#### EXEMPLAR 1 OF INVESTIGATIVE PRACTICAL – FROM THE SYLLABUS

**PART A-THE PROPOSAL**

**Observation**

Ten year old John observed that after his grandfather planted some bean seedlings, he immediately applied a blue liquid to them which he had carefully measured out into the watering can. He asked his older sibling what was the blue liquid their grandfather applied to the seedlings and why did he measure it.

**Hypothesis**

Increasing the concentration of fertilizer applied to bean seedlings increases the number of leaves produced in the bean seedlings.

**Aim:** To determine if increasing the concentration of artificial fertilizer increases the number of leaves produced in the bean seedlings.

**Materials:** Clean washed sand, distilled water, 5 beakers, red beans, 5 plastic trays of the same dimensions, foil trays, 4 measuring cylinders, a liquid fertilizer.

**Method**

1. Clean and dry all apparatus before beginning the experiment.
2. Label the four trays as follows: no fertilizer, ¾ strength, ½ strength, ¼ strength.
3. Take the fertilizer and make it up to full strength following the manufacturer’s instructions. Make up to one litre. Label this full strength.
4. Make up dilute solutions of the fertilizer as follows.
5. Measure out 150 ml of the full strength into a beaker. Using a measuring cylinder measure 50 ml of distilled water and add to the beaker. Label this ¾ strength.
6. Measure out 100 ml of the full strength into a beaker. Using a measuring cylinder measure 100 ml of distilled water and add to the beaker. Label this ½ strength.
7. Measure out 50 ml of the full strength into a beaker. Using a measuring cylinder measure 150 ml of distilled water and add to the beaker. Label this ¼ strength.
8. Fill the trays with the washed dried sand. In each tray plant four (4) beans. Each bean should be planted no more than 1 cm below the surface and should be spaced as far away from each other as the container allows.
9. Saturate the soils in the tray labelled no fertilizer, by adding measured amounts of distilled water until sand is moist. Add the same volume of distilled water to each of the other trays.
10. To tray labelled no fertilizer add 15 ml of distilled water. To tray labelled full strength measure out 15 ml and add to tray labelled full strength. Repeat the procedure for the remaining trays. Repeat the addition of the 15 ml of liquid to the appropriately labelled tray for the next ten days. Ensure that the solution is added the same time each day.
11. Place trays in a bright, well-ventilated area. Observe the trays each day. Record the day on which the beans germinated. Count the number of leaves on each seedling and record in a table. Observations such as the colour of the leaves and stem and the size of leaves can also be recorded.

**Expected results**

It is expected that the tray containing the full strength fertilizer would have the greatest number of leaves, followed by the ¾ strength, the ½ strength and the ¼ strength. The tray containing no fertilizer should have the least number of leaves.

**PART B- THE IMPLEMENTATION**

**Introduction**

Plants take up water and mineral salts from the soil. The mineral salts are required to ensure proper growth of plants. Nitrates, phosphates, potassium, iron, calcium and sulfate are some of the minerals required and they can be found in artificial fertilizers but must be applied in the amounts required by the plant.

The number of leaves produced by seedlings in a given time, changes in length, mass and surface area can be used to demonstrate growth in plants. In this experiment the relationship between the quantity of fertilizer added and the growth rate of the seedlings will be explored.

**Method**

1. All apparatus was cleaned and dried before beginning the experiment.
2. The four trays were labelled: A-no fertilizer; B-¾ strength; C-½ strength and D-¼ strength.
3. The fertilizer was collected and made up to full strength following the manufacturer’s instructions. 500 ml of solution was made up and labelled full strength. Dilute solutions were made as follows:
4. 150 ml of the full strength was measured out and poured into a beaker. Using a measuring cylinder; 50 ml of distilled water was measured and added to the beaker labelled ¾ strength;
5. 100 ml of the full strength was measured out and poured into a beaker. Using a measuring cylinder; 100 ml of distilled water was measured and added to the beaker labelled ½ strength;
6. 50 ml of the full strength was measured out and poured into a beaker. Using a measuring cylinder; 150 ml of distilled water was measured and added to the beaker labelled ¼ strength.
7. The trays were filled with the washed dried sand. In each tray four (4) beans were planted. Each bean was planted no more than 1 cm below the surface and were spaced out.
8. The sand in the tray labelled no fertilizer was saturated with 100ml distilled water and the same volume of distilled water was added to each of the other trays.
9. To tray labelled no fertilizer, 15 ml of distilled water was added. To tray labelled full strength 15 ml of the full strength solution was measured out and added to tray. The procedure was repeated for the remaining trays.
10. The addition of the 15 ml of liquid to the appropriately labelled tray was repeated for the next ten days. The solution was added the same time each day.
11. Trays were placed in bright, well-ventilated area. The trays were observed each day. The day the beans germinated was recorded. At the end of ten days the number of leaves on each seedling was counted and recorded in a table. Observations such as the colour of the leaves and stem and the size of leaves were also be recorded.

