty and item discrimination. Item difficulty is taken in terms of the proportion of individuals completing the item successfully, and item discriminating index refers to the degree to which it differentiates between those obtaining high scores and those obtaining low scores in the test. However, in the development of the present test of ‘Scientific Creativity’, item difficulty could not be determined in the conventional way because the items in the test demanded responses of divergent nature. The statements were selected for the final test on the basis of discrimination value of each item calculated on the basis of ‘t’ value.

**Scoring**

First of all, the students’ responses were checked to ensure that no response has been rewritten. At the same time, all the irrelevant, ridiculous, incomplete and ambiguous responses were searched for and marked with coloured ink pencil. They were ignored while scoring. The responses were scored using the scoring scheme. The scores obtained for each item and the total scores for each individual were
marked. On the basis of the total score obtained, the scores of 50 response sheets were arranged in the descending order. Then the top and bottom respondents were identified as high group and the low group. The ‘t’ value was calculated using the formula

\[ t = \frac{\bar{X}_H - \bar{X}_L}{\sqrt{\frac{\sum (X_H - \bar{X}_H)^2 + \sum (X_L - \bar{X}_L)^2}{n(n-1)}}} \]

where,

- \( \bar{X}_H \) = the mean score on a given statement for the high group
- \( \bar{X}_L \) = the mean score on the statement for the low group
- \( n \) = number of cases

\[ \sum (X_H - \bar{X}_H)^2 = X_H^2 - \left( \frac{\sum X_H}{n} \right)^2 \]

\[ \sum (X_L - \bar{X}_L)^2 = X_L^2 - \left( \frac{\sum X_L}{n} \right)^2 \]

Those items for which significant difference were noticed were selected for the final test. When all the items in the draft test were found to be discriminating those yielding the highest critical ratios were selected. The details regarding the item analysis are given in Table 4.12.
### Table 4.12
**Item Analysis Data for Scientific Creativity Test**

<table>
<thead>
<tr>
<th>Test</th>
<th>Item Number</th>
<th>‘t’ value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test I</td>
<td>Question No. 1</td>
<td>6.396</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>1.3038</td>
<td>rejected</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>1.344</td>
<td>rejected</td>
</tr>
<tr>
<td></td>
<td>Question No. 4</td>
<td>5.810</td>
<td>accepted</td>
</tr>
<tr>
<td>Test II</td>
<td>Question No. 1</td>
<td>2.629</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>2.669</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>0.581</td>
<td>rejected</td>
</tr>
<tr>
<td></td>
<td>Question No. 4</td>
<td>2.653</td>
<td>accepted</td>
</tr>
<tr>
<td>Test III</td>
<td>Question No. 1</td>
<td>4.119</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>3.190</td>
<td>accepted</td>
</tr>
<tr>
<td>Test IV</td>
<td>Question No. 1</td>
<td>0.435</td>
<td>rejected</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>1.860</td>
<td>rejected</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>2.973</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 4</td>
<td>2.125</td>
<td>accepted</td>
</tr>
<tr>
<td>Test V</td>
<td>Question No. 1</td>
<td>3.43</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>2.40</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>4.43</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 4</td>
<td>0.119</td>
<td>rejected</td>
</tr>
<tr>
<td>Test VI</td>
<td>Question No. 1</td>
<td>2.57</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>3.47</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>4.50</td>
<td>accepted</td>
</tr>
<tr>
<td>Test VII</td>
<td>Question No. 1</td>
<td>4.866</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 2</td>
<td>4.444</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Question No. 3</td>
<td>0.332</td>
<td>rejected</td>
</tr>
<tr>
<td>Test VIII</td>
<td>Section A</td>
<td>3.397</td>
<td>accepted</td>
</tr>
<tr>
<td></td>
<td>Section B</td>
<td>2.925</td>
<td>accepted</td>
</tr>
</tbody>
</table>
Preparation of the Final Form of Scientific Creativity Test

The final form of the battery of tests to measure scientific creativity consists of

1. Part A – Fluency
2. Part B – Flexibility
3. Part C – Originality
4. Part D – Sensitivity to problem
5. Part E – Elaboration and Redefinition

Part A – Fluency

a) World Fluency – Prefixes

Here, the subject has to write as many words as possible which begin with a specified prefix.

e.g. Try to write as many scientific words as possible within the time allowed.

