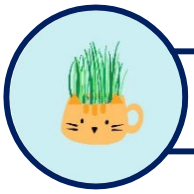
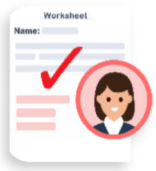
Cat Grass Investigation



Cat Grass Investigation

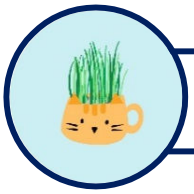
Table of Content



Notes for teachers

- Scan the QR code to get the electronic files.
- Teachers are strongly encouraged to adapt and modify these resources as necessary.

Innovations in Biology Investigations



Cat Grass Investigation

Overview

- The *Cat Grass Investigation* is situated in the context of growing cat grass indoors using artificial lighting.
- Students investigate the effect of different wavelengths of light from LED lamps on the photosynthetic rate by measuring the rate of Hill reaction (Spencer, 2018).
- Students have the opportunity to design and carry out an experiment in which they set up replicates, consider the importance of controls, and evaluate the generalisability of the data in making claims about plant growth.

Teaching Plan & Key Features

Prerequisite knowledge (scientific ideas)
- The process of photosynthesis
- The relationship between photosynthesis, respiration, and plant growth

Prerequisite manipulative skills
- Using an autopipette to transfer a small volume of solution

Lesson	Lesson sequence	Duration (mins)	Resources
Stage ❶ Preparing for the investigation • It is situated in an authentic, daily-life context related to the use of artificial lighting for growing cat grass (**Contextualisation**). • Students read information to familiarise themselves with the background of the investigation (*Reading Materials*). • Students' experimental designs of a similar investigation are collected and discussed in class (*Diagnostic Assessment*).			
Before Lesson 1	• The teacher distributes *Worksheet 1* for students to complete at home so that they can be familiar with the background of the investigation.		*Worksheet 1*
1	• The teacher discusses the investigation context with students. • The teacher provides feedback on students' responses in *Worksheet 1*. • Students complete *Worksheet 2* to design an investigation.	40	*Worksheet 2*
Stage ❷ Designing the investigation • Students have the chance to evaluate their own and their peers' experimental set-ups (*Self & Peer Evaluation*).			
2	• The teacher provides feedback on students' experimental designs in *Worksheet 2*.	40	Student Samples 1
3	• The teacher presents the main investigation context and discusses with students questions related to their experimental designs. • The teacher provides students with the laboratory manual for preparation at home.	40	Teacher Notes 1

Stage ❸ Carrying out the investigation • Students use microscale instrumentation that reduces the time of the experiments (**Microscale Instrumentation**). • Students collect more complex data sets by setting up replicates (**Complex Data Set**).			
4	• The teacher asks questions to help students connect their lab experience and related ideas/scientific inquiry skills. • Students carry out the investigation.	40	Laboratory Manual
Stage ❹ Explaining and evaluating data • Students share data on the *Google Spreadsheet* (*Digital Tool*). • Students use data to support their claims about the effect of different wavelengths of light on the photosynthesis of cat grass and discuss the generalisability of the results.			
Before Lesson 5	• Students complete data reporting and analysis at home. • The teacher collects and marks student responses.		Teacher Notes 2
5	• The teacher provides feedback on students' performance related to data reporting and analysis**.**	40	Teacher Notes 2

Important Notes

- Students are *not* required to learn the detailed reasons for the effects of different wavelengths of light on the photosynthesis of cat grass. Rather, they are expected to use their data to support their claims about the effects.
- Students are *not* expected to know the details of Hill reaction to successfully complete this investigation.

Instructional Materials

Stage 1 Preparing for the investigation

Student Worksheet 1

Notes for teachers

- Teachers can distribute *Worksheet 1* and instruct students to read the background information related to the investigation as a take-home assignment.
- Students' responses can be collected using a *Google Form*.
- Depending on the student performance, some questions can be discussed in class.

Task 1

- Read the following information and source materials in the *Data File*.
- Answer the questions that follow.

Scenario

The scenario is set in an everyday context (i.e., growing cat grass indoors).

Cat grass is a mixture of grasses grown from seeds, such as wheat, barley, oats, and rye. Cat grass is safer for cats to eat than outdoor grass, which may have been treated with pesticides. Cat grass is also a rich source of vitamins, minerals, and dietary fibres.

Wheatgrass is a type of cat grass that is commonly grown indoors. Wheatgrass seeds are sown in moist soil. After germination, artificial light, such as light-emitting diode (LED) lamps, are used to supply light for the seedlings to grow. Wheatgrass is ready for cats to eat around 2 weeks after germination.

Source: https://www.amazon.com/Cat-Planter-Hairball-Digestive-Manufactured/dp/B01JNI9W9E

In this investigation, you would like to investigate the photosynthesis and growth of wheatgrass.

Read the *Data File* to familiarise yourself with the background of the investigation. You will use your biological knowledge of photosynthesis and plant growth and how to design valid and reliable experiments to complete this investigation.

Scan the QR code to get a copy of the *Google Form*.

Data File

Your biology teacher asks you to read the following source materials to prepare yourself for designing an investigation related to studying photosynthesis and plant growth:

The reading material contains relevant history of science.

