Cambridge Assessment International Education

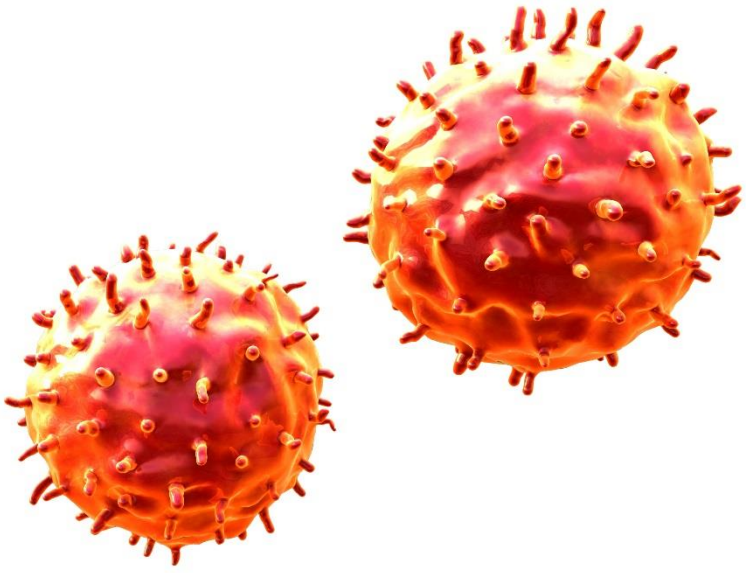
Teaching Pack

Environmental factors affecting germination

Cambridge IGCSE™

Biology 0610

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE™ (9–1) Biology **0970**
- Cambridge IGCSE™ Biology (US) **0438**
- Cambridge IGCSE™ Combined Science **0653**
- Cambridge IGCSE™ Co-ordinated Sciences (Double Award) **0654**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge O Level Biology **5090**
- Cambridge O Level Combined Science **5129**



Version 2.0

Cambridge Pathway

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

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Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

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Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Environmental factors affecting germination

This *Teaching Pack* focuses on the effect of acid rain on the germination of seedlings. The main source of acid rain is the burning of fossil fuels: sulfur and nitrogen oxides released into the air combine with water and fall as acid rain. This pack could be linked to the discussion of the sources and effects of pollution, particularly the negatives associated with burning fossil fuels.

Important note
The effects on the environment of acid rain is Supplementary syllabus content. However, the focus of the pack is to develop the skills of planning, making observations and measurements, regardless of the context. Therefore, the pack can be used for learners following both the Core and Extended syllabuses.

The experiment has links to the following syllabus content (see syllabus for detail):

- 20.3 Pollution

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- plan experiments and investigations, and select appropriate equipment
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 20.3 Pollution

Going forward

The knowledge and skills gained from this experiment will be useful when you teach conservation.

Briefing lesson: Observations, measurements & planning

Resources	• Worksheets A,B, C and D
Learning objectives	By the end of the lesson: • ***all*** learners should be able to define key terms relating to data and variables, such as estimate, measure, dependent and independent. • ***most*** learners should be able to suggest what data could be gathered in an investigation and how this could be measured. • ***some*** learners will be able to evaluate the suitability of different methods of data collection.

Timings	Activity
10 min 5 min	**Starter/introduction** Give pairs of learners Worksheet A. Ask them to match each key word to its meaning. They should have encountered these words before. However, learners often struggle to remember the definitions of the different types of variable (control, dependent and independent). For support, show them an example. To assess understanding, pairs take it in turns to suggest the meaning of a word. Discuss answers as a class and learners mark their own work, correcting any answers they got wrong. Make sure that any misconceptions are resolved before moving on to the main lesson.
10 min 5 min	**Main lesson** Arrange learners into groups of 2–4; consider putting learners in larger groups for support or in smaller groups to challenge their thinking. Give each learner Worksheet B and Worksheet C. Ask them to review the lab scene on Worksheet B and identify as many examples linking to the key words on Worksheet C, as they can (so, what could be measured, what could be observed and so on, what could be used to calculate a mean, etc.). They should have their corrected Worksheet A next to them for reference. If support is required, you could write the following example for 'Estimate' on Worksheet C before making the copies: *The volume of liquid in the bottles A, B and C could be estimated: A is half full, B is one quarter full, and C is one third full.* Circulate the room to review what learners are doing and give hints or suggestions. For example, the ruler on the desk could be used to *measure* length; the different species of fish in the tank could be an example of a *dependent variable*. Review learners' ideas as a class. This could be done per group, with learners nominating a speaker. Discussions should arise as to what could be estimated, what can be observed and what could be measured. Interesting points should be discussed further to consolidate understanding of the key terms when planning an investigation. *Continues on next page …*

Timings	Activity
	***Main lesson continued …*** Still in their groups of 2–4, give each learner Worksheet D. Ask them to read the two scenarios and identify the type of data that could be collected; how it could be collected; if estimations are appropriate rather than exact measurements; and what equipment would be needed. This gives learners an opportunity to discuss what data could be collected and should strengthen their ability to identify quantitative and qualitative data. Allow 5 minutes to review the learners' answers. Groups could be put together so that learners can swap and discuss their ideas. Circulate the room during this task to check that learners have used as many key words from Worksheet A as possible. Correct any misconceptions.
	**Plenary** Learners feedback to the whole class on their group discussions. This gives an opportunity to discuss their chosen method of data recording and measurement. Encourage learners to evaluate their peer's suggested methods during the discussion. Use prompts such as "*What do you think of how they chose to do that?*", or "*Would that work well, could it be improved?*"; This will help learners to reflect on the task. Make sure the discussion includes when it is appropriate to make estimates rather than exact measurements, as this will be covered in the practical lesson.

Lab lesson: Option 1 – run the experiment (Part 1)

Note that due to a germination period of 5 days, this lesson will run over two sessions.

Resources	• Worksheets E, F and G • *Teacher walkthrough* video, *Teacher method (Part 1), Teacher notes (Part 1)* • Equipment as outlined in the *Teacher notes (Part 1)*
Learning objectives	By the end of the lesson: • ***all*** learners should be able to identify the variables in an investigation, and suggest how to measure or control them. • ***most*** learners should be able to plan and conduct an investigation. • ***some*** learners will be able to design a table to record the measurements to be made in an investigation.

Timings	Activity
10 min	**Starter/introduction** Before the start of the lesson, lay out all the required equipment for the experiment on a trolley or a table at the front of the room. Pause the *Virtual experiment* video on the photo of the germinating seed. Ask learners to stand around the table/trolley and tell them that they are going to investigate the effect of acid rain, a form of pollution, on the germination of seeds and you want them to think how they would do it using the equipment they can see. (The planning activity takes place in the main part of the lesson.) Make sure they understand what is meant by acid rain and germination. You might find it helpful to show the image from the *Virtual experiment* video. Although this isn't a cress seed, it can help to remind learners that germination is a process of growth, and not a fixed state. This should help them think about what they might look for when investigating the *effect* on germination. Have a quick discussion of initial ideas of how to investigate the brief. This gives you the opportunity to check and guide their ideas.
20 min	**Main lesson** Arrange learners into groups of 2–4 and each give each learner Worksheet E to support their planning. Learners return to their tables to carry out the task using the equipment they can see on the table/trolley as guidance. Make sure learners understand that 0.1 M, 0.5 M and 1 M represent the concentration of the acids, and clarify the meaning of a lower concentration as 'a weaker acid' in terms of pH. Tell them to answer questions 1–3 and then stop. Review answers to the questions: individuals put their hands up to answer and learners then discuss as a class. Agree on the 'correct' answers and learners amend their answers on Worksheet E accordingly. *Continues on next page …*

Timings	Activity
15 min	**Main lesson continued …** Give learners Worksheet F and Worksheet G and tell them they will now carry out the experiment in their groups following the method given on Worksheet F. Give them a few minutes to read each step, then discuss as a class the importance of health and safety by going through the following risk assessment on the board.

Risk	Hazard	Prevention
Acid	Could be spilt onto skin, clothes or get into the eyes, and cause burns or irritation.	Take care when using the acid not to spill it. Tell the teacher immediately if spillage does occur. Wear eye protection. Wear lab coats if available. Wash hands after the experiment.

Run through the method as a class to check that learners understand what is required. You could challenge some learners to compare their suggested method with that of Worksheet F. They could discuss what the strengths and weakness of each method and whether they think there will be a difference in the data collected.

Learners are now ready to start the experiment. Make sure they collect their eye protection first.

Safety

Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.

As you circulate, ask questions and guide discussions (see notes in the *Teacher method*).

Explain to the learners that they will look at the samples again after five days, and that over the next five days you will routinely add distilled water to each sample so that a lack of water isn't a variable that effects growth.

10 min

Once they have finished the experiment, they can answer the rest of the questions (4–8) on Worksheet E.

5 min	**Plenary** Ask learners to form a hypothesis of what they will see after five days based on what they know about the effect of pollution on the environment. They could describe what they might see in the control versus the other samples.

Teacher notes (Part 1)

Watch the *Teacher walkthrough* video and read these notes. Note that this part of the experiment runs until the Petri dishes are put into the window sill in the video.

Each group will require:

- approximately 60 cress seeds
- Petri dishes × 4
- circular filter paper × 4 (to fit base of Petri dish)
- distilled water
- 0.1 Molar (M) Hydrochloric acid* (HC*l*)
- 0.5 M HC*l*
- 1 M HC*l*
- dropping pipettes × 3
- adhesive tape
- eye protection
- glassware pen or sticky labels and pen

*Sulfuric acid could be used instead of Hydrochloric acid if you trust your learners to use it. Here, we describe the method using HC*l*. Only adapt the method to include sulfuric acid following a suitable risk assessment.