Question: Nu .................................................................

(Time limit: 1 mt)

b) Ideational Fluency

Ideational fluency has to do with the rate of generation of a quantity of ideas. This is mostly on the lines of Guilford’s ideational fluency (thing categories). The items in the test are designed to measure chiefly fluency. Instructions emphasise number of responses produced rather than their quality although unusual responses will naturally tend to increase with the total number of responses produced.

Question: List the biologically related items which can be called ‘Circle’

(Time limit: 1½ mts)
Methodology

c) **Associational Fluency**

Here, the subject has to produce a word that could be associated with two given words. This pertains to the completion of a relation.

Question: Write down as many words as possible, which will have association with the given pair.

Question: Organic compounds, carbohydrates. ............................................

(Time limit: 2 mts)

**Part B – Flexibility**

a) **Unusual Uses**

This is a modification of Guilford’s brick uses test intended to measure semantic spontaneous flexibility. In the typical item of this kind, the subject is required to write unusual uses for a given object.

Question: Microscope

(Time limit: 1½ mts)

**Part C – Originality**

(a) **Remote Consequences**

This is an adaptation of Guilford’s consequences (Remote) intended to measure originality. Each item starts with a highly improbable universal event, and the subject has to imagine and then write the consequences making as many guesses as he can, of the occurrence of that event

Question: What would happen when man understands the languages of birds and animals?

(Time limit: 2 mts)
b) **Picture Completion**

This test is derived from Torrance Minnesota Tests. The subject is asked to sketch down some object or design by making addition to an incomplete figure given and to give a suitable title to the complete figure. The sketches are expected to be different from one another.

Question: An incomplete figure is given. Add any number of lines and complete the figure in scientific pattern.

(Time limit: 2 mts)

---

**Part D: Sensitivity to Problem**

a) **Product Improvement**

This is also a modification of Guilford’s apparatus test intended to measure sensitivity to problems. The subject has to suggest improvements for common lab equipments. The suggestions are expected to be interesting and unusual, but need not be practicable in the accepted sense of the term.

Question: Write suggestions for improving a ‘test-tube’.

(Time limit: 1½ mts)
Part E: Elaboration and Redefinition

This means building upon given information, to round out a structure, to make it more detailed. Here, the examinee is given some facts and told to write definitions based on these facts.

a) Figural Definition

Certain pictures are given and the subject has to note what they have seen in the pictures (Time limit: 1 mt).

(b) Symbolic Redefinition

Hidden in the puzzle box are the names of some animals. They may be spelled backwards, forwards, up, down, or in any direction in a diagonal. Write them with number and classify them as arthropods and molluscs (Time limit: 5 mts).

<table>
<thead>
<tr>
<th>T</th>
<th>N</th>
<th>A</th>
<th>A</th>
<th>I</th>
<th>P</th>
<th>E</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>I</td>
<td>A</td>
<td>N</td>
<td>Y</td>
<td>L</td>
<td>F</td>
<td>K</td>
</tr>
<tr>
<td>E</td>
<td>G</td>
<td>E</td>
<td>W</td>
<td>G</td>
<td>U</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>T</td>
<td>U</td>
<td>Ł</td>
<td>A</td>
<td>I</td>
<td>P</td>
<td>A</td>
<td>I</td>
</tr>
<tr>
<td>I</td>
<td>L</td>
<td>F</td>
<td>R</td>
<td>C</td>
<td>E</td>
<td>R</td>
<td>T</td>
</tr>
<tr>
<td>M</td>
<td>S</td>
<td>U</td>
<td>P</td>
<td>O</td>
<td>T</td>
<td>C</td>
<td>O</td>
</tr>
</tbody>
</table>
Table 4.13
Number of Items Included in the Final Form of the Test