Source 1: Hill reaction

In 1939, Robert Hill, a scientist working at the University of Cambridge, studied the process of photosynthesis. He discovered that when an artificial electron acceptor 'A' is introduced to isolated chloroplasts from broken plant cells under the illumination of light, the artificial electron acceptor, after accepting the electrons, is reduced (to AH_2). Oxygen (O_2) is evolved. This reaction is called the *Hill Reaction*:

Water + Electron acceptor → Reduced form of electron acceptor + oxygen

$$2\ H_2O + 2\ A \rightarrow 2\ AH_2 + O_2$$

On the basis of his data, he proposed that electrons are produced in a certain biochemical process in isolated chloroplasts. Under illumination, the process evolves oxygen and reduces unknown substances (electron acceptors within the chloroplasts) that are not easily removed from the chloroplasts. This substance is not carbon dioxide.

Questions for thought

1. We now know that the unknown substance receives the electrons produced in the biochemical process (i.e. the final electron acceptor in the photochemical process). What is this substance? *(You may want to scan this QR code to watch an animation if you are not sure about the process in the photochemical reaction.)*

Teachers can insert a QR code that shows an animation from readily available resources such as the textbook publisher.

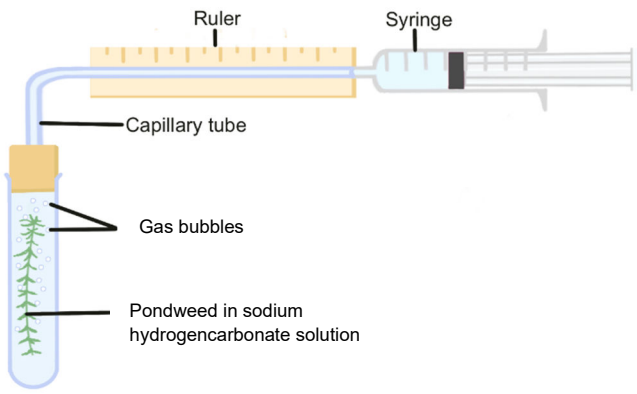
The reading material includes an animation to consolidate student learning of the relevant science concepts.

Source 2: Measuring the rate of photosynthesis

Several methods can be used to measure the rate of photosynthesis.

Method 1: Measursuring the rate of oxygen release

Oxygen is produced during photosynthesis. The rate of photosynthesis of pondweed can be measured by placing the pondweed in sodium hydrogencarbonate solution and illuminating it with light. The oxygen released is collected with a capillary tube. The photosynthetic activity can be calculated from the amount of gas released over a certain period of time.



Method 2: Measuring the rate of photochemical reaction

In photochemical reactions, electrons are generated from water under light illumination. DCPIP (2,6-dichlorophenol indophenol), a blue dye, can act as an artificial electron acceptor and becomes colourless when reduced (i.e., when it accepts electrons). When DCPIP is added to isolated chloroplasts, it is reduced by the electrons produced in the photochemical reaction of photosynthesis when the chloroplasts are illuminated. The higher the rate of photochemical reactions, the higher the rate at which DCPIP is reduced and turns colourless. The time it takes for the blue DCPIP to decolourise can be used to calculate photosynthetic activity.

Scan the *QR code* to see the action of DCPIP on isolated chloroplasts under light illumination.

The video provides conceptual assistance to understanding experimental design.

Method 3: Measuring the rate of increase in dry mass

Photosynthesis produces carbohydrates, which lead to a gain in the mass of the plant. This method involves 'serial harvests', in which several plants are harvested and dried to constant mass and then weighed. This is repeated several times over a certain period. The increase in dry mass of the plants at different harvest times allow for the calculation of photosynthetic activity.

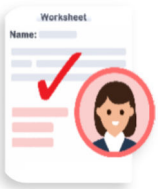
Questions for thought

1. Respiration occurs all the time in plants. Which of the above method(s) measure(s) the balance between the rate of photosynthesis and the rate of respiration? Briefly explain your choice.

Method(s):

Your explanation:

Student Worksheet 2



Notes for teachers

- Teachers can provide feedback on student responses in *Worksheet 1* if necessary.
- Teachers can then distribute *Worksheet 2* and instruct students to design the investigation.
- Teachers can show students the materials and apparatuses to facilitate their design. See the *Supplementary Resource section* for a list of materials.
- Some student work samples are shown below to illustrate possible student thinking.

Task 2

- Answer the questions that follow.

1. You are given the following information:

Investigation question:

"What is the effect of light intensity on the rate of photosynthesis of wheatgrass?"

Materials and apparatus:

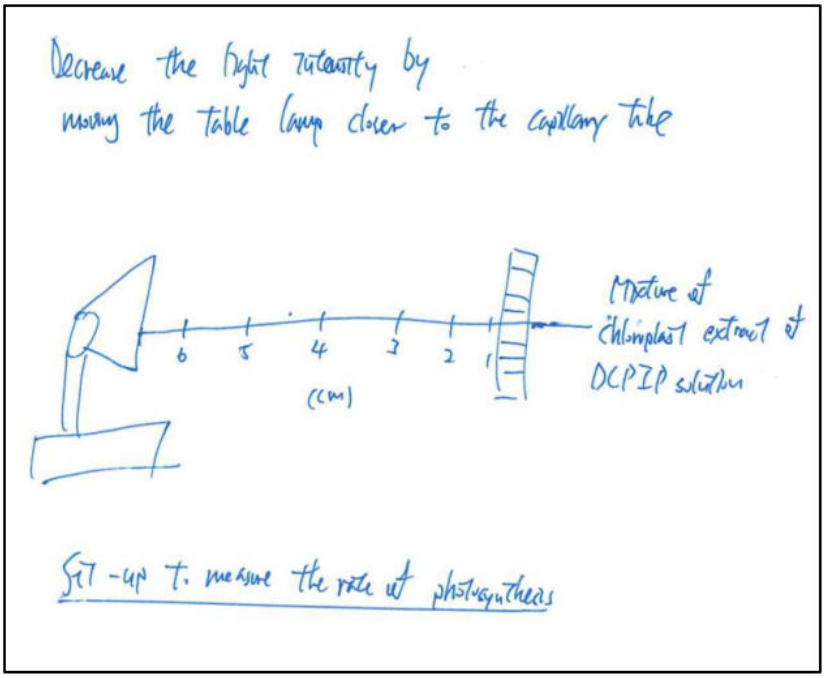
DCPIP solution	Wheatgrass chloroplast extract	Capillary tubes
Table lamp	Aluminium foil	Timer
LED light bulb (White)	Ruler	Ice-bath
Autopipette tip	Micropipette	White tile
Camera		