Safety

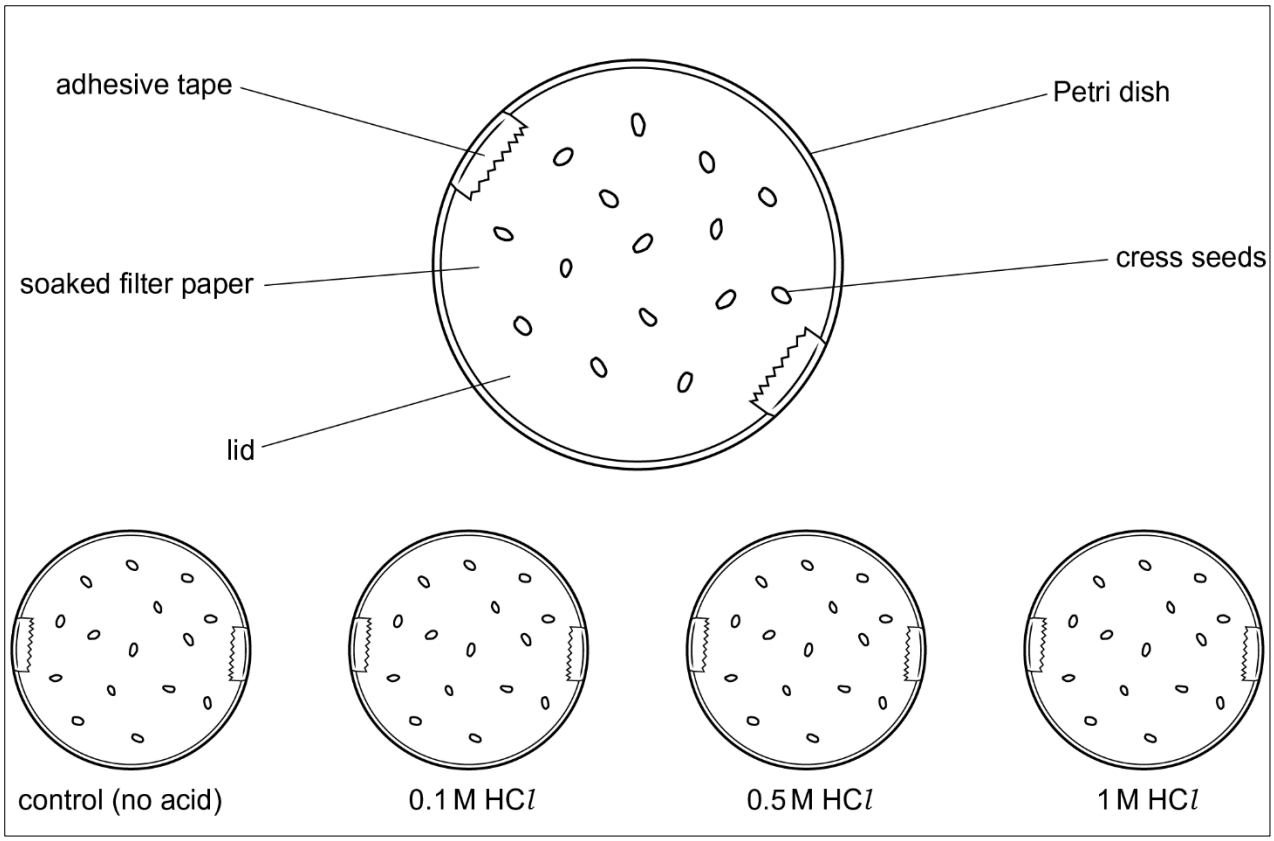
The information in the table overleaf is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Variations to this experiment can be used at your discretion depending on the ability of the groups. **Risk assessments should be completed for any adaptations.**

Substance	Hazard	First aid
Hydrochloric acid [2.0 mol/dm^3]	 GHS07 (*moderate hazard* **MH**)	**In the eye:** Flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** Remove to fresh air. See a doctor if breathing becomes difficult. **Swallowed:** Wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** Remove contaminated clothing, then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** For release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.
Dilute hydrochloric acid [0.1 mol/dm^3] [0.5 mol/dm^3] [1.0 mol/dm^3]	 GHS07 (*moderate hazard* **MH**)	**In the eye:** Flood the eye with gently-running tap water for 10 min. See a doctor. **Vapour breathed in:** Remove to fresh air. See a doctor if breathing becomes difficult. **Swallowed:** Wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Spilt on the skin or clothing:** Remove contaminated clothing, then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** For release of gas, consider the need to evacuate the lab and open all windows. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into a bucket. Neutralise with sodium carbonate. Rinse with plenty of water. Wipe up small amounts with a damp cloth and rinse it well.
Plants, fungi and seeds	IRRITANT  **GHS06 (*acutely toxic* T)**	**Skin rash from irritant plants:** Cool the affected area with cold water (if available) and cover with a sterile dressing. You might self-medicate by rubbing a nettle sting (acidic) with a dock leaf (alkaline).

Experiment set-up (Part 1)



Teacher method (Part 1)

This is your version of the method for the first part of the experiment.

Do not share this method with learners. Give them Worksheet F.

Before you begin
Plan how you will group your learners during the experiment session.

Think about:
- the number of groups you will need (group size 2–4 learners)
- the amount of equipment / chemicals required
- if you want apparatus already provided on tables, or at the front of the class
- decide where the Petri dishes will be left for the five-day germination period.

During the experiment
Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes
1. Learners collect the equipment they need from the front of the class.	*Remind them to carry the acid carefully.*
2. They place a piece of filter paper into each Petri dish.	
3. Learners count out 15 cress seeds.	*You can use other numbers of seeds, but they must be the same in each sample.*
4. They scatter the cress seeds onto the filter paper in one of the Petri dishes.	*Encourage learners to scatter them so that the available space is used as much as possible, rather than all in one area.*
5. Learners then soak the filer paper with distilled water. They should note down the volume of water used as this might vary from group to group. The same volume of water should be added to each sample.	*Soaking a typical size Petri dish should take approximately 5–10 drops or 2–3cm^3 but it might take more/less. Make sure learners read the volume off the pipette accurately.*
6. They add a lid and use two small pieces of tape to seal the lid on two sides. They should make sure the tape does not obscure the contents of the dish.	*Remind learners not to seal the lid all the way around as they need to let oxygen get in.*

Step	Notes
7. This needs to be labelled at the edge of the dish as the control. 'C' is sufficient. They should not obscure the contents of the dish with the label.	
8. Learners need to soak the filter paper of the other Petri dishes with the same amount of acid as distilled water was used in the control.	*Reassure learners that it doesn't matter how much they've added, so long as they used the same amount for each sample.*
9. Then they repeat the process of adding the filter paper, soaking it, scattering seeds, covering, sealing for 0.1M, 0.5M and 1M HCl.	*Remind them that once the filter paper has acid on it, they should not touch the filter paper with their bare hands.*
10. They need to label each dish appropriately.	
11. Learners need to put their four samples in the agreed place. Explain that the cress seeds need to be put in light conditions with a mild temperature, around 21°C, in order to grow. Ask them where they think they should be stored.	*Near the window works well provided it does not get too cold.*
12. Explain to the learners that over the next five days you (not them) will routinely add distilled water to each sample so that a lack of water isn't a limiting factor on growth.	*Add the same volume of water to each sample, including the control. Five drops added on or around day 3 would be sufficient if conditions are 20–26°C. If the temperature is > 26°C, then the samples might need watering twice before the day 5 review. Use your discretion.*
13. Growth should be reviewed over time by you or a technician to make sure that some of the samples are growing.	*The samples may need to be moved to a warmer location, or be watered more regularly, if growth does not occur as expected.*

Clean-up

After the experiment learners should:

- make you are aware of any acid spillages (**you** should clean them up not the learners)
- return all equipment and any unused chemicals to you
- tidy up their work space
- ensure they have cleared up any water spillages
- wash their hands thoroughly.

Lab lesson: Option 1 – run the experiment (Part 2)

This lesson should be run about five days after Part 1.

Resources	• Worksheets H, I, J(1), J(2) and K • *Teacher walkthrough* video, *Teacher method (Part 2), Teacher notes (Part 2)* • Equipment as outlined in the *Teacher notes (Part 2)*
Learning objectives	By the end of the lesson: • ***all*** learners should be able to collect quantitative and qualitative data. • ***most*** learners should be able to make estimations. • ***some*** learners will be able to interpret their findings based upon their data collections.