**Results**

TABLE SHOWING THE EFFECT OF CONCENTRATIONS OF FERTILIZER ON THE GROWTH OF BEAN SEEDLINGS

|  |  |  |
| --- | --- | --- |
| **Tray** | Total number of leaves after 10 days | Additional observations |
| **No Fertilizer** | 18 | Leaves were small and yellow. Stems were also yellow and were shortest. |
| **Full strength** | 45 | Leaves were large and dark green. Stems were also green and were the tallest. |
| **¾ strength** | 33 | Leaves were larger than those in the tray with ½ strength fertilizer but smaller than full strength. Stems were greener and taller than  those in the tray with ½ strength, ¼ strength and no fertilizer |
| **½ strength** | 27 | Leaves were larger than those in the tray with ¼ strength fertilizer but smaller than ¾ strength. Stems were greener and taller than those in the tray with ¼ strength and no fertilizer. |
| **¼ strength** | 22 | Leaves were larger than those in the tray with no fertilizer but smaller than ½ strength. Stems were greener and taller than those  in the tray with no fertilizer |

**Discussion**

Plants need the minerals to provide the elements needed to make constituents such as proteins, DNA, chlorophyll and cellulose. Magnesium is an important part of the chlorophyll molecule, required by the plant to photosynthesize. In the absence of magnesium and hence, chlorophyll leaves are yellow and smaller. Nitrates are required to make amino acids and proteins and DNA. If it is absent, the plant is stunted and the leaves are fewer in number and smaller.

Other minerals such as phosphates, potassium, iron, calcium and sulfate are also required for making DNA, parts of cell membranes, and enzymes for respiration and photosynthesis. In the absence of these chemicals plant growth is slowed, the numbers of leaves produced and the size of these leaves is lessened.

These chemicals are required in specific amounts and that is why when using artificial fertilizers that they be must be applied in the amounts suggested by the manufacturer. Too much fertilizer can also have a negative effect on the growth of the seedlings but this was not investigated in this experiment.

Therefore, it is clear that increasing the concentration of fertilizer applied to bean seedlings increases the number of leaves produced in the bean seedlings. The seedlings have taller, greener stems, with more leaves which are larger and greener.

**Conclusion**

Increasing the concentration of fertilizer applied to bean seedlings increases the number of leaves produced in the bean seedlings.

**Limitations**

Every effort was made to reduce experimental error as much as possible. All conditions were kept constant. However, the following may have contributed to experimental error:

1. Whether all four beans in each tray germinated and continued to grow for the ten days of the experiment;
2. Whether the volumes of fertilizer added each day was enough provide the appropriate amounts of minerals required for growth for the ten days and contained enough water to compensate for the water loss due to evaporation.

**Reflections**

From this investigation, I have a greater appreciation for the importance of minerals for plant growth. I also recognise the importance of following the manufacturer’s instructions. I can now appreciate why farmers add fertilizers to increase the yield of the produce and why fertilizers are heavily used in countries/lands where the soils are not very fertile. I also learnt why the production of fertilizer is a billion dollar industry.

This practical is based on Section B Life Processes and Disease, Nutrition, Specific Objectives 2.5 and

Growth Specific Objective 8.1. Please note that the demands of the practical can be adjusted depending on the capabilities of the class and the equipment/apparatus available at the school. Instead of counting the number of leaves students could:

1. Measure the height of the four stems daily and calculate the average daily height for the four beans for each tray. A graph of average height against day number could be plotted for each tray on the same graph;
2. Tag leaves and measure their surface area each day on square paper. The average surface area of the leaves for the four bean seedlings for each tray can be calculated and a graph plotted;
3. Histograms could be plotted instead of line graphs;
4. Germinate more beans using larger trays and calculate the dry mass daily for each tray. A graph can be plotted once again.