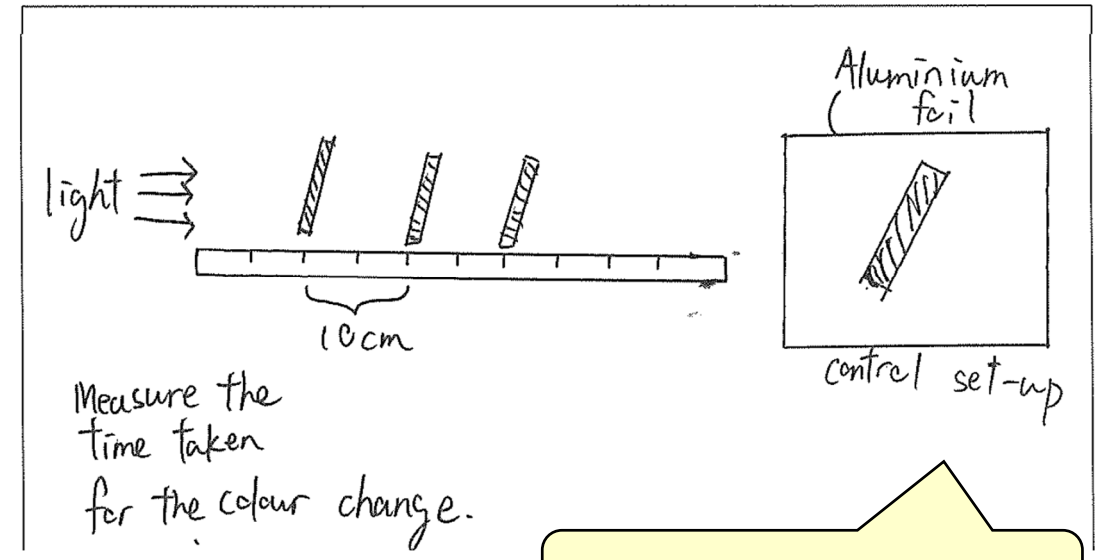
(a) Briefly describe how you would use the materials to design an investigate to achieve the aim. Draw your experimental design in the box below.

Students are allowed to draw *and* explain their design decisions.

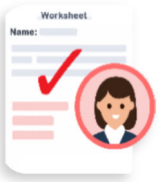
Students designed a related experiment and explained their design decisions.

Examples of students' experimental designs



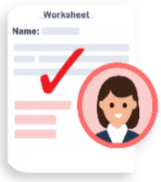


Students receive feedback on their design of a related experiment during class discussion.



Notes for teachers

- Teachers can choose some students' diagrams (anonymised) of experimental set-ups for students to evaluate.
- Teachers can discuss students the following ideas such as how students manipulate the independent variable, whether replicates are set up, whether controls are needed, position of the table lamp.



Notes for teachers

- After receiving feedback on their experimental designs, the following shows the main investigation context for students to work on.
- There are some questions that teachers may use to guide students in thinking about and assessing the scientific inquiry skills related to their experimental designs
- Some student work samples are shown below to illustrate possible student thinking.

Task 3

Scenario

Cat grass is a mixture of grasses grown from seeds, such as wheat, barley, oats, and rye. Cat grass is safer for cats to eat than outdoor grass, which may have been treated with pesticides. Cat grass is also a rich source of vitamins, minerals, and dietary fibres.

Wheatgrass is a type of cat grass that is commonly grown indoors. Wheatgrass seeds are sown in moist soil. After germination, artificial light, such as light-emitting diode (LED) lamps, are used to supply light for the seedlings to grow. Wheatgrass is ready for cats to eat around 2 weeks after germination.

In this investigation, you would like to study the effect of different wavelengths of light from LED lamps on the rate of wheatgrass photosynthesis. This information is important for determining the light conditions that maximise the growth of cat grass.

Source: https://www.amazon.com/Cat-Planter-Hairball-Digestive-Manufactured/dp/B01JNI9W9E

Design of investigation

Investigation question:

"What is the effect of different wavelengths of light from LED lamps on the rate of photosynthesis of wheatgrass?"

Students designed another experiment individually after the whole class discussion.