Timings	Activity
10 min	**Starter/introduction** Arrange learners into groups (2–4) as before. They collect their samples. Explain that they cannot measure the length of each shoot precisely due to the safety risks of touching seedlings in the acid solutions. Set the following discussion: *The length of the seedlings will be estimated rather than recorded accurately. Is this an appropriate level of accuracy for this investigation?'* Make sure learners understand that this level of accuracy is appropriate as the aim of the experiment is to determine if there is a *general* relationship between acidic conditions and the effect on growth. A general trend is enough to understand how acid rain and other pollution might affect plants in the real world, so more precision is not required. Also, they can't measure exactly due to safety implications of handling seedlings grown in acids. Explain that length ranges will be used and the number of seedlings within each range will be recorded. Ask why they might do this, and how they could estimate length into a range.
10 min	**Main lesson** Remind learners that they need to: count the number of germinated seeds; estimate the length of the seedlings; and observe the appearance of the seeds and seedlings. Discuss and agree as a class, how they will determine if a seed has germinated (e.g., tip of shoot is visible) and which part of the seedling gets measured (e.g. shoot). Demonstrate how to estimate the shoot length at the front of the class. Explain that they place the ruler on the lid and use this as a guide to help them estimate the shoot length by measuring from the point where the shoot emerges from the seed coat to the tip of the shoot. Make sure they understand that this is an estimate and not a measurement because it is a rough approximation of the length rather than an exact reading. Explain that they will add a tally in a given length range for each seedling. A seedling can only be recorded in one range; ask why. The length of the seedlings in a sample will be recorded as the range with the highest tally. Discuss the accuracy of this and if it's appropriate. Establish that this is appropriate as it will show the range in which the most growth occurred and is enough for the general trend they are looking at. (However, discussions could occur on improving the accuracy by repeating the experiment three times to calculate a mean.) *Continues on next page …*

Timings	Activity
30 min	**Main lesson continued …** **Before** the lesson, review the growth of the class samples and if necessary, adjust the length ranges provided on Worksheet J(1). Give learners the Worksheet H (the method), Worksheet I (experiment set-up) and either Worksheet J(1) or Worksheet J(2). Learners record their observations and data on the appropriate version of Worksheet J: challenge more able learners to use Worksheet J(2) where they have to choose their own length ranges. They are asked to do this according to their observations of the seedlings they have. They should look at the lengths in each sample and make approximate ranges that would fit. Remind them that they are looking at the length of seedlings and so are only looking at germinated seeds; a seedling with shoot length of 0 mm is a seed that hasn't germinated and so this cannot be included in the range. Learners will need to review all samples to decide upon suitable ranges of growth. This could be a discussion point when reviewing this with learners. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. Remind learners **not** to remove the lids and **not** to touch the contents inside; they must be wearing eye protection and should wash their hands with running water and soap when they have finished. Learners should start with the control sample and then move on to their other samples. Once they have finished collecting their results, ask them to summarise them into the table on Worksheet K. Ask learners to refer back to their method on Worksheet E. Now they have done the experiment, how does their method compare? Are there any similarities? Is there anything that they would do differently?
10 min	**Plenary** Ask learners to evaluate the method for the experiment. Has it enabled them to investigate the impact of acid rain on seed germination? Give learners a minute to think about their answer and then do a class assessment by asking them to put their hands up if they think: (1) this method will give valid data; or (2) this method will not give valid data. Learners could be further prompted to explain and justify their views. Learners could be challenged to suggest how they could improve the method.

Teacher notes (Part 2)

Watch the *Teacher walkthrough* video and read these notes.

Each group will require:

- small ruler (15 cm)
- mounted needle (to help with counting)
- paper towels
- access to a running water and soap

Safety

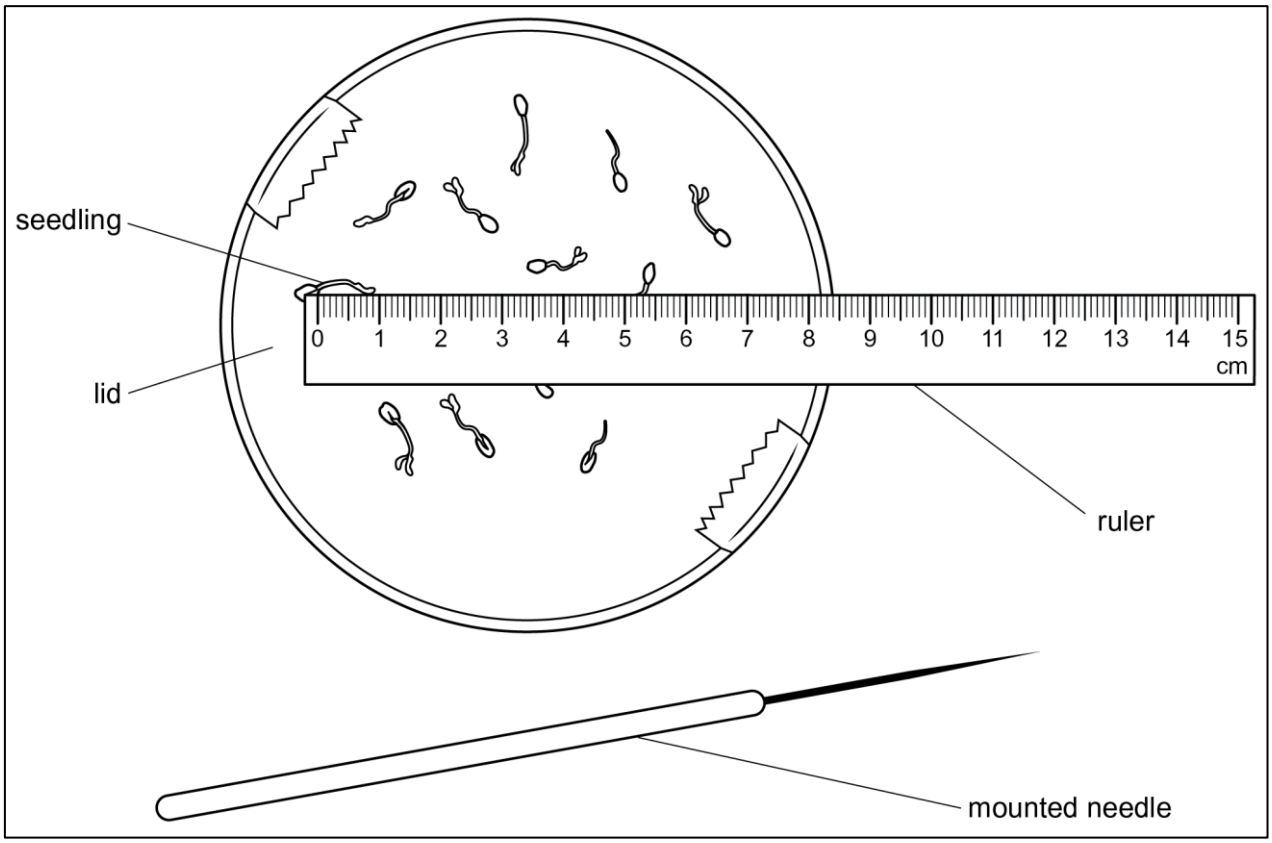
The information in the table on page 11 is a summary of the key points you should consider before undertaking this experiment with your learners.

As a safety precaution, learners **must not**:

1 remove the lids of the Petri dishes when counting and measuring the cress seedlings
2 touch the filter paper or cress seedlings that have been in the acidic solutions
3 use their own rulers for measuring.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Experiment set-up (Part 2)



Teacher method (Part 2)

This is your version of the method for Part 2 of this experiment. Do not share this method with learners. Give them Worksheet H.

Before you begin
Decide if you will get the learners to collect their samples or if it is safer to have them set out in the learners' work space already.

During the experiment
Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes
1. Review the samples periodically before conducting this lesson to check that the samples are growing; add water or change conditions if required.	*The controls should have established shoots after five days. There should also be some germination in the samples with the lower concentration acids.*
2. Check that the growth of seedlings would fit into the suggested ranges of: 0 to 1 mm (includes > 0 and ⩽ 1) 1 to 5 mm (includes > 1 and ⩽ 5) 5 to 10 mm (includes > 5 and ⩽ 10) 10 to 15 mm (includes > 10 and ⩽ 15) > 15 mm	*You may have to adjust these ranges on Worksheet J(1) according to the growth seen in the class samples. Make sure learners understand the ranges and what is meant by the symbols > and ⩽.*
3. Ask learners to collect their Petri dishes if you have not already laid them out on their work space.	*Decide on the safest approach for your class; it might be appropriate to minimise learner handling of the Petri dishes.*
4. Direct learners to record their observations and data on Worksheet J(1) or Worksheet J(2), depending on their capabilities. More able learners should use Worksheet J(2).	*Learners should not touch the filter paper or cress seeds with their hands. Learners might need help to estimate the length of the shoots.*
5. Invite feedback from the class as to what they have observed and recorded. This could be collected onto the board.	*A possible extension task could be to compare data with other learners.*

Clean-up
After the experiment learners should:

- put their equipment back onto a trolley to be cleaned by the technician
- tidy up their work space
- wash their hands thoroughly using hand wash.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual experiment* video • Worksheets E, J(1) and J(2), K and L
Learning objectives	By the end of the lesson: • ***all*** learners should be able to collect qualitative and quantitative data. • ***most*** learners should be able to make estimations. • ***some*** learners will be able to interpret their findings based upon their data collections.

Timings	Activity
10 min	**Starter/introduction** Tell learners that they are going to investigate the effect of acid rain, a form of pollution, on the germination of seeds and you want them to plan how they might do it. Explain that you will watch part of a video first to make sure they understand what is meant by acid rain and germination. Play the video until it reaches an automatic pause on the Equipment shot. Although the photo of germination in the video isn't of a cress seed, it can help to remind learners that germination is a process of growth, and not a fixed state. This should help them think about what they might look for when investigating the *effect* on germination. Have a quick discussion of initial ideas of how to investigate the brief. This gives you the opportunity to check and guide their ideas.
10 min 5 min	**Main lesson** Arrange learners into groups of 2–4 and show them the equipment on the video. Explain that they will use this along with Worksheet E to support their planning. Ask them to answer questions 1–3 on the worksheet and then stop. Review answers to the questions: individuals put their hands up to answer and learners then discuss as a class. Agree on the 'correct' answers and learners amend their answers on Worksheet E accordingly. Discuss as a class, the importance of health and safety if they were to carry out the experiment themselves, by going through the following risk assessment.