<table>
<thead>
<tr>
<th>Component</th>
<th>Subcategory</th>
<th>Number of items</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fluency</td>
<td>1. Word fluency</td>
<td>2</td>
<td>2 mts</td>
</tr>
<tr>
<td></td>
<td>2. Ideational fluency</td>
<td>3</td>
<td>4 1/2 mts</td>
</tr>
<tr>
<td></td>
<td>3. Associational fluency</td>
<td>2</td>
<td>4 mts</td>
</tr>
<tr>
<td>2. Flexibility</td>
<td>1. Unusual uses</td>
<td>3</td>
<td>4 1/2 mts</td>
</tr>
<tr>
<td>3. Originality</td>
<td>1. Remote consequences</td>
<td>2</td>
<td>4 mts</td>
</tr>
<tr>
<td></td>
<td>2. Picture completion</td>
<td>2</td>
<td>4 mts</td>
</tr>
<tr>
<td>4. Sensitivity to problems</td>
<td>1. product improvement</td>
<td>3</td>
<td>6 mts</td>
</tr>
<tr>
<td>5. Elaboration and redefinition</td>
<td>1. Figural definition</td>
<td>1 (4)</td>
<td>4 mts</td>
</tr>
<tr>
<td></td>
<td>2. Symbolic redefinition</td>
<td>1</td>
<td>5 mts</td>
</tr>
</tbody>
</table>

|                              |                                  |                 | 38 minutes |

Scoring Procedure

This test has been scored mainly for five components (factors) of creativity, viz., fluency, flexibility, originality, sensitivity to problems and elaboration and redefinition. Each item of the test receives five types of scores and sum of all the types scores for all the items of the test is defined as the total score of the scientific creativity of the students.

a) Fluency Scores

Fluency is separated by the number of right, relevant and unrepeated responses. The total number of scores obtained from all the items in each subtest is the total fluency score of the test.
b) **Flexibility Scores**

Flexibility in scientific creativity is represented by the ability to solve scientific problems through different approaches. These approaches are classified into categories. One score was designed for each category. No additional score is assigned for more than one response in a category.

c) **Originality Scores**

It is based on the degree of uncommonness of the response. They were classified on a five point scale. The originality weight for various items was determined with the help of the following table:

**Table 4.14**

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Grouping in terms of uncommon responses</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Responses given by less than 1% of the sample</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Responses given by 1 to 2% of the sample</td>
<td>3</td>
</tr>
<tr>
<td>3.</td>
<td>Responses given by 2 to 5% of the sample</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Responses given by 6% to 12% of the sample</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>Responses given by 12% and more of the sample</td>
<td>0</td>
</tr>
</tbody>
</table>

The total of the scores is taken as the total score of the Originality.

d) **Sensitivity to Problem**

The score for each question can be found out by counting the responses (excluding those repeated in an identical form) and assigning one score each to such unrepeated response. The sum of the scores of all the test items will give the total score for sensitivity to problems.
e) Elaboration and Redefinition

It is represented by the number of right, relevant and unrepeated responses. One score was given for each right, unrepeated and relevant response. The total number of scores obtained from all the items is the elaboration and redefinition scores.

The total creativity score is the sum total of the scores obtained for fluency, flexibility, originality, sensitivity to problem and elaboration and redefinition.

Psychometric Details of the Test

(a) Reliability of the Test

The reliability of the test was established using test-retest method and split-half method. The test-retest reliability coefficient was found to be 0.67. The reliability coefficient obtained using the Spearman-Brown Prophecy formula is 0.64. This shows that the test is a reasonably reliable one.

(b) Validity of the Test

The validity of the test was established empirically by comparing the scores of the test with another comprehensive test of creative thinking developed by Nair and Sumangala (1978) for use in the secondary schools of Kerala. The validity coefficient obtained is 0.62 which shows that the test is a reasonably valid one.

Reliability

The test has a split-half reliability of 0.85 (N = 110) which shows that the test is a highly reliable one.
4.2.5 SCIENCE CURIOSITY INVENTORY

The investigator observed that there is no sufficient tool to measure science curiosity of higher secondary students. Hence, the investigator prepared a verbal tool to measure science curiosity. For the preparation of the tool, the investigator referred various types of interest inventories, such as the Kuder Inventories, the Strong inventories and Kerala University Science Interest Inventory.