Materials and apparatus:

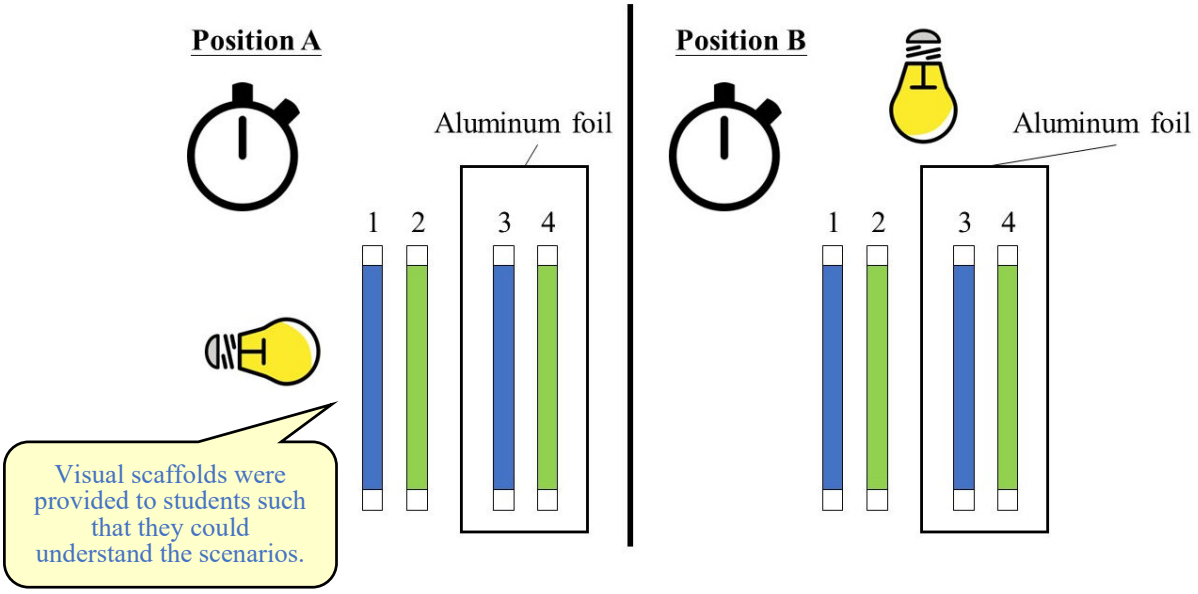
- You are given the following materials and apparatus:

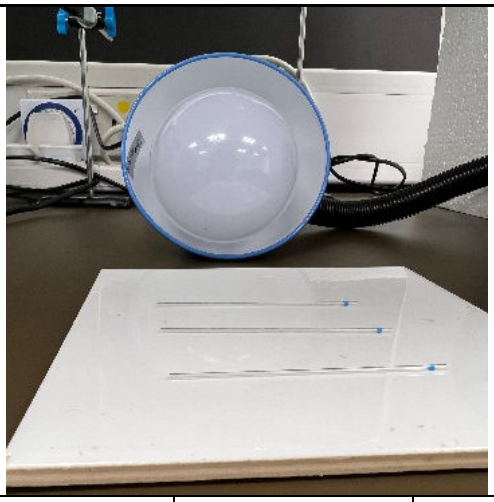
DCPIP solution	Wheatgrass chloroplast extract	Capillary tubes
Table lamp	Aluminium foil	Timer
LED light bulb of different colours (Red, Green, Blue, White)	Ruler	Ice-bath
Autopipette tip	Autopipette	White tile
Camera		

Possible questions

1. Your teacher suggests that you should use the following set-ups, but you are not sure in which position you should place the light source (see the diagrams and photos below).

Position A *(lamp placed horizontally)*	**Position B** *(lamp placed vertically above the capillary tubes)*





	Tube 1	**Tube 2**	**Tube 3**	**Tube 4**
Chloroplast extract	✓	✓	✓	✓
DCPIP	✓		✓	
Distilled water		✓		✓
Light	✓			

(a) In which position (A or B) would you put the light source? Why?

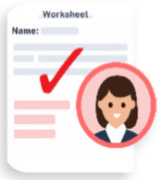
Position (Put a '✓' into the correct box)	**Reason**
☐ A ☐ B	

2. Johnny claims that the DCPIP solution would be reduced by other substances in the chloroplast extract.

   Examining which tube (1, 2, 3, 4) would allow Johnny to verify his claims? Why?

3. Suggest *one* way you could modify the set-up to reduce measurement errors. Explain why the modification would reduce measurement errors.

How to reduce measurement error	**Explanation of why this would reduce measurement error**