Hazard	Risk	Prevention
Acid	Could be spilt onto skin, clothes or get into the eyes, and cause burns or irritation.	Take care when using the acid not to spill it. Tell the teacher immediately if spillage does occur. Wear eye protection. Wear lab coats if available. Wash hands after the practical.

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Timings	Activity
10 min	**Main lesson continued …** Resume play of the video; it will show someone carrying out the experiment and then will pause automatically before the results are shown. Ask learners to form a hypothesis of what they will see after five days based on what they know about the effect of pollution. They could describe the control versus the other samples. Remind learners that they need to: count the number of germinated seeds; estimate the length of the seedlings; and observe the appearance of the seeds and seedlings. Discuss and agree as a class, how they will determine if a seed has germinated (e.g., tip of shoot is visible) and which part of the seedling gets measured (e.g. shoot). Explain that if they were doing the experiment, they could not measure the length of each shoot precisely due to the safety risks of touching seedlings in the acid solutions. Display Worksheet L for the whole class to see and demonstrate how to estimate the shoot length. Explain that they place the ruler on the photo and use this as a guide to help them estimate the shoot length by measuring from the point where the shoot emerges from the seed coat to the tip of the shoot. Make sure they understand that this is an estimate and not a measurement because it is a rough approximation of the length rather than an exact reading. Set the following discussion: *Is estimating the length of the seedlings an appropriate level of accuracy for this investigation?'* Make sure learners agree that it is. The aim of the experiment is to determine if there is a *general* relationship between acidic conditions and the effect on growth. A general trend is enough to understand how it might apply to plants in the real world, so measuring the precise growth in each seedling is not necessary. Explain length ranges will be used. Ask why they might do this, and how they might do this. Explain that they will add a tally in a given length range for each seedling. A seedling can only be recorded in one range; ask them why. The overall length of the seedlings in a sample will be recorded as the range with the highest tally. Discuss the accuracy of this and if it's appropriate. Establish that this is appropriate as it will show the range in which the most growth occurred and is enough for the general trend they are looking at. (However, discussions could occur on improving the accuracy by repeating the experiment three times to calculate a mean.)
15 min	Click on the 'Data collection' button and give learners Worksheet L. Explain that these are photos taken from the samples in the video (answers are on Worksheet K/L suggested answers). Ask them to count how many seeds have germinated and to estimate the length of each shoot for those seeds that have germinated. They record their data on Worksheet J(1); more able learners can use Worksheet J(2) to challenge them to choose their own length ranges. They are asked to do this according to their observations of the seedlings. They should look at the lengths in each sample and make approximate ranges that would fit. Remind them that they are looking at the length of seedlings and so are only looking at germinated seeds; a seedling with shoot length of 0 mm is a seed that hasn't germinated and so this cannot be included in the range. Learners will need to review all samples to decide upon suitable ranges of growth. This could be a discussion point when reviewing this with learners. *Continues on next page …*

Timings	Activity
	Main lesson continued … Resume the video so that learners can make observations of the appearance of the seeds and seedlings. The audio will tell them the number of seeds that have germinated and the most common length range in each sample, so they can compare this to their results. Once they have finished collecting their results, ask them to summarise them into the table on Worksheet K. The video will pause on the results summary table, so learners can compare. The rest of the video discusses plotting a graph and the results, which will be covered in the *Debriefing lesson*. Have discussions about any differences between the method shown and their methods on Worksheet E. Learners can now answer questions 4–8 on Worksheet E.
	**Plenary** Learners evaluate the method for the experiment. Has it enabled them to investigate the impact of acid rain on seed germination? Give them a minute to think about their answer and then do a class assessment by asking them to put their hands up if they think: (1) this method will give valid data or (2) this method will not give valid data. Learners could be further prompted to explain and justify their views. Learners could be challenged to suggest how they could improve the method.

Debriefing lesson: Analysis of results

Resources	• Learners' completed Worksheets E and K • Worksheets M, N, O and P • *Virtual experiment* video
Learning objectives	By the end of the lesson: • ***all*** learners should make conclusions based on data. • ***most*** learners should be able to draw a graph to represent their data. • ***some*** learners will be able to evaluate the effectiveness of their investigation and suggest improvements.

Timings	Activity
10 min	**Starter/introduction** Give learners Worksheet M and ask them to match the key word to the correct description. Allow learners to work in pairs to discuss possible answers. Have a class discussion on the meaning of the key terms. Focus in particular on the meaning of categoric and continuous data as learners can often get these terms confused and discussing this will help them with the main task. Discuss if the quantitative data (length of the shoots) they collected in the previous lesson is categoric or continuous. Make sure that all learners are clear on the data being continuous. Ask learners what type of graph they should draw to present this data and why. If necessary, discuss the different types of graph most commonly used for different types of data: bar charts (categoric data); line graphs (to show change, for example over time, for continuous data); pie charts (to show fractions of a whole), etc.
5 min 15 min	**Main lesson** Ask learners to discuss in groups of 2–4 what makes a good graph and ask them to come up with three ideas. Allow learners a minute to discuss and then check their ideas as a class. Make sure any misconceptions are resolved. Ask learners to look at their summary data on Worksheet K. Ask them what might make their count more meaningful. If no one suggests it, discuss calculating the percentage germination of seeds for each acid concentration. Display the following formula: $$\text{percentage germination} = \frac{\text{number of germinated seeds in sample}}{\text{total number of seeds in sample}} \times 100$$ Tell them to plot a graph of the percentage of germinated seeds against the concentration of acid. Give learners the graph checklist on Worksheet N to support them. Explain they need to draw a curve of best fit. Some learners may require a sketch of the graph on the board for further support; a graph has been drawn from the data in the *Virtual experiment* video on Worksheet O. To challenge learners, ask them to draw a graph without using Worksheet N and then use the worksheet to peer assess or self-assess their work. *Continues on next page…*

Timings	Activity
20 min	**Main lesson continued …** Explain that now they have presented their data visually, they are ready to start interpreting their data and writing conclusions. Learners work in groups of 2–4 again. Ask them to create a mind map on a piece of paper or in their books with the central question: *'Why is it important to use data to make conclusions?'* Examples of possible answers include: • conclusions based on data would be more reliable • data can show a trend which can be applied to a situation • data can be reproduced and so conclusions would be more valid. *(For more information on how to draw mind maps, see page 9 of the Cambridge Learner Revision Guide.)* Prompt discussion from learners and ask for at least one reason why from each group. Link this discussion to the need for scientific testing to compare what results we think we should obtain with what we actually obtain, and how this supports the hypothesis, which in this context is that acid rain adversely affects seed germination. Explain that they will now interpret and conclude their findings. They should make statements about their results, back these up with examples from their data and then suggest the impact of their findings in a wider context. Learners should understand the importance of using data as evidence from the earlier discussion. Learners use the scaffolding on Worksheet O to help them summarise their conclusion in words. This practises extended writing skills in a scientific context. They do this on paper or in their note books. Encourage learners to use the key words from Worksheet M. Learners should be able to conclude that increasing the concentration of acid has a negative effect not only on the number of germinating seeds but on the appearance of shoots and seeds, i.e. the condition of the seeds and seedlings. Learners should be able to discuss this effect in the wider context of acid rain and suggest its adverse impact, for example, on habitats or the food chain. During the tasks, prompt learners and guide their answers by asking them questions. Challenge learners to justify their answers. If learners struggle to use data in their answers, you could pause the task periodically to review answers of other learners as examples of good answers. You might like to play the rest of the *Virtual experiment* video (from 6:15 to the end) which presents and discusses the results.
10 min	**Plenary** Arrange learners in groups of 2–4. Ask them to evaluate their investigation. Recap the meaning of 'valid' data and ask the learners whether the method and design of the experiment produced valid results. Question learners as a group to respond with 'yes' or 'no' and ask them to use their extended writing work to justify/explain their argument. Challenge learners to suggest how they could improve their data collection or amend the experiment for further investigation. Suggestions could include confirming that the data is reproducible by conducting several tests and calculating a mean.

