AN EXPERIMENT DESIGNED BY A STUDENT

LEARNING OUTCOMES: 1, 2, 4, 8, and 9 **TOTAL MARKS 40**

The curriculum statement requirement is that students must complete four summative practicals, one from each theme in the curriculum statement. In at least two summative practicals students must formulate a hypothesis, design an experiment to test the hypothesis, carry out the designed experiment, interpret the results, and evaluate the experiment.

An experiment designed by a student should be presented in two parts;

1. **Experimental Design**
2. **Practical Report**

The Experimental Design is assessed by the teacher and, based on teacher advice, the student may or may not make appropriate modifications before conducting the experiment. After data have been collected and analysed, a formal report (the Practical Report) that presents the hypothesis actually tested and the method actually used, is submitted and assessed.

This document contains a practical report produced by a student who has designed, then carried out, an experiment to investigate one aspect of photosynthesis. The student followed the steps below.

1. Experimental Design

The student was required to formulate a testable hypothesis, present the method and materials to be used to test this hypothesis, identify the independent and dependent variables and state four factors that needed to be kept constant. The method had to provide sufficient detail for someone else to repeat the experiment. It was acceptable to present the method using labelled diagrams and in dot point format.

2. Submission of Experimental Design to the teacher

Before conducting the experiment the student presented the experimental design to the teacher and the experimental design skills were assessed (see marks scheme, page 9).

3. Modification of Experimental Design

If appropriate, modifications were made. For example, in the work sample presented below, the method did not indicate which hydrogen carbonate salt was to be used, or whether any thought had been given to using a stock solution or explaining how the various dilutions were to be obtained.

4. Conduct of the experiment

The student then carried out the experiment, based on the modified design.

5. Writing of the final Practical Report

In the final report, the hypothesis actually tested and method actually used were presented.

The criteria (presentation, interpretation and evaluation, and communication) and qualifying questions used for assessment of this practical are set out in the marks scheme on page 9. (The criterion Practical skills was not assessed by the teacher in this particular practical.)

STUDENT REPONSE

PART A: EXPERIMENTAL DESIGN

The Rate of Photosynthesis

Hypothesis:
Hydrogen carbonate concentration will have no effect on the rate of photosynthesis.

Is testable; links dependent and independent variables.

Variables:
Independent: Hydrogen Carbonate solution

Identifies the factor that is deliberately varied, but is a bit vague. e.g. concentration of hydrogen carbonate would be better.

Dependent: Time taken for the leaf discs to rise

Identifies the factor that is measured.

Factors held constant:
Number of leaf discs
Light intensity
Same type of leaf
Amount of each solution placed in the beakers

Identifies factors that are held constant, but is too vague. e.g. number of leaf discs per beaker and volume of solution in each beaker, would be better.

Apparatus:
Fresh Agapanthus leaves
Large Syringe
6 x 100mL beakers
Distilled water
Cork borer
Overhead projector
20mL measuring cylinder
Forceps
Stop watch
Varying hydrogen carbonate solutions

Does not indicate the actual concentrations of the solutions used
Does not indicate which hydrogen carbonate salt is to be used (e.g. sodium? potassium?)
How many agapanthus leaves/
What is the volume of the 'large' syringe?
what is the diameter of the cork borer?

Procedure:

1. Use a cork borer to cut out 80 leaf discs (diameter 1cm) from the leaves.
2. Place immediately in distilled water.
3. Label six 100mL beakers A, B, C, D, E, F.
4. Add 40mL of liquid to each beaker:

5. To
   - A add water
   - B 0.5% of Hydrogen Carbonate Solution
   - C 1% of Hydrogen Carbonate Solution
   - D 2% of Hydrogen Carbonate Solution
   - E 3% of Hydrogen Carbonate Solution
   - F 4% of Hydrogen Carbonate Solution

6. Remove the plunger from the syringe and half-fill it with distilled water
7. Transfer leaf discs to the syringe. Put the plunger back in and remove all the air.
8. Place a finger over the tip of the syringe, to create an airtight seal. Pull the plunger down, so that some suction is created. (The discs should have air bubbles around them as the air is being removed.)
9. Remove the finger from the tip of the syringe. (All the leaf discs should sink to the bottom. If there are some discs still floating, the above process (step 7) will be repeated.)
10. Place ten discs in each beaker, using the forceps.
11. Place all the beakers on the overhead projector
12. Measure the time taken for each disc to rise.