#### EXEMPLAR 2 OF INVESTIGATIVE PRACTICAL – FROM THE SYLLABUS

**Part A - THE PROPOSAL**

**Observation**

Mary noticed several similarities and differences among her classmates but was particularly intrigued with the variation in earlobes. Some of her classmates had free hanging earlobes while some had attached earlobes. These observations led her to wonder about the general pattern of inheritance of this trait and how this trait is passed from parents to offspring.



**A – Free hanging ear lobes B – Attached ear lobes**

**Hypothesis:**

Students with free hanging earlobes will have both parents with free hanging earlobes, while students with attached earlobes will have both parents with attached earlobes.

**Aim:** To investigate the pattern of inheritance for free hanging earlobes versus attached earlobes using data from classmates, their siblings and their parents.

**Materials:** paper; pencil; clip-board.

**Method**

* + - 1. Separate the class into two groups: those with free hanging earlobes and those with attached earlobes.
      2. Record the presence or absence of free hanging earlobes versus attached earlobes for yourself, your siblings and your parents.
      3. Select five additional classmates at random (if you have free hanging earlobes, select two (2) classmates from the “free hanging earlobes group” and three (3) from the “attached earlobes group”. If you have attached earlobes, select two (2) classmates from the “attached earlobes group” and three (3) from the “free hanging earlobes group”). Obtain earlobe information for them as well as their siblings and both of their parents.
      4. Record the earlobe information for all six (6) students (include yourself), and their siblings and parents in a table.
      5. Analyze the phenotypic information for both groups, assuming that the genes for this characteristic are inherited according to Mendelian genetics. Answer the following questions:
  1. Did all students with free hanging earlobes have both parents and all siblings with free hanging earlobes?
  2. Did all students with attached earlobes have both parents and all siblings with attached earlobes?
  3. Assign genotypes to the parents and use Punnet squares and Mendelian genetics to predict the genotypes of the offspring (students and their siblings). Based on your analysis, are free hanging earlobes a dominant or recessive trait? Why or why not?

**Expected Results**

It is expected that students with free hanging earlobes will have both parents with free hanging earlobes and all sibling will free hanging earlobes. The same pattern is expected for those students with attached earlobes. The critical analysis of this study will involve determining the genotype of the students, children and parents based on the phenotypes observed.

**PART B- IMPLEMENTATION**

**Introduction**

Genes control the physical appearance of an organism. Genotype represents the hereditary information or exact genetic makeup of an organism for a particular trait. The phenotype is the actual observed property resulting from the expression of those genes as a physical characteristic (For example, free hanging versus attached earlobes). For diploid organisms of which humans are an example, every gene comes in two copies or alternate forms known as alleles, one, which comes from the mother, and one, which comes from the father. The combination of these two alleles is called the genotype and it is this combination that controls our physical characteristics (phenotypes). The common means to express genotypes is to use a capital letter “E” for a dominant allele and a lower case letter “e” to represent a recessive allele.

Some physical traits are considered discrete traits because they are governed by one set of genes. The expression of those traits depends on whether the genotype is homozygous dominant (EE), heterozygous (Ee) or homozygous recessive (ee). In this experiment, the distribution and inheritance of those two discrete traits will be investigated. It will be assumed that only one pair of genes controls the traits free hanging versus attached earlobes and that this gene is inherited according to Mendelian Genetics.