Worksheets and suggested answers

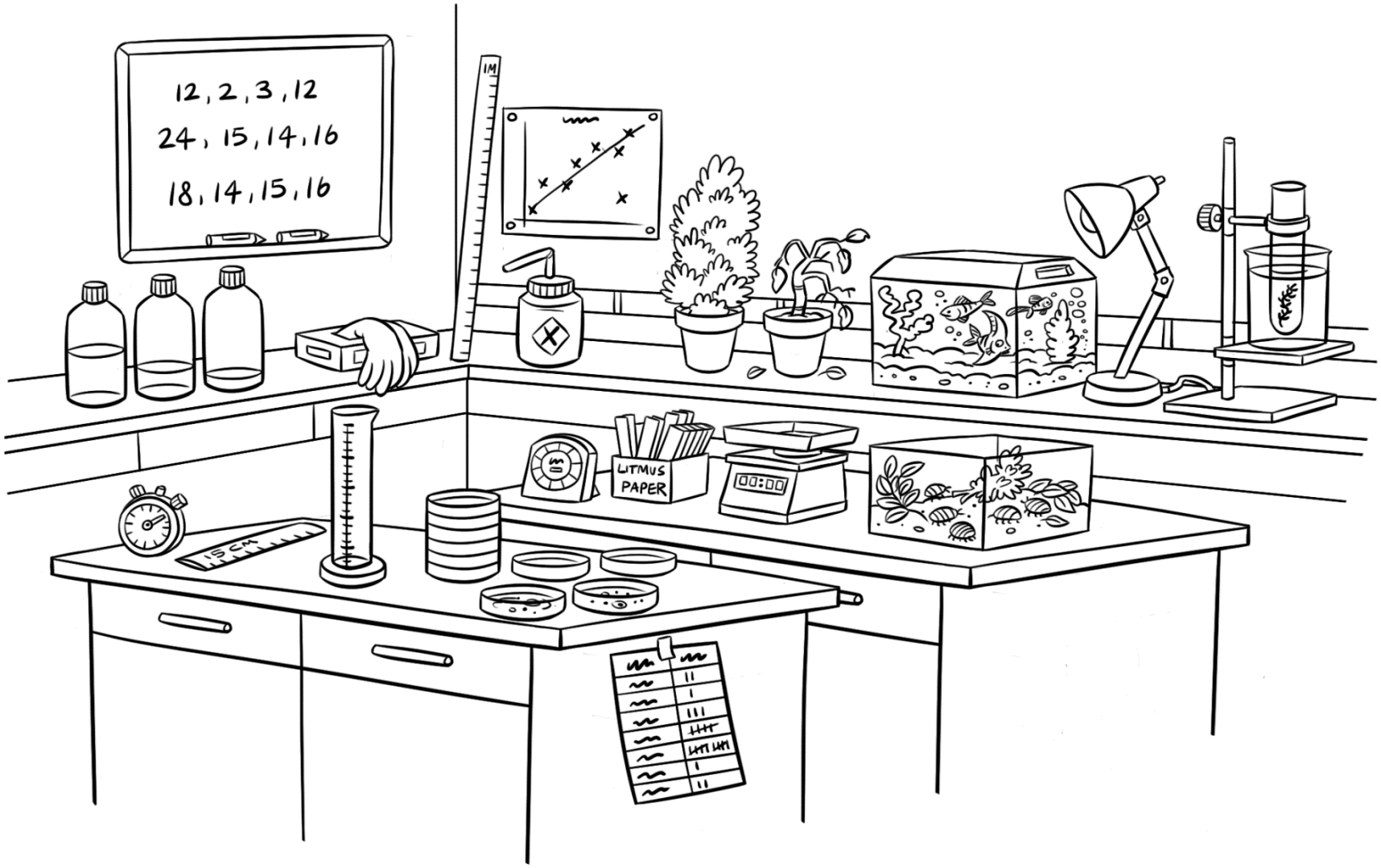
	Worksheets	Suggested answers
For use in the *Briefing lesson:*		
A: Key word match up	**25**	**47**
B: Laboratory scene	**26**	**—**
C: Collecting data	**27**	**48**
D: Scenarios	**28–29**	**49**
For use in *Lab lesson: Option 1:*		
E: Planning a practical	**30–32**	**51**
F: Method (Part 1)	**33**	**—**
G: Equipment set-up (Part 1)	**34**	**—**
H: Method (Part 2)	**35**	**—**
I: Equipment set-up (Part 2)	**36**	**—**
J(1): Data collection	**37**	**—**
J(2): Data collection	**38**	**—**
K: Data summary	**39**	**53**
For use in *Lab lesson: Option 2:*		
E: Planning a practical	**30–32**	**51**
J(1): Data collection	**37**	**—**
J(2): Data collection	**38**	**—**
K: Data summary	**39**	**53**
L: Estimating seedling length	**40–42**	**53**
For use in the *Debriefing lesson:*		
M: Making conclusions	**43**	**54**
N: Graph checklist	**44**	**—**
O: Graph from *Virtual experiment* video	**43**	**—**
P: Writing up	**46**	**55**

Worksheet A: Key word match up

Match each key word to its description.

Mean	Using a range or approximation to roughly calculate the value or number of something.
Anomaly	A description of what can be seen.
Estimate	A variable that you change.
Dependent variable	A variable that you keep the same.
Independent variable	This type of data is observed and cannot be measured using numbers.
Control variable	A variable that you measure.
Quantitative	A value that does not fit the pattern of data. It should be ignored when calculating a mean.
Qualitative	This type of data expresses a number range or quantity.
Observation	This is an average value calculated by finding the sum of all the data points, then dividing by how many data points there are.
Measurement	Accurately recording quantitative data.

Worksheet B: Laboratory scene



Worksheet C: Collecting data

Identify examples of each key word that you can see on Worksheet B and record them below. Explain how they can be used as an example of the key word.

Key word	Example on Worksheet B
Estimate	
Anomaly	
Mean	
Dependent variable	
Independent variable	
Control variable	
Quantitative	
Qualitative	
Observation	
Measurement	

Worksheet D: Scenarios

Scenario (a)

Scientists want to investigate factors that affect woodlice behaviour. They set up two areas within a woodlice tank, one shaded and one in full light. They will find out how many woodlice there are in each area at different times of the day. Complete the table below in your groups.

What could be investigated?	How could this be measured? Include the type of variable and data involved.	What equipment would be needed?

Scenario (b)

Scientists want to investigate factors that can affect the growth and condition of plants. They put three different plants into three soils, each with a different pH: acidic, neutral and alkali. Complete the table below in your groups.

What could be investigated?	How could this be measured? Include the type of variable and data involved.	What equipment would be needed?

Worksheet E: Planning a practical

Task: Investigate the effect of acid rain on the germination of cress seeds.

Method outline: Cress seeds are grown in Petri dishes on filter paper soaked with a solution. Three different concentrations of acid will be tested. The samples are observed after five days.

1. What data could you collect to measure the effect of acids on the germination of cress seeds?

Quantitative	Qualitative

2. Identify the variables in the experiment.

Independent variable	
Dependent variable(s)	
Variable(s) that need to be controlled	

3. Describe a method for the experiment. Use the equipment list, and your answers to questions 1 and 2 to help you.

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4. Complete a risk assessment:

Hazard	Risk	Prevention

5. Why is it important to have a control sample?

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6. What other factors could affect the experiment and how will you manage these?

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7. Given your answer to question 6, what conditions should your samples be stored in over the five days? Why?

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8. Why do you think you need to look at the sample again after five days?

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Worksheet F: Method (Part 1)

1. Collect all your equipment from the front of the class.

2. Place a piece of circular filter paper into the bottom of a Petri dish.

3. Count out 15 cress seeds and scatter them (at random) onto the filter paper.

4. Fill a dropping pipette with distilled water.

Record the volume of water in the pipette.

5. Soak the filter paper with the distilled water from the pipette. If the paper is still dry in places, add more water.

Make sure you record the volume of any additional water added.
Record the total volume of water used.

6. Add a lid to the Petri dish.

7. Seal the lid on the Petri dish with two small pieces of adhesive tape on either side to secure the sample. Refer to the set-up diagram on **Worksheet G** to see what the samples should look like. Do **not** seal the lid all the way around, as you need to allow air to enter the Petri dish.

8. Label the sample as the control using the letter 'C'.

You will need to observe the seeds through the lid, so make sure the label is near the edge of the lid and does not cover the central area of the Petri dish.

9. Repeat steps 2 and 3 with a new Petri dish.

10. Use a dropping pipette to soak the filter paper with 0.1M hydrochloric acid. Use the same volume of acid as the total volume of distilled water you used earlier.

Take care when handling hydrochloric acid. Do not get it on your skin. Tell your teacher immediately if there are any spillages. Do not touch filter paper soaked in acid.

11. Seal a lid on the Petri dish as per the instructions in step 7.

12. Label the sample '0.1 M'.

13. Using the correct labels, repeat steps 2, 3, 10, 11 and 12 for 0.5M and 1M of hydrochloric acid.

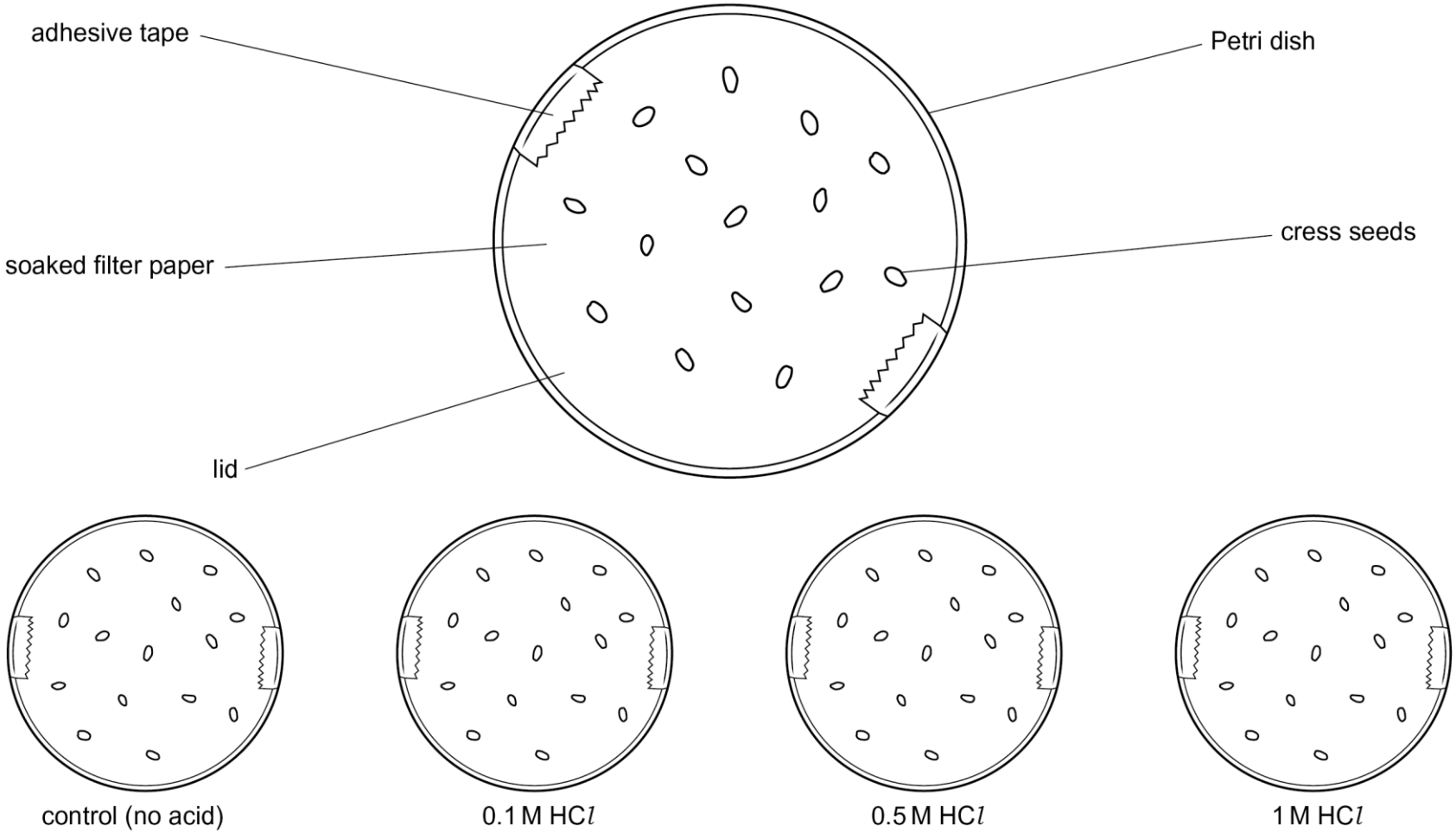
14. Leave your samples in a suitable area.