Should explain the method for obtaining each concentration of hydrogen carbonate (e.g will the student use a stock hydrogen carbonate solution and subsequent dilutions?)
Should the overhead projector light be switched on?
Does not describe how the time taken for each disc to rise will be measured.
Otherwise provides sufficient detail for someone else to repeat the experiment.

PART B: Student Practical Report

The Rate of Photosynthesis

Background Information:
Photosynthesis is a series of chemical reactions, which use light energy to convert carbon dioxide and water into glucose, a simple sugar. The first stage of photosynthesis requires light energy and occurs in the grana. Enzymes necessary for the final stage of photosynthesis in which sugar is manufactured are located in the stroma. Oxygen is a by-product of photosynthesis.

Organisms that make all the energy-rich compounds they need from simple inorganic substances are called autotrophs. As stated above, they do this through the process of photosynthesis. This comes from the Greek work photos meaning light.

Provides some information about photosynthesis, but does not focus on the aspects most relevant to this practical. For example, there is no explanation of the relationship of photosynthesis to a leaf (where are grana found?), or linking photosynthesis to the rising of leaf discs. The connection between rate *and* time for discs *to rise should be explained. Setting out relevant background information for the practical requires the student to use biological terms and conventions correctly, and to communicate logically and clearly. Therefore Communication skills are partly assessed here.*

The overall equation for photosynthesis is:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Purpose:
To investigate the effect of hydrogen carbonate concentration on the rate of photosynthesis.

Hypothesis:
That the hydrogen carbonate concentration will have no effect on the rate of photosynthesis.

Apparatus and Materials:
Fresh Agapanthus leaves
Large Syringe
6 x 100mL beakers
Distilled water
Cork borer
Overhead projector
20mL measuring cylinder
Forceps
Stop watch
sodium hydrogen carbonate solutions (0%, 0.5%, 1%, 2%, 3%, 4%)

Marks were allocated in Part A: Experimental Design.
Inclusion of the number of leaves, and the volume of the syringe would be expected here as a response to feedback given in Part A.

Method:
1. The cork borer was used to cut out 80 leaf discs from the leaves. Old and woody areas were avoided. Each disc was 1 cm in diameter and they were immediately placed in distilled water to prevent them from drying out.
2. Six 100mL beakers were placed out and labelled beaker A, B, C, D, E, F. 40 mL of distilled water was placed in beaker A. 40mL of 0.5% Hydrogen Carbonate Solution was placed in beaker B. 40mL of 1% Hydrogen Carbonate Solution was placed in beaker C. 40mL of 2% Hydrogen Carbonate Solution was placed in beaker D. 40mL of 3% Hydrogen Carbonate Solution was placed in beaker E. 40mL of 4% Hydrogen Carbonate Solution was placed in beaker F.
3. The plunger was removed from the syringe. It was then half-filled with distilled water, and the leaf discs were transferred to the syringe. The plunger was put back in and all the air was removed.
4. A finger was placed over the tip of the syringe, which created an airtight seal. The plunger was pulled down, so that some suction was created. The discs had air bubbles around them as the air was being removed.

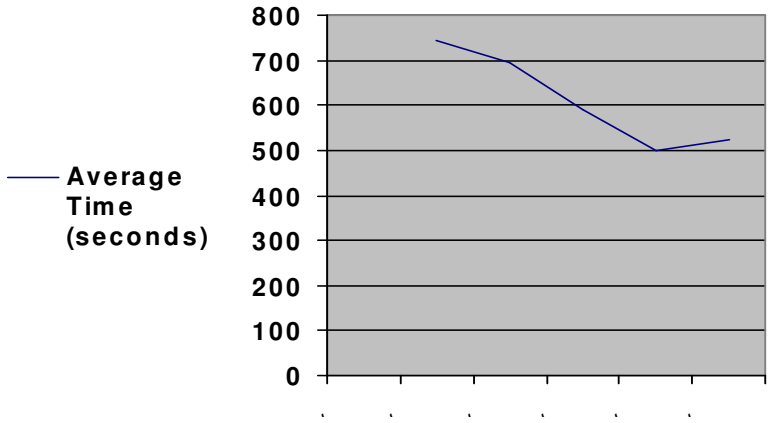
5. The finger was removed from the tip of the syringe, and all the leaf discs sank to the bottom. If there were some discs still floating, the above process (step 4) was repeated.
6. Ten discs were placed in each beaker, using the forceps. All the beakers were then placed on the overhead projector, and the time taken for each disc to rise was recorded.