Construction of the Items

The procedure for developing the Science Curiosity Inventory is summarised below. The investigator prepared suitable items relating to science curiosity. For this, a verbal tool is prepared.

Preparation of the Science Curiosity Inventory (Draft form)

In the process of standardising the inventory, it is administered to a large representative sample of the type of persons for whom it is designed. The draft form of the inventory consists of verbal items to determine the science curiosity of higher secondary students.

For the draft form of the inventory, 40 items were prepared. All precautions are taken to see that the items contained in the science curiosity of higher secondary students. Care was also taken to see that the alternatives appeared are of equal level of attraction to the students. The draft form of the inventory is given as Appendix N.

Administration of the Science Curiosity Inventory (Draft form)

The draft form of the inventory was administered to 100 higher secondary students studying in Standard XI in the schools of Thiruvananthapuram district. The investigator strictly followed the directions regarding the administration of the
inventory implicitly. The booklets were distributed when all the students were comfortably seated. They were strictly told not to open the booklets until they were asked to do so. When the distribution of papers was complete, the testees were given instructions to answer the questions. They were specifically directed not to mark on any part of the booklet other than in the response sheet specified for it. The respondents were asked to put into mark (×) to the correct choice as decided by the respondent.

**Scoring for Item Analysis**

Each of the correct answer was given one score. The scores were added and entered at the top of the response sheet.

**Item Analysis**

The purpose of item analysis was to find out the items that are acceptable for the Science Curiosity Inventory. It is a process of establishing suitability of item for inclusion in the final form of the inventory. It shows how difficult or easy an item is, how it discriminates between two groups – the high and low. The quality of each item should be determined by analysing two important characteristics of items, namely,

(a) Difficulty Index and

(b) Discriminating Power.

Of the different methods to find item analysis, the easiest and simplest method, ‘Kelley’s method’ is used for the Science Curiosity Inventory. Samples of 100 students were taken for the pilot test. According to this method, the highest 27% and lowest 27% from the total score obtained for the Science Curiosity Inventory are
taken, after scoring. The answer sheets were arranged in ascending order. Then the difficulty index and discriminating power were calculated by using the formula

\[
\text{Difficulty Index} = \frac{U + L}{2N} \quad \text{and}
\]

\[
\text{Discriminating Power} = \frac{U - L}{N}
\]

(The details of values calculated for difficulty index and discriminating power are given in Table 4.16).

\[
U - \text{The number of students passing the item in upper group}
\]

\[
L - \text{The number of students passing the item in lower group}
\]

\[
N - \text{The number of pupils in each group}
\]

Generally, the difficulty index (DI) of a good item is considered to be between 0.4 and 0.6 (Pillai, 1967). A discriminating power (DP) of more than 0.4 is considered to be ideal. This means that an item satisfying both the above criteria is readily acceptable. However, if a few easy items are preferred, a Difficulty Index of more than 0.6 may be deemed acceptable. In the same way, a few difficult items are to be given with those having discriminating power less than 0.4 is considered essential (Garrett, 1982). However, after conducting a preliminary test, if sufficient number of items with discriminating power not less than 0.4 are not available, those items with discriminating power less than 0.4 may be considered for practical purposes. The details regarding the item analysis are given in Table 4.15.
### Table 4.15