Seeds need light and oxygen in order to germinate.
All samples must be placed in the same conditions.

Worksheet G: Equipment set-up (Part 1)

Make sure that you follow the diagram carefully. The placement of the seeds is random, do not copy the diagram.

Take particular care when handling acids.



Worksheet H: Method (Part 2)

1. Collect your Petri dish samples.

2. Do **not** remove the lids or touch the filter paper or the cress with your hands.

3. Use Worksheet J to record the number of germinated seeds.

Remember that even a very small tip emerging from the seed is enough to include the seed in the count for germinated seeds.

4. Record your observations of the appearance of the seeds and seedlings.

Observe the colour of all seeds. For the seeds that have germinated, observe the appearance of the shoot and leaves. If there are no leaves, that is also an observation. Is the seedling straight, stunted or damaged?

5. Place a ruler on top of the lid (do **not** remove the lid) to estimate the length of each seedling.

This is only relevant to germinated seeds. Measure from where the shoot leaves the seed coat to the tip of the shoot or leaves (see **Image 1** below). If the seedling is no longer in the seed coat, measure the shoot from the point shown in **Image 2** below, i.e. from the little nodule at the end of the shoot.

Image 1

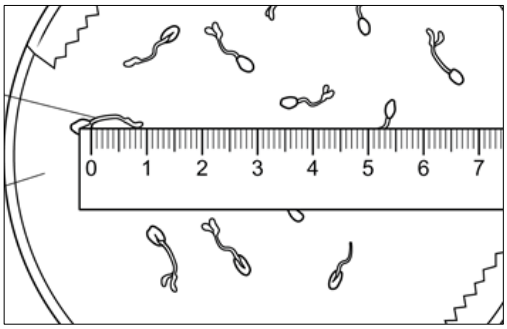
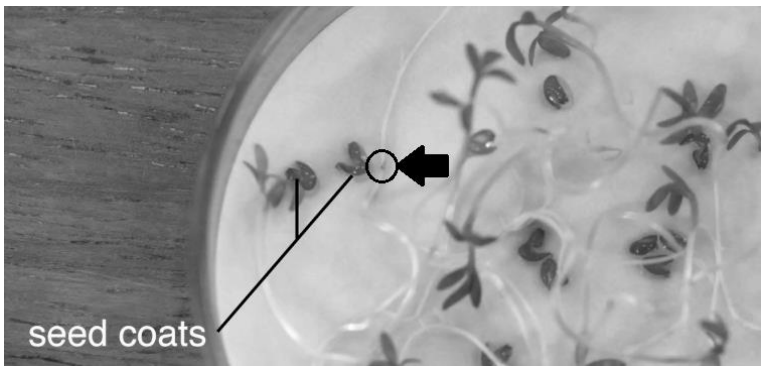


Image 2



6. Use a tally to record your estimate in the appropriate length range.

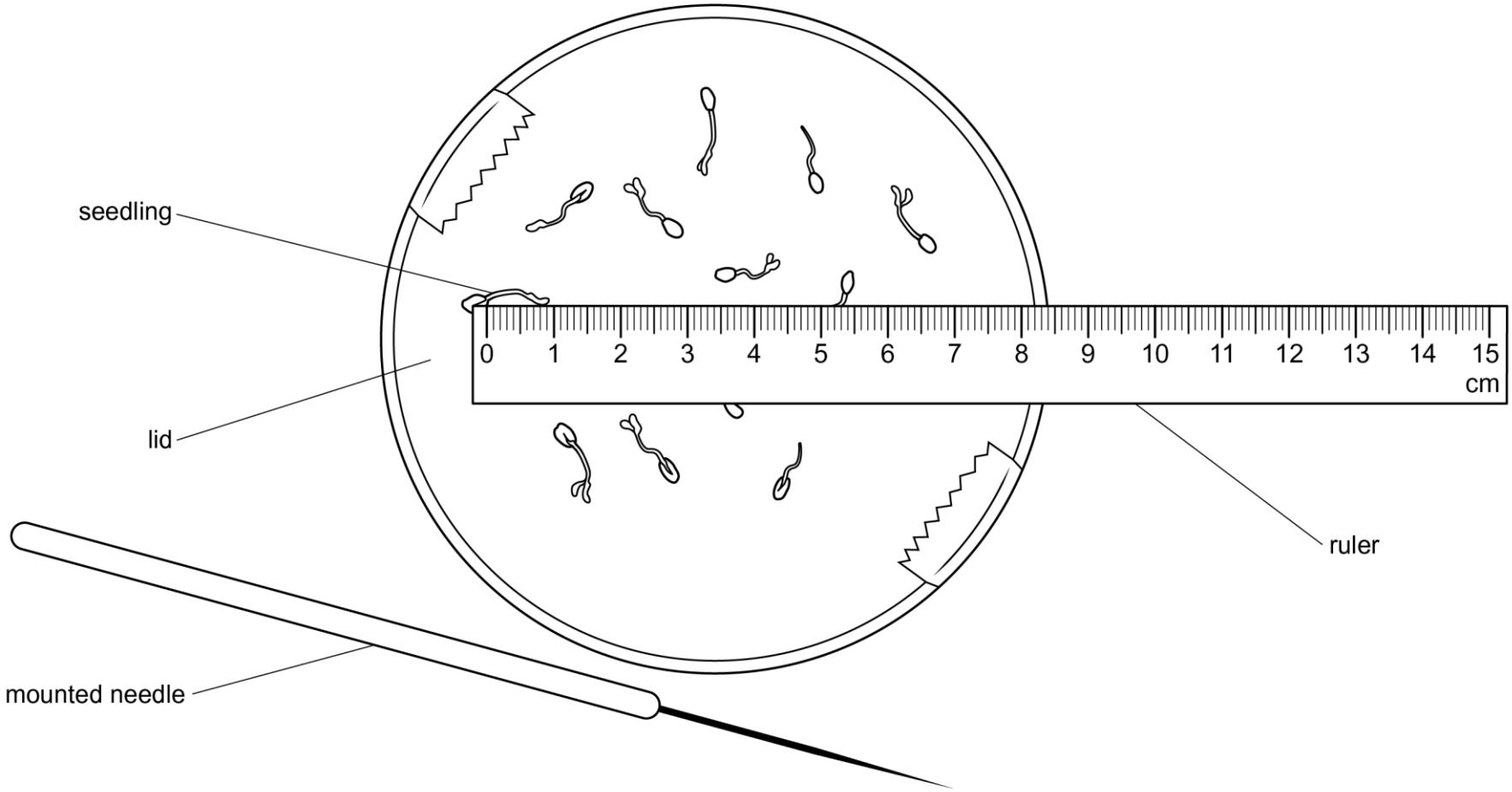
7. Return your equipment to your teacher.

8. Wash your hands under running water using soap.

Worksheet I: Equipment set-up (Part 2)

Use the mounted needle to help you count the seeds that have germinated. Use the ruler to estimate the length of each seedling.

Counting and measuring should be done through the lid. Do **not** remove the lid.



Worksheet J(1): Data collection

Record your data in the spaces provided.