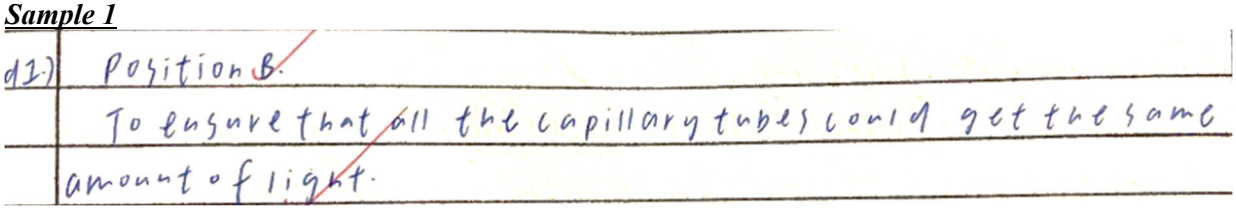


Notes for teachers

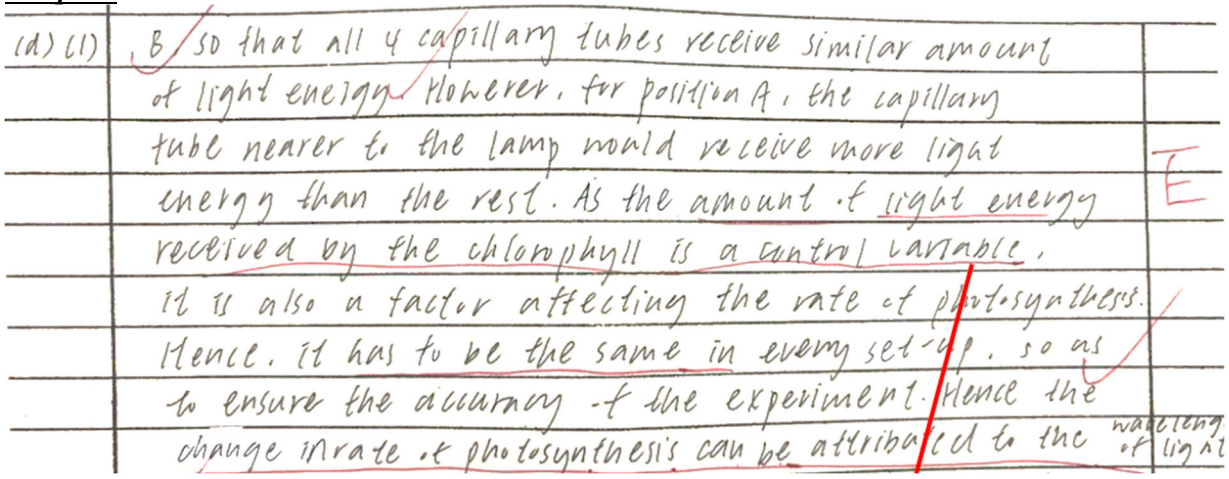
- Q.1(a) assesses students' understanding of control variables. Placing the light bulb in position B ensures that all the tubes receive uniform light illumination. It is important to control the amount of light received as it can influence the rate of the Hill reaction.
- Q.1(b) assesses students' understanding of control set-up. If the DCPIP solution is reduced by other substances in the chloroplast extract, the DCPIP solution would lose colour in tube 3 even without light illumination.
- Q.1(c) assesses students' understanding of strategies to reduce measurement errors.

The following are some examples of students' responses to Q.1:

Sample 1



Sample 2

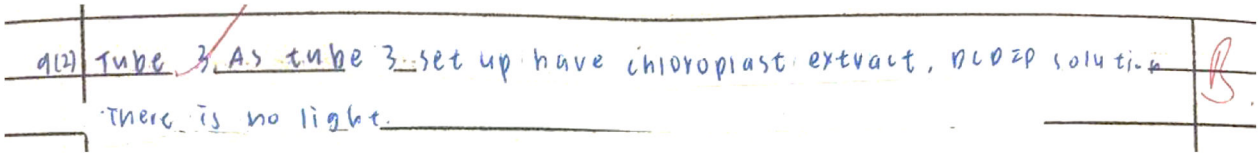


About the samples

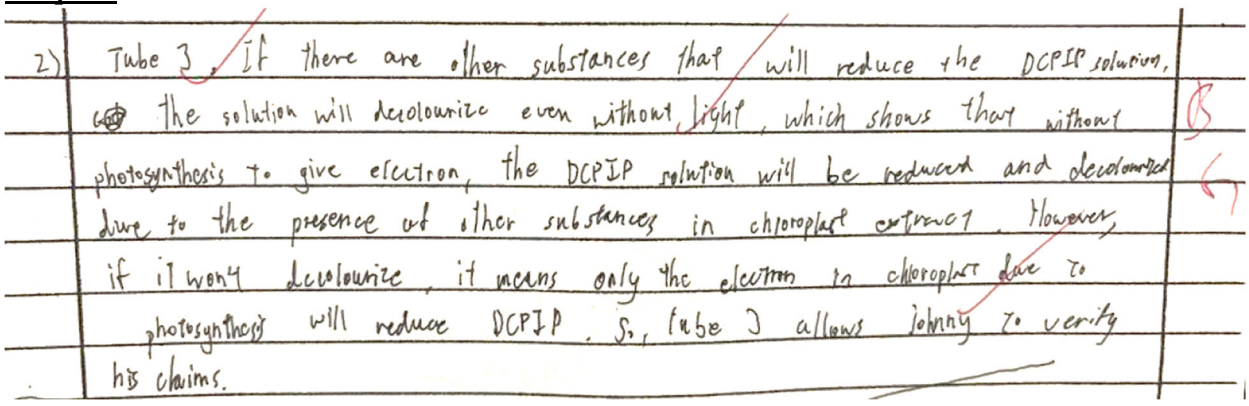
- Both samples identified the correct lamp position and the importance of ensuring that all the capillary tubes receive the same amount of light illumination.
- Sample 2 additionally identifies light as a control variable which is a factor affecting photosynthesis (the variable to be measured).