**Item Analysis Data: Science Curiosity Inventory**

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Upper class</th>
<th>Lower class</th>
<th>Difficulty index</th>
<th>Discriminating power</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>1</td>
<td>0.38</td>
<td>0.67</td>
<td>accepted</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>9</td>
<td>0.56</td>
<td>0.44</td>
<td>accepted</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>5</td>
<td>0.240</td>
<td>0.111</td>
<td>discarded</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>17</td>
<td>0.722</td>
<td>0.18</td>
<td>discarded</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>5</td>
<td>0.5</td>
<td>0.63</td>
<td>accepted</td>
</tr>
<tr>
<td>6</td>
<td>22</td>
<td>9</td>
<td>0.574</td>
<td>0.481</td>
<td>accepted</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>5</td>
<td>0.481</td>
<td>0.592</td>
<td>accepted</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>3</td>
<td>0.296</td>
<td>0.370</td>
<td>accepted</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>1</td>
<td>0.092</td>
<td>0.111</td>
<td>discarded</td>
</tr>
<tr>
<td>10</td>
<td>23</td>
<td>13</td>
<td>0.67</td>
<td>0.37</td>
<td>discarded</td>
</tr>
<tr>
<td>11</td>
<td>19</td>
<td>2</td>
<td>0.039</td>
<td>0.63</td>
<td>discarded</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>1</td>
<td>0.26</td>
<td>0.44</td>
<td>discarded</td>
</tr>
<tr>
<td>13</td>
<td>23</td>
<td>0</td>
<td>0.43</td>
<td>0.85</td>
<td>accepted</td>
</tr>
<tr>
<td>14</td>
<td>21</td>
<td>3</td>
<td>0.444</td>
<td>0.67</td>
<td>accepted</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
<td>3</td>
<td>0.388</td>
<td>0.56</td>
<td>accepted</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>2</td>
<td>0.41</td>
<td>0.666</td>
<td>accepted</td>
</tr>
<tr>
<td>17</td>
<td>16</td>
<td>8</td>
<td>0.44</td>
<td>0.3</td>
<td>discarded</td>
</tr>
<tr>
<td>18</td>
<td>26</td>
<td>9</td>
<td>0.65</td>
<td>0.63</td>
<td>accepted</td>
</tr>
<tr>
<td>19</td>
<td>20</td>
<td>3</td>
<td>0.43</td>
<td>0.63</td>
<td>accepted</td>
</tr>
<tr>
<td>20</td>
<td>16</td>
<td>11</td>
<td>0.5</td>
<td>0.185</td>
<td>discarded</td>
</tr>
<tr>
<td>21</td>
<td>24</td>
<td>12</td>
<td>0.67</td>
<td>0.444</td>
<td>accepted</td>
</tr>
<tr>
<td>22</td>
<td>24</td>
<td>8</td>
<td>0.60</td>
<td>0.60</td>
<td>accepted</td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td>12</td>
<td>0.666</td>
<td>0.444</td>
<td>accepted</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>13</td>
<td>0.703</td>
<td>0.444</td>
<td>accepted</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>16</td>
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<td>0.592</td>
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<tr>
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<td>0.407</td>
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</tr>
<tr>
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<td>4</td>
<td>0.111</td>
<td>-0.074</td>
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</tr>
<tr>
<td>29</td>
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</table>
### Methodology

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Upper class</th>
<th>Lower class</th>
<th>Difficulty index (0.4 to 0.7)</th>
<th>Discriminating power (above 0.4)</th>
<th>Remarks</th>
</tr>
</thead>
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<td>0.407</td>
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<td>0.52</td>
<td>accepted</td>
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<td>5</td>
<td>0.444</td>
<td>0.52</td>
<td>accepted</td>
</tr>
</tbody>
</table>

#### Criteria for Selection of Items

It was seen that most of the items were discriminated between the two extreme groups. However, it was decided to select the best discriminating items (items with difficulty value between 0.4 and 0.7 and discriminating power above 0.7 are good items). Accordingly, 30 items were selected for the final form of the inventory.

#### Final form of the Science Curiosity Inventory

The final form of the science curiosity inventory consisting of 30 items was prepared. A copy of the Science Curiosity inventory (final form) is given as Appendix Q. A separate scoring sheet was developed which is given as Appendix R.
Reliability and Validity of the Science Curiosity Inventory

1. **Reliability**

   The reliability of the present inventory has been established using two methods—test-retest method and split-half method. Test-retest method is most obvious method.

   **(a) Test-retest Method**

   The reliability coefficient in this case is simply the correlation between the scores obtained by the same individual on two administrations of the inventory. The test-retest reliability of the inventory has been obtained from 100 subjects selected randomly from the population. The reliability coefficient obtained is 0.76.