Sample: Control

Number of germinated seeds:

Approximate length of seedlings:

Length range / mm	Tally
0 mm to 1 mm (includes > 0 to ⩽ 1)	
1 mm to 5 mm (includes > 1 to ⩽ 5)	
5 mm to 10 mm (includes > 5 to ⩽ 10)	
10 mm to 15 mm (includes > 10 to ⩽ 15)	
Over 15 mm (includes > 15)	

Appearance of seeds and seedlings:

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Sample: 0.1 M HC*l*

Number of germinated seeds:

Approximate length of seedlings:

Length range / mm	Tally
0 mm to 1 mm (includes > 0 to ⩽ 1)	
1 mm to 5 mm (includes > 1 to ⩽ 5)	
5 mm to 10 mm (includes > 5 to ⩽ 10)	
10 mm to 15 mm (includes > 10 to ⩽ 15)	
Over 15 mm (includes > 15)	

Appearance of seeds and seedlings:

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Sample: 0.5 M HC*l*

Number of germinated seeds:

Approximate length of seedlings:

Length range / mm	Tally
0 mm to 1 mm (includes > 0 to ⩽ 1)	
1 mm to 5 mm (includes > 1 to ⩽ 5)	
5 mm to 10 mm (includes > 5 to ⩽ 10)	
10 mm to 15 mm (includes > 10 to ⩽ 15)	
Over 15 mm (includes > 15)	

Appearance of seeds and seedlings:

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Sample: 1 M HC*l*

Number of germinated seeds:

Approximate length of seedlings:

Length range / mm	Tally
0 mm to 1 mm (includes > 0 to ⩽ 1)	
1 mm to 5 mm (includes > 1 to ⩽ 5)	
5 mm to 10 mm (includes > 5 to ⩽ 10)	
10 mm to 15 mm (includes > 10 to ⩽ 15)	
Over 15 mm (includes > 15)	

Appearance of seeds and seedlings:

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Worksheet J(2): Data collection

Record your data in the spaces provided. Think of suitable length ranges for your samples.

Sample: Control

Number of germinated seeds:

Approximate length of seedlings:

Length range (mm)	Tally

Appearance of seeds and seedlings:

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Sample: 0.1 M HC*l*

Number of germinated seeds:

Approximate length of seedlings:

Length range (mm)	Tally

Appearance of seeds and seedlings:

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Sample: 0.5 M HC*l*

Number of germinated seeds: …….

Approximate length of seedlings:

Length range (mm)	Tally

Appearance of seeds and seedlings:

……

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Sample: 1 M HC*l*

Number of germinated seeds: …….

Approximate length of seedlings:

Length range (mm)	Tally

Appearance of seeds and seedlings:

……

……

……

Worksheet K: Data summary

Sample	Number of germinated seeds	Most common length / mm	Appearance

Worksheet L: Estimating seedling length

Estimate the length of each seedling in each sample.

This is only relevant to germinated seeds. Measure from where the shoot leaves the seed coat to the tip of the shoot or leaves (see **Image 1** below). If the seedling is no longer in the seed coat, measure the shoot from the point shown in **Image 2** below, i.e. from the little nodule at the end of the shoot.

Image 1

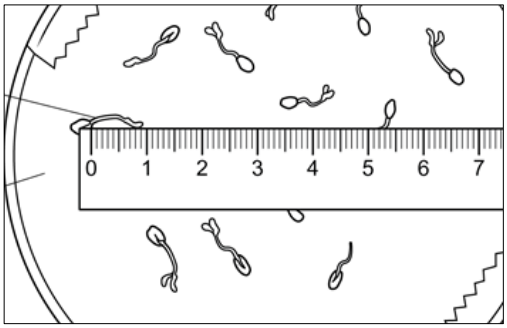
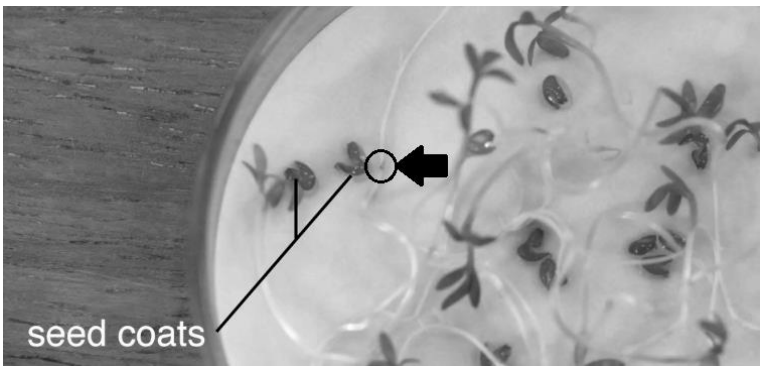
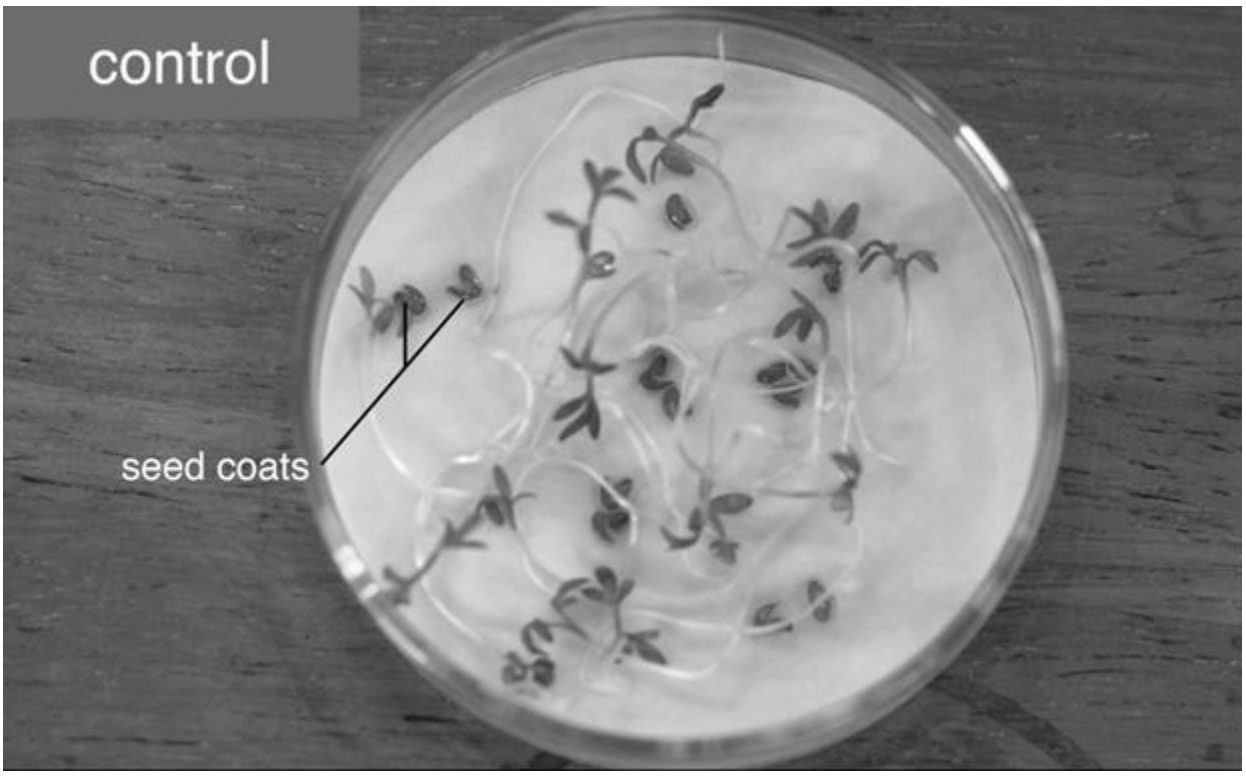
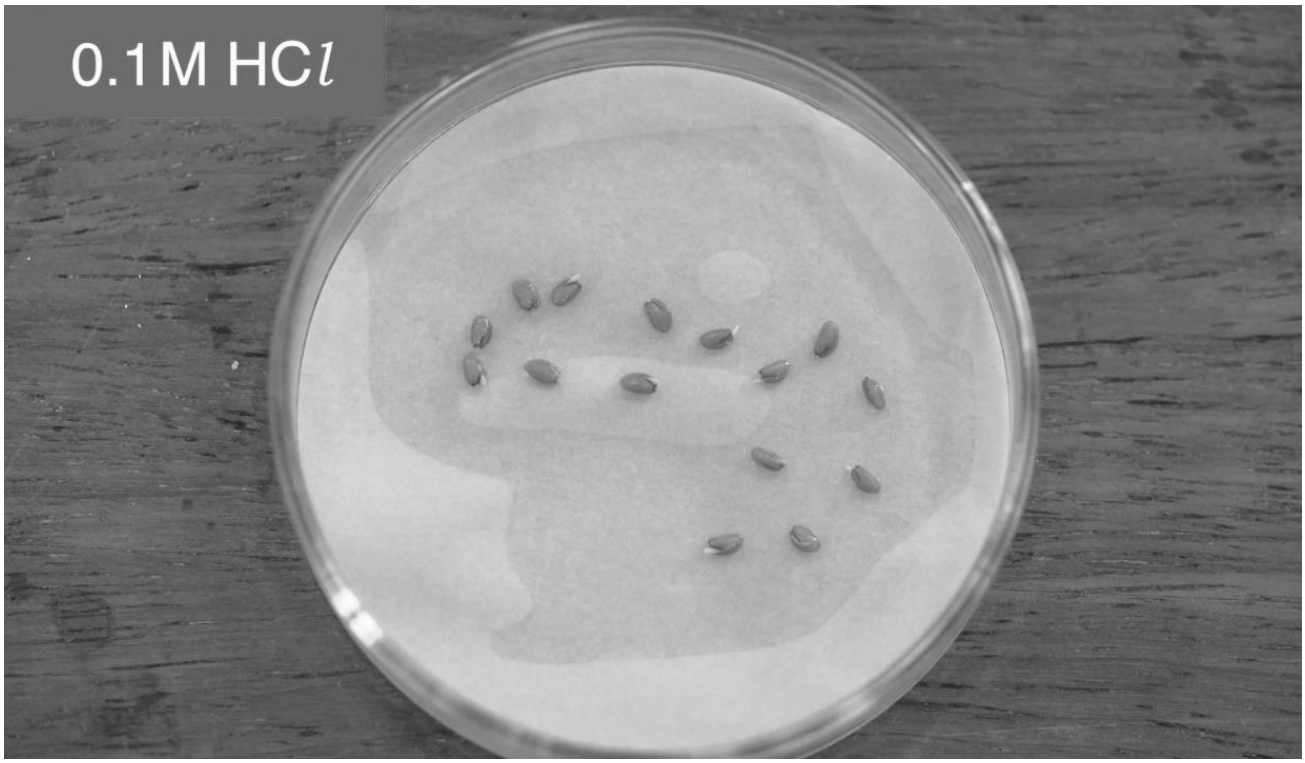
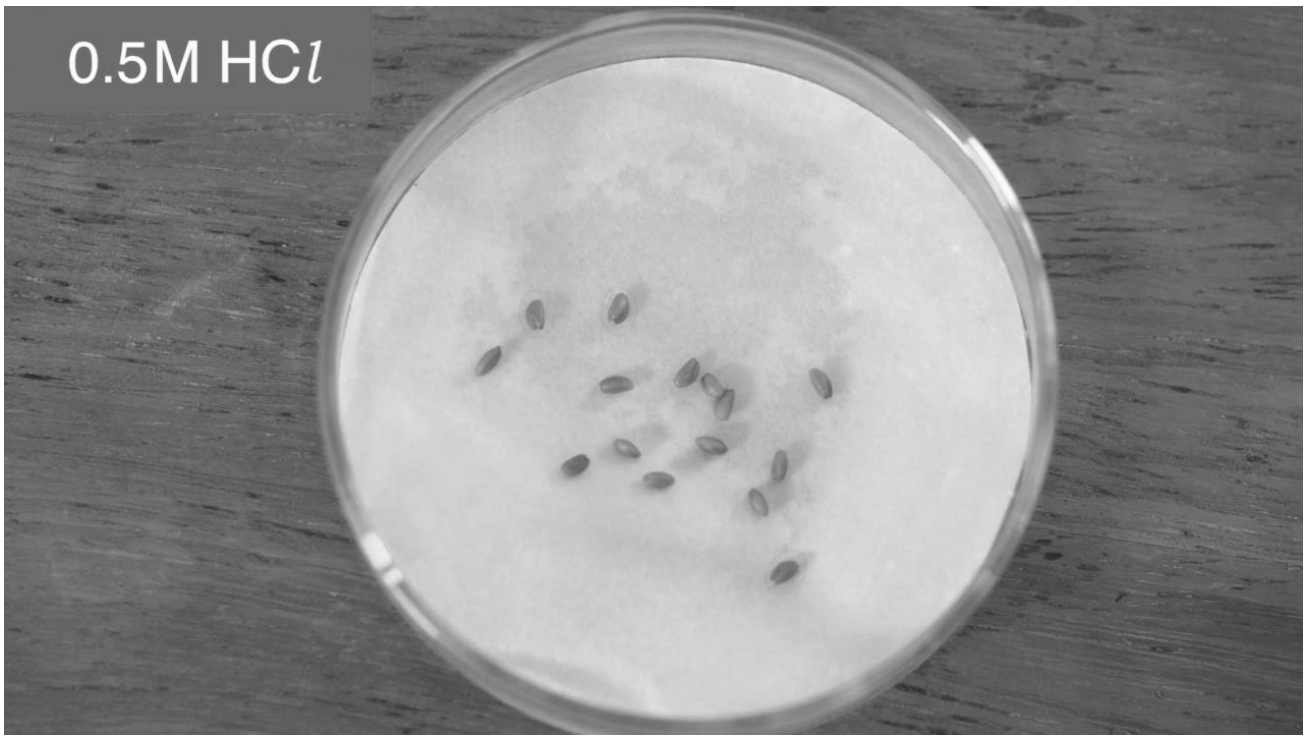