- *Marks were allocated in Part A: Experimental Design. Student has now identified the hydrogen carbonate salt but it is still not clear if serial dilutions have been used. A teacher should know how a student has obtained these concentrations.*

Results:

Hydrogen Carbonate Concentration	0%	0.5%	1%	2%	3%	4%
Average Time (seconds)	-	743.6	696	591.8	499.3	524.9
Reciprocal Time x10^{-3} (1/seconds)	0	1.35	1.44	1.69	2.00	1.91

- *The student has tabulated the data but:*
- *the % symbol should appear alongside the hydrogen carbonate concentration and not in the body of the table.*
- *the data should be presented to the same number of significant figures. Whole numbers for the average times would be more appropriate in this case.*
- *the average time for discs to rise in the absence of hydrogen carbonate should be indicated as greater than time actually measured. Reciprocal time is not 0.*
- *why was reciprocal of time calculated? It has not been referred to anywhere else in this report.*



- *axes chosen correctly.*
- *graph should have a title.*
- *scale on horizontal axis is not linear.*
- *vertical axis is not appropriate.*
- *% should appear on x-axis label(sodium hydrogen carbonate concentration(%)).*
- *points not plotted correctly.*
- *a line of best fit should be used since random errors are likely.*

Interpretation and evaluation

1. Interpretation

In general, the pattern that I identified was that as the hydrogen carbonate solution increased, it generally took less time for the leaf discs to rise. Although this is not entirely true, as at 5% Hydrogen Carbonate Concentration, the time it took for the discs to rise, took a bit longer than the previous 4% solution.

- *Has apparently identified the relationship between the hydrogen carbonate concentration and the time taken for the discs to rise, although needs to refer to hydrogen carbonate concentration (not solution) in the first sentence.*
- *Has referred to numeric values for hydrogen carbonate concentration but not for the time taken for the discs to rise.*
- *'However' should be used, not 'Although' to begin the last sentence.*
- *It is customary to write in the third person, i.e. 'the pattern identified" not 'the pattern I identified'.*
- *There is no attempt to interpret this data. The interpretation should be an attempt to relate the behaviour of the leaf discs in the various solutions to what is happening in the leaves – both the airspaces and the cells. It should be quite clear how photosynthesis may be responsible for the measurements made.*

2. Evaluation

Errors:

Systematic:

Wrong solution may have been used (not sodium hydrogen carbonate)

Random:

(a) Leaf discs cut from different places in the leaf and may have different thickness
(b) May have damaged some leaf discs.
(c) Beakers placed on overhead projector differently, thus giving different light intensities.
(d) More than one leaf disc was used at each solution. (Sample space was 10.) This was to reduce the impact of random errors.
(e) My group did not repeat the experiment, but other students have done it in previous years.

- *Recognises that the solution could be a source of systematic error, thus using an alternative solution would affect the results. However, has not engaged with the concept of a fresh solution being used to verify results.*
- ***No discussion** about possible errors involved in use of the stop watch.*
- ***No discussion** to indicate an understanding of the difference between systematic and random errors.*
- *(a) and (b) should be explained more fully - relate technical problems to cells.(e.g. 'Since rate of discs rising depends on the amount of oxygen produced by photosynthesizing cells, parts of the leaf with fewer functioning photosynthetic cells will be slower to rise and could give misleading results. This illustrates why it is important to have a large number of discs (i.e. a large sample space).)*
- *Identifies a component of the experiment that is replicated, and correctly relates this to random error.*
- *Suggests that the student recognises that repetition involves the experiment being carried out by different workers, at different times. However, this, and its significance, should be made quite clear.*

Precision and Accuracy:

Accuracy indicates how close the result is to the true value.