The following are some examples of students' responses to Q.2:

Sample 1



Sample 2

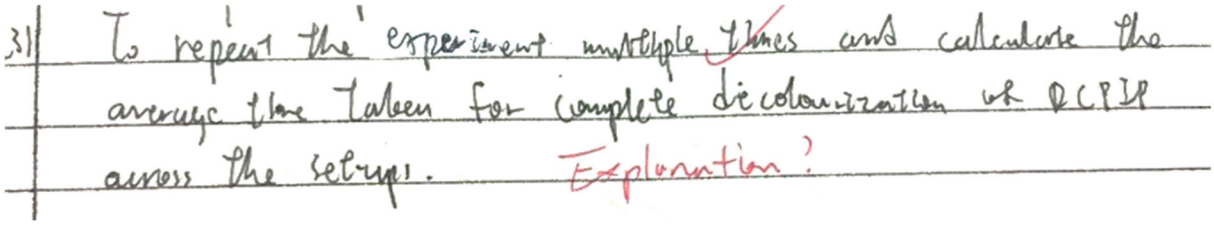


About the samples

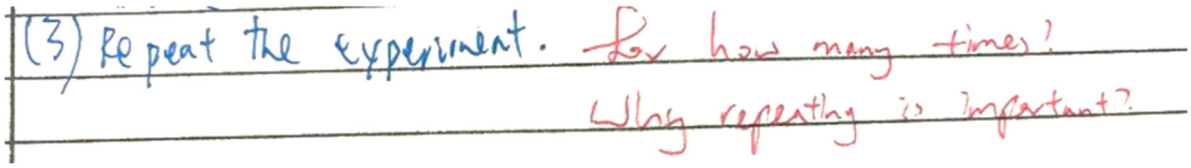
- Both samples identified the correct tube.
- Sample 2 provides a full explanation of the function of this tube.

The following are some examples of students' responses to Q.3:

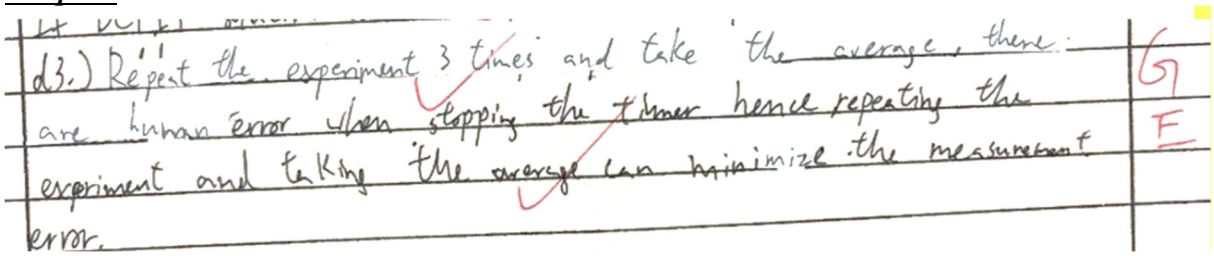
Sample 1



Sample 2



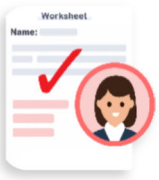
Sample 3



About the samples

- All the samples identified a strategy (i.e., repeating the experiment). However, how repeating the experiment can reduce the impact of measurement errors is only explained in Sample 3.
- Students often have difficulties in explaining why repeating an experiment/measurement can reduce the impact of random errors.

Laboratory Manual



Notes for teachers

- It is suggested that chloroplast extract is prepared for students. If appropriate, students may be asked to perform chloroplast extraction. See the *Supplementary Resource* for the relevant procedures.
- Each group is asked to collect data on two light colours (i.e., white and red, blue and red, white and green, and blue and green). Class data are shared.
- Teachers can distribute the manual for students to read and prepare before the investigation.
- Teachers can ask questions to check if students fully understand the procedures.
- The *Supplementary Resource* section contains the list of materials.
- Scan the QR code to view the process of the experiment.

Task 4

- Read the following procedures to carry out the investigation.

Procedure

1. Place a table lamp with a light bulb 5 cm above a white tile (do not turn it on yet).
2. Use a micropipette to transfer 50 µL of chloroplast extract into a capillary tube (reference tube).
3. Place the capillary tube under the table lamp.
4. Transfer 50 µL of chloroplast extract with DCPIP into a capillary tube.
5. Repeat *Step 4* three times (i.e., 4 tubes containing chloroplast extract with DCPIP).
6. Wrap one capillary tube with aluminium foil (control tube).
7. Place the four tubes next to the control tube under the table lamp (see *Figure 1*).
8. Turn on the lamp (white), and start the timer.
9. Record the time (*t*) taken for the colour of each tube to match the colour of the reference tube in the table below. (As the colour of the tube contents is difficult to see under the coloured lights, the remote is used to switch the coloured bulb to 'white' for 1 second every 60 second to check the colour matching.)

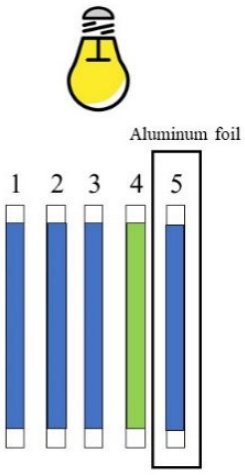
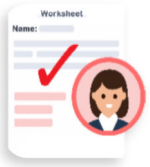


Figure 1

10. Repeat the above steps for the other colour (red) of light bulb by switching the controller.
11. Record the time for *each* of the experimental tubes (tubes 1, 2, and 3) to change the colour.
12. Calculate the average time for colour change and the average rate of colour change (1/average time for colour change). (If no colour change occurs after 20 minutes, record '>1200' and enter the rate of colour change as '0.00'.)
13. Report your group data in this *Google Sheet* by scanning the QR code.

Scan the QR code to get a copy of the *Google Sheet*.

Teacher Notes 2



Notes for teachers

- The following are possible questions that teachers can use to guide students in thinking about or assessing their scientific inquiry skills related to data analysis and interpretation.
- Student work samples are shown below to illustrate possible student thinking to Q.2.