   **(b) Split-half Method**

   The reliability of the inventory was also established using the split-half method. In the split-half method, the scores were divided into two halves, one for even numbers and other for odd numbers. The reliability coefficient obtained through this method is 0.78. The reliability coefficient obtained shows that the inventory is highly reliable one.

**Validity**

Validity implies truthfulness. Validity of a scale is defined as “the accuracy with which it measures what it is intended to measure (Remmers and Gage, 1955, p.122). Evidence regarding the validity of a test lies mainly in the procedure adopted for developing the test. The Science Curiosity Inventory was prepared very carefully following all the principles of test construction. Moreover, the coherence of the items in the inventory was assured through item analysis. The item selection procedure may
be interpreted as proof of internal validity of the inventory. The face validity of the inventory was ascertained by showing the prepared inventory to experts for their assessment. Moreover, the obtained reliability coefficient gives ample indication of the validity of the inventory. All these factors show that the prepared Science Curiosity Inventory is reasonably valid.

4.3 EXPERIMENTAL DESIGN AND PROCEDURE ADOPTED

The basic experimental design adopted in the present investigation was Pre-test – Post-test Parallel Group Design. The investigator selected XI standard students for the experimental study.

The investigator selected schools from Thiruvananthapuram Revenue District for conducting the experimental study.

The investigator took eight hours for teaching the topic ‘Phylum Mollusca’. Details regarding the sample selected for the experimental study are given in Table 4.16.

Table 4.16

The Sample Selected for Experimental Study

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Name of School</th>
<th>Type of Teaching</th>
<th>Total Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DLM</td>
<td>LM</td>
</tr>
<tr>
<td>1.</td>
<td>Holy Angle’s Convent H.S.S., Thiruvananthapuram.</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>2.</td>
<td>Govt. G.H.S.S., Pattom, Thiruvananthapuram.</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>162</td>
<td>160</td>
</tr>
</tbody>
</table>

*DLM – Discovery Learning Model  LM – Lecture Method*
Total number of students selected for experimental teaching was 322, 114, 116 and 91 from each school respectively. Two divisions from each school were selected for Discovery Learning and the other division was exposed to Lecture Method.

After selecting the schools for experimental study, the investigator made necessary arrangement with the Heads of the schools for conducting the experiments. The Achievement Test in Biological Science, Test of Process Skills in Biological Science, Test of Creativity in Biological Science and Science Curiosity University (pre-test) were administered to both the groups, viz., the Experimental group and Control group. After administration of the test, the control group was exposed to Lecture method and the experimental group was exposed to an Instructional Material based on Discovery Learning Model.

**Exposition to an Instructional Material based on Discovery Learning Model**

The experimental group was exposed to an instructional material based on Discovery Learning model. Students were encouraged to observe and study different types of Molluscs and encouraged to collect the organisms (different types of molluscs). They were also encouraged to find out molluscs morphological features, habit, habitat, nature and economic importance. Opportunity was given to classify the observed organisms on the basis of observed differences and similarities. Students were encouraged to develop facts, concepts and principles from the collected data. The discovered/developed facts, concepts, principles and so on were processed and evaluated through separate observation and discussion.
Methodology

Exposition to Lecture Method

The control group was exposed to the Lecture Method which is in essence, the regular classroom procedure. The topic, i.e., PHYLUM MOLLUSCA was taught systematically by the investigator.

Post-testing

When the experimental teaching was over, the final measures of science process skills, scientific creativity, science curiosity and achievement were assessed by administering the Post-test Achievement (the same test was used for pre and post testing) to both the groups.

4.4 STATISTICAL TECHNIQUES USED

The following statistical techniques were used for analysing the data:

1. Test of Significance for difference between means was used to study whether there is significant difference between the means of the groups (DLM and LM) under study.

2. To compare the effectiveness of an Instructional Material in Biological Science based on Discovery Learning Method and Lecture Method on the Science Process Skills, Scientific Creativity, Science Curiosity and Achievement in higher secondary students, Analysis of Covariance (ANCOVA) was applied.

The details of the analysis of data using Analysis of Covariance and other relevant statistical techniques have been compiled in the next chapter.