**Method**

* + - 1. The class was separated into two groups: those with free hanging earlobes and those with attached earlobes.
      2. The presence or absence of free hanging earlobes versus attached earlobes was recorded for my siblings, my parents and myself.
      3. Five additional classmates were selected at random (Given that I have free hanging earlobes, two (2) additional classmates were selected from the “free hanging earlobes” group" and three (3) from the “attached group”. If I had had attached earlobes, 2 additional classmates would have been selected from the “attached group” and three (3) from the “free hanging earlobes group”). Earlobe information for my selected classmates as well as their siblings and both of their parents was collected.
      4. The earlobe information for all six (6) students (including myself) and their siblings and parents were recorded in a table.
      5. The phenotypic information for both groups was analyzed. The following questions were explored:

1. Did all students with free hanging earlobes have both parents and all siblings with free hanging earlobes?
2. Did all students with attached earlobes have both parents and all siblings with attached earlobes?
3. Assign genotypes to the parents and use Punnett squares and Mendelian genetics to predict the genotypes of the offspring (students and their siblings). Based on your analysis, are free hanging earlobes a dominant or recessive trait? Why or why not?

**Results**

**TABLE 1 -SHOWING EARLOBE INFORMATION FOR THE 6 STUDENTS, THEIR SIBLINGS AND THEIR PARENTS**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **#** | **Group 1: Free hanging** | **Siblings** | **Parents** | **#** | **Group 2:**  **Attached earlobe** | **Siblings** | **Parents** |
| **1** | Michael\* | Tyson-free | Mom- free  Dad – free | **4.** | Veronica | Ty-Attached  Mike – attached | Mom- attached  Dad – attached |
| **2** | Shawon | Nekisha- Free  Yohan – Free | Mom – attached  Dad – free | **5** | Shantelle | Chris – attached  Leonnie - free | Mom – free  Dad – free |
| **3** | Allison | Kevin – attached  Jacob – attached  Maxine – free | Mom – free  Dad – attached | **6** | Tyson | Tanisha – free | Mom – free  Dad - attached |

*Free – free hanging earlobes Attached – attached earlobes*

*(\*)Represents person conducting the experiment.*

*Note: Not all children with attached earlobes had both parents with attached earlobes, nor did all children with free hanging earlobes have both parents with free hanging earlobes.*

**TABLE 2 SHOWING COMMENTS BASED ON PHENOTYPE OF PARENTS AND CHILDREN.**

|  |  |  |
| --- | --- | --- |
| # | Student | Comments |
| 1 | Michael | Both of Michael’s parents have free hanging earlobes and both children including Michael have free hanging earlobes. This would support free hanging earlobes being a dominant trait. This would support the hypothesis and expected results. |
| 2 | Shawon | Shawon’s mom has attached earlobes while her dad has free hanging earlobes. However, all the children have free hanging earlobes. This would suggest that free hanging earlobes are dominant to attached earlobes |
| 3 | Allison | Allison’s mom has free hanging earlobes while her father has attached earlobes. However, two of the children have attached earlobes and two of the children have free hanging earlobes. This would indicate that free hanging is dominant but that the parent (mom) with free hanging earlobes would have to be heterozygous (Ee). That is the only way they could have children that are have both free hanging and attached. |
| 4 | Veronica | Veronica’s parents both have attached earlobes. Veronica and her two siblings also have attached earlobes. This would support that attached earlobes is recessive and that if both parents have it (ee) then all children will be born homozygous recessive (ee) and have attached earlobes. |
| 5 | Shantelle | Both of Shantelle’s parents have free hanging earlobes. However, only one of the three children has free hanging earlobes. Two have attached earlobes. These observations indicate that both parents have to be heterozygous dominant (Ee). This would make it possible that two parents with free hanging earlobes would still be able to have children with free hanging and attached earlobes. |
| 6 | Tyson | Tyson’s mom has free hanging earlobes while his dad has attached earlobes. One of the children has free hanging earlobes while the other has attached earlobes. This would indicate that Tyson’s mother has to be heterozygous (Ee) and his dad has to be homozygous recessive (ee). That would be the only combination of genotypes that would result in children with attached or free hanging earlobes |

PUNNET SQUARES: Based on the observations, we will assume free hanging earlobes to be a dominant trait. Homozygous dominant (AA) as well as heterozygous (Aa) will represent Free Hanging Earlobes; while homozygous recessive (aa) can only represent Attached Earlobes.

1. Possible Genotype of Michael’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: Free | |
|  |  |
| Mom: Free |  | EE | EE |
|  | EE | EE |

All children would have free hanging earlobes.

2. Possible Genotype of Shawon’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: Free | |
|  |  |
| Mom: Attached |  | Ee | Ee |
|  | Ee | Ee |

All children would still have free hanging earlobes but their genotype would be heterozygous (Ee). Because free hanging is dominant to attached, having one copy of the “E” would be enough to have children with free hanging earlobes.