Task 5

Possible questions

1. Which of the following claim(s) is/are supported by *the data your group obtained*? (Put a '✓' into the appropriate box(es).)

(a)	The rate of photosynthesis of the cat grass is lowest under green light.	☐
(b)	The rate of photosynthesis of the cat grass is higher under blue light than red light.	☐
(c)	The rate of photosynthesis of the cat grass is higher under white light than red light.	☐
(d)	The rate of photosynthesis of the cat grass is highest under blue light.	☐
(e)	None of the above.	☐

2. David found that the rate of photosynthesis of the cat grass is highest under white light than under the other light colours he tested (e.g., green and red). He claims that the growth of the cat grass will be highest when grown under white light.

   Do you agree with this claim? Why?

   Agree ☐
   Disagree ☐

   Explanation:

3. Propose *one* meaningful investigative question that relates to your experimental data.

Notes for teachers

- Q.1 assesses students' understanding of making valid claims based on available data and evidence.
- Q.2 assesses students' understanding of the generalisability of their conclusion.
- Q.3 assesses students' ability to generate a new investigation question that extends the present investigation.

The following are some examples of students' responses to Q.2:

Sample 1

4. David found that the rate of photosynthesis of the cat grass is highest under white light than other light colours he tested (e.g., green, red). He claims that the growth of the cat grass will be highest when grown under white light. Do you agree with this claim? Why?

Agree ☑

Disagree ☐

Explanation:

The white light combined all of the colours, so it contains all different wave lengths which the cat grass can absorb the optimum wave length for its growth

Sample 2

Those ATP can be used in Calvin cycle. More light intensity increase the rate of photosyntlesis. and release ATP.

4. David found that the rate of photosynthesis of the cat grass is highest under white light than other light colours he tested (e.g., green, red). He claims that the growth of the cat grass will be highest when grown under white light. Do you agree with this claim? Why?

Agree ☑

Disagree ☐

Explanation:

① It implies that the cat grass absorbs more under white light energy during photochemical reaction. Excited electron ~~reduced~~ pass through electron transport chain. During photochemical reaction, the

About the samples

- Both samples wrongly stated that the evidence supports the claim about the growth of the cat grass.
- The students seemed to use biological facts they know to answer the questions rather than assess the generalisability of their results by attending to the relationship between photosynthesis and plant growth.

Sample 3

4. David found that the rate of photosynthesis of the cat grass is highest under white light than other light colours he tested (e.g., green, red). He claims that the growth of the cat grass will be highest when grown under white light. Do you agree with this claim? Why?

Agree ☐

Disagree ☑

Explanation:

The growth rate of the cat grass is not only depending on the the colour of the light supply, e.g. light intensity: a green or red light with a higher light intensity will have a higher rate of photosynthesis than a white light with lower light intensity, rate

5. Propose *one* meaningful investigative question that relates to your experimental data.

Sample 4

4. David found that the rate of photosynthesis of the cat grass is highest under white light than other light colours he tested (e.g., green, red). He claims that the growth of the cat grass will be highest when grown under white light. Do you agree with this claim? Why?

Agree ☐

Disagree ☑

Explanation:

The growth rate may be affected by many other factors such as the temperature and oxygen concentration.

Sample 5

4. David found that the rate of photosynthesis of the cat grass is highest under white light than other light colours he tested (e.g., green, red). He claims that the growth of the cat grass will be highest when grown under white light. Do you agree with this claim? Why?

Agree ☐

Disagree ☑

Explanation:

Other factors also may lead the growth of cat grass for example, the rate of respiration will be different.

About the samples

- All the samples correctly stated that plant growth can also be affected by other factors.
- However, the factors identified are not entirely scientifically accurate. For example, Sample 2 identified oxygen concentration as a factor that can affect plant growth.

Supplementary Resources

Possible Modifications

1. Effect of darkness on decolourised DCPIP in chloroplast extract

- When a chloroplast extract containing DCPIP is exposed to light, the DCPIP becomes decolourised. If this decolourised extract is then placed in darkness, the blue colour of the DCPIP will gradually return.
- Teachers may ask students to explain the reason for these observations.

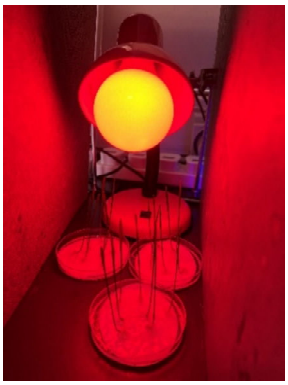
Scan the QR code to see a video.

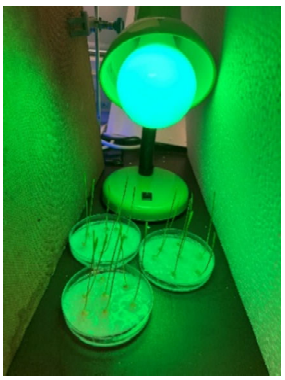
2. Investigating the mode of action of herbicides

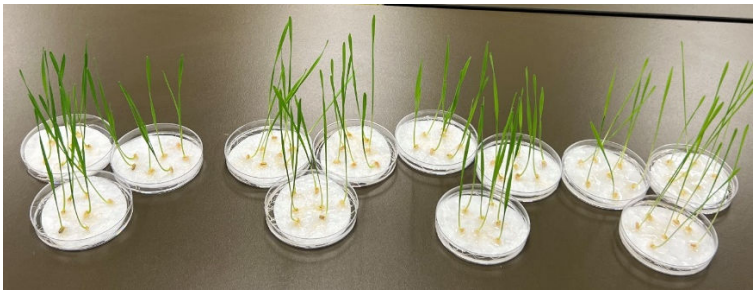
- This set-up can also be used to investigate the mode of action of herbicides (see *Photosynthesis Inhibitor Investigation*).