By using the same size cork borer for cutting leaves, we made sure that it kept the experiment accurate, as no beakers had different size leaf discs, thus giving them an advantage or disadvantage. We were also fairly accurate again, because we had the same person timing the same beaker at all times. There may have been a problem with accuracy here though, as we only had two people timing, therefore they had to look after 3 beakers each, which could mean that there was a few timing mistakes. Because each beaker may have been exposed to different light intensities some beakers may have had an advantage over others.

- *Correctly states the meaning of accurate. However does not indicate an understanding that accuracy depends on the extent to which systematic errors are minimised. The examples given affect random error. The cork borers and timers could be a source of systematic error, although the skill in using them would most likely be sources of random error.*

We were fairly precise, as we timed the leaf discs to the nearest second.

- *Precision reflects the amount of scatter in the results. The student has confused resolution of the measuring instrument (timer) and possibly, the use of significant figures, with precision. However since the range of times for the discs to rise has not been included in the data, any comment about scatter cannot be substantiated.*

Conclusions:

My results did not support my hypothesis "that the hydrogen carbonate concentration will have no effect on the rate of photosynthesis". The concentration of hydrogen carbonate solution does have an effect on the time it takes the leaf discs to rise, as can be seen above. The higher the concentration, the less time it takes for the discs to rise. If my results did support my hypothesis, then the line would be horizontal. I would change the hypothesis to "If we change the hydrogen carbonate concentrations, then the leaf discs will take different times to rise."

- *Has recognised that the data is inconsistent with that predicted by the hypothesis.*
- *The relationship between the discs rising and photosynthesis needs to be stated.*
- *The modified hypothesis attempts to take account of the results obtained, but could be more specific about the relationship between the hydrogen carbonate concentration and the time taken for the discs to rise.*
- *The amount of scatter in the raw data would give an indication of the significance in the difference in the results at 3% and 4% hydrogen carbonate. This should be discussed.*

Overall comment

- *There is no discussion of what is actually happening (in terms of cells and photosynthesis).*
- *There is no discussion of whether the final change in trend in the results is actually significant, and if so, what it means?*
- *There is no discussion of the significance of testing the discs in distilled water.*
- *Does not appear to know the difference between 'solution' and 'concentration'.*
- *The discussion should be written in the third person.*
- *The quality of this report would have been greatly enhanced by using a discussion style, and explaining ideas (e.g. random errors) clearly.*

Design Practical: Factors affecting photosynthesis

Name: _____ Date: _____

Criteria for Judging Performance	Teacher's Comments	Mark
Experimental Design Skills How clearly does the student state a testable hypothesis? How clearly does the student identify the independent and dependent variables? How clearly does the student identify factors that need to be held constant? How clearly does the student design and describe the procedure?	Apart from lack of detail with respect to the nature of the hydrogen carbonate, and details of making up the solutions, this was well done.	**8/10**
Presentation How well does the student construct tables with appropriate headings, number of significant figures and units shown? How well does the student construct a graph with appropriate choice of axes, scales and units? How well does the student accurately plot points and draw a line of best fit?	Both table and graph had faults (see text boxes.)	**5/10**
Interpretation and Evaluation How clearly does the student describe the pattern of results? How well does the student identify sources of and distinguish between random and systematic errors? How well does the student explain the importance of the number of samples and repeating the experiment? How well does the student discuss the accuracy and precision of the results of the experiment? How effectively does the student analyse and evaluate an experiment and suggest improvements? How effectively does the student interpret the results and draw a valid conclusion?	Random and systematic errors needed discussion and explanation. Errors, accuracy and precision were considered, but understanding was not clearly demonstrated. Analysis of data superficial. Interpretation of results by relating to events in the plant cells was not attempted. Conclusion inadequate.	**6/15**
Communication To what extent does the student use biological terms and conventions correctly? How logically and clearly does the student present information?	Biological terms and conventions used correctly, and generally logical, but the meaning was not always clear as more explanations and discussion were needed	**3/5**
Total		**22/40**

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