3. Possible Genotype of Allison’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: attached | |
|  |  |
| Mom: Free |  | Ee | Ee |
|  | ee | ee |

Half of the children could have free hanging and half could have attached. The Mendelian ratio would be

1:1.

4. Possible Genotype of Veronica’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: attached | |
|  |  |
| Mom: Attached |  | ee | ee |
|  | ee | ee |

If both parents are homozygous recessive (ee)/Attached earlobes, then all children would have attached earlobes.

5. Possible Genotype of Shantelle’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: free | |
|  |  |
| Mom: Free |  | EE | Ee |
|  | Ee | ee |

If both parents were heterozygous, they would still show free hanging earlobes. However, their children could either display free hanging or attached earlobes. The ratio would be 3:1

6. Possible Genotype of Tyson’s parents and those of the children.

|  |  |  |  |
| --- | --- | --- | --- |
|  | | Dad: attached | |
|  |  |
| Mom: Free |  | Ee | Ee |
|  | ee | ee |

If the mom is heterozygous (Ee) and the dad homozygous recessive (ee), then they could have children with free hanging ear lobes or attached earlobes in a ratio of 1:1.

**Discussion**

Simple dominance is a case where a single dominant allele will mask the expression of a single recessive allele. As such, persons with a physical characteristic only need one parent to show that trait for it to show up in the children. In the case of simple dominance, a person with the dominant trait could either be (EE or Ee) because only 1 of the dominant alleles is necessary to show the trait.

Information on phenotypes of parents can be used to create monohybrid crosses using Punnet squares to determine Mendelian ratios regarding possible expression of traits in offspring. The prediction is simply a matter of listing all the possible combinations of alleles in for a given offspring/child. From these results it will be possible to determine whether free hanging or attached earlobes is a dominant trait.

From the phenotypic data and Punnet square crosses it was clear that our hypothesis was not fully supported. Two parents with free hanging earlobes can still have children with attached earlobes because they could both be heterozygous dominant. A cross between Ee x Ee would result in a 3:1 phenotypic ratio of “Free-Hanging” to “Attached”. However, two parents with homozygous dominant genotype EE x EE could only produce children with free hanging earlobes. Two parents with attached earlobes (homozygous recessive alleles) ee x ee could only have children with attached earlobes. Other combinations are also possible, e.g. example, Ee x ee or EE x ee.

**Conclusion**

“Free Hanging” earlobe is a dominant trait. For a child to have free hanging earlobes, he only needs at least one parent to have free hanging earlobes because the “E” allele masks the “e” allele. For a person to show attached earlobes, he/she would need to get an “e” allele from each parent. Both parents will have to carry the recessive form of the gene, even though both may have ‘free hanging’ ear lobes

**Limitations**

Every effort was made to reduce experimental error in this experiment. However, the experiment may be improved by:

1. Including information on grandparents;

2. Also, care must be taken with obtaining accurate information on the phenotype of their siblings and parents, from classmates.

**Reflections**

From this investigation, I have acquired a better understanding of genetics including genes, alleles, genotype versus phenotype, and Mendelian ratios. I can now appreciate how traits are passed on from one generation to another using information from a simple survey. I now realize that some traits are dominant while others are recessive and that it is our genotype that determines whether a trait will be expressed as a physical characteristic (for example, hair color, freckles, dimples, free hanging versus attached earlobes). This investigation also has applications to the study of genetic diseases, which can also be passed on from parent to offspring. One of the most striking things I learned from this investigation is that both parents can have free hanging earlobes but their child could still be born with attached earlobes. This could apply to cases where parents appear normal but a child is born with a genetic disorder. Overall, this was an interesting practical where I got to apply critical thinking skills to answer questions about heredity.

This practical is based on Section C, Continuity and Variation, Specific Objectives 1.1 and 2.7-2.10.

**Note to the teacher:** For discrete traits, students don't have to be limited to the ear lobe phenotype. They can use traits including dimples, hairline and, tongue rolling. They can also use data from continuous traits such as height. Also, if the practical is overwhelming with 6 students, it can be done with 4 students