3. Investigating the effect of different wavelengths of light on the growth of cat grass

- The effect of different wavelengths of light on the growth of cat grass can be studied by growing cat grass seeds on moist cotton wool.
- Surface-sterilise the seeds using 20% bleach for 20 minutes and grow the seeds on moist cotton wool.
- Cat grass normally germinates within 1–2 days. Visible morphological differences between different light treatments can be seen within a week.







Technician Notes

1. Materials for Task 2

Materials for each group

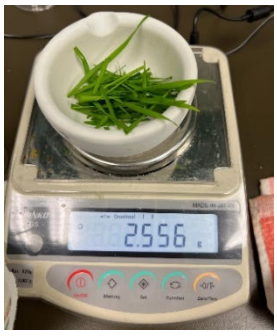
• DCPIP solution	• Wheatgrass chloroplast extract	• Capillary tubes
• Table lamp	• Aluminium foil	• Timer
• LED light bulb (White)	• Ruler	• Ice-bath
• Autopipette tip	• Autopipette	• White tile
• Camera		

		
Table lamp	LED light bulb (RGB)	Capillary tube

2. Materials for Task 4

Chemicals to be prepared

- *Extraction Buffer* (250 mL) (Dissolve 2.7 g of hydrated disodium hydrogen phosphate, 1.0 g of anhydrous potassium dihydrogen phosphate, 33 g of sucrose and 0.25 g of potassium chloride in 250 mL of distilled water. Adjust pH to 7.5. Store at 4°C refrigerator.)
- *DCPIP solution* (100 mL) (Dissolve 0.1 g of DCPIP and 0.4 g of potassium chloride in 100 mL of distilled water. *Note*: DCPIP solution should be freshly prepared prior to use.)



Extraction of chloroplasts (~30 mL)

1. Weigh 4 g spinach leaves/ 6 g cat grass leaves.
2. Cut the leaves into small pieces using a pair of scissors.
3. Add 40 cm^3 of ice-cold *Extraction Buffer* solution.
4. Add a spoonful of sand.
5. Grind the leaves using a mortar and pestle.
6. Filter the leaf extract using muslin cloth to remove leaf debris
7. Store the filtrate on an ice bath.

Trial run

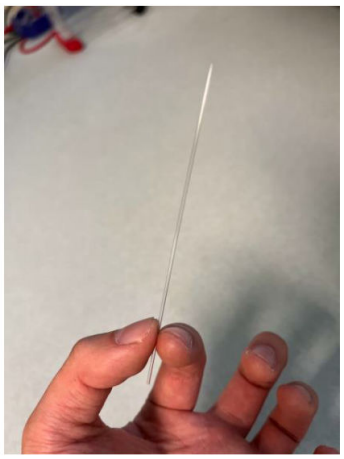
1. Add 1 mL of leaf extract to a 1.5 mL tube.
2. Add 0.15 mL 0.1% DCPIP solution to a 1.5 mL tube.

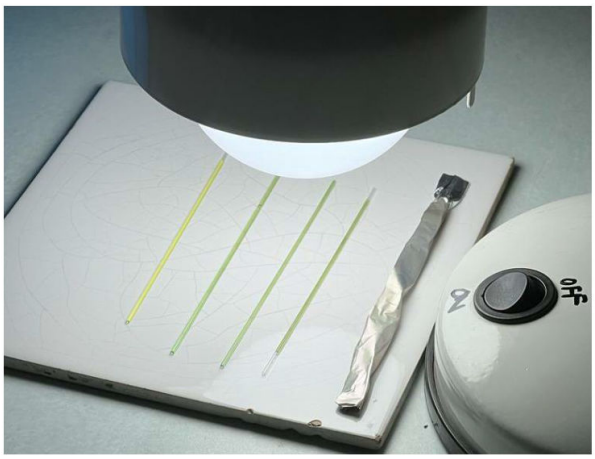
3. Trial run to see if the time for the white light to change colour is within 5 minutes. Adjust the volume of 0.25 mL 0.1% DCPIP if needed.
4. Prepare the chloroplast extract for each group
    - 1 mL chloroplast extract + distilled water
    - 1 mL chloroplast extract with DCPIP (with aluminium) + DCPIP (with the optimised volume)

Materials for each group

• *1 mL Chloroplast extract in 1.5 mL tube	• Table lamp with colour controller	• Capillary tubes X 10
• *1 mL Chloroplast extract with DCPIP in 1.5 ml tube (aluminium foil)	• LED light bulb of different colours (Red, Green, Blue, White)	• White tile
• Ice bath	• Ruler	• Timer
• Autopipette (P-200)	• Autopipette tip (P-200)	• Aluminium foil

* on ice bath





References

Spencer, R. (2018). Pitch perfect: Investigating the effects of different wavelengths of light on the rate of photosynthesis and grass growth. *School Science Review*, *100*(371), 15–20.

This project is supported by Quality Education Fund (Project No. 2019/0283)

此計劃由優質教育基金贊助 (計劃編號 2019/0283)

nnovations in Biology Investigatior

Faculty of Education
The University of Hong Kong
香港大學教育學院

優質教育基金
Quality Education Fund