Image 2









Worksheet M: Making conclusions

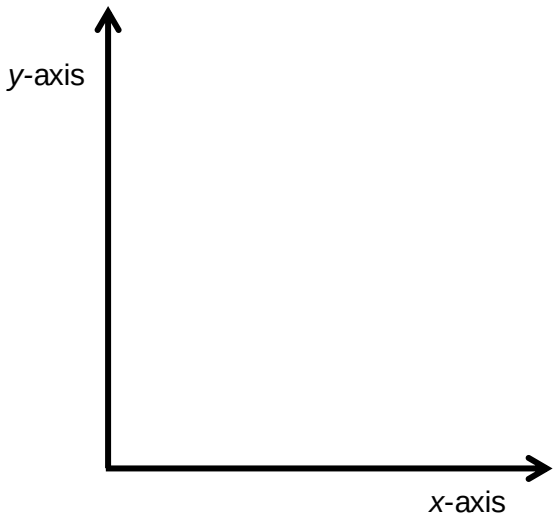
Match the key words with the definitions:

Continuous data	This is data that does not fit the pattern or trend.
Categoric data	This graph is drawn using continuous data.
Valid	Data fits into distinct categories.
Reproducible	This graph is drawn using categoric data.
Trend	If the experiment was repeated again the same results would be obtained.
Line graph	Describes a pattern in data.
Anomalous data	The experiment method measures what it sets out to investigate.
Bar graph	Data could take any value.

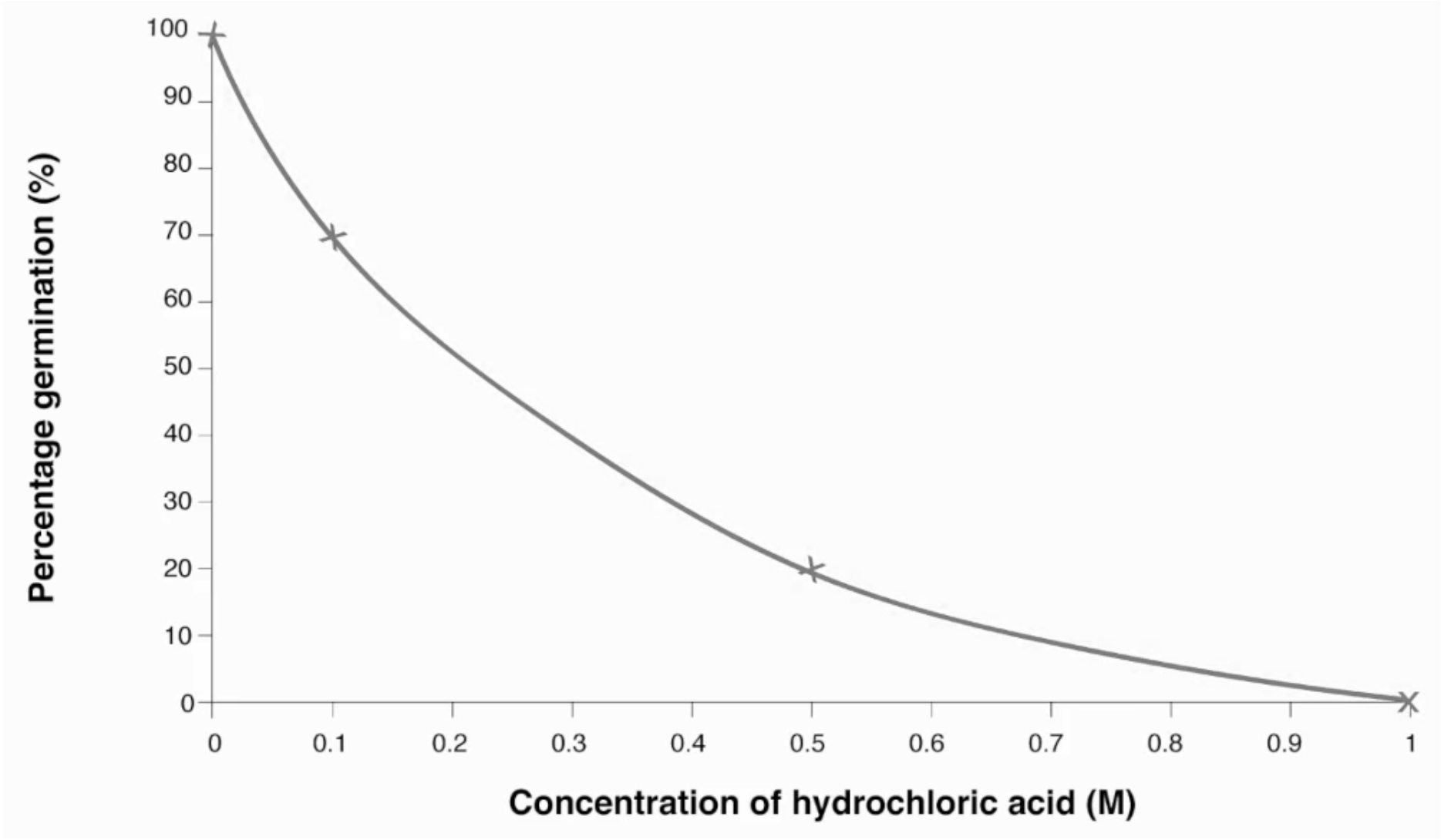
Worksheet N: Graph checklist

Use the checklist below to make sure that the graph that you have drawn is accurate and has all of the necessary detail.

Graph checklist	Done (tick)
The graph axes have been drawn with a ruler and a sharp pencil.	
The dependent variable is on the *y*-axis.	
The independent variable with unit is on the *x*-axis.	
The graph is a line graph.	
The scale on the *x*-axis is even and appropriate.	
The scale on the *y*-axis is even and appropriate.	
The available space has been used well.	
A smooth curve has been drawn through the points.	



Worksheet O: Graph from *Virtual experiment* video



Worksheet P: Writing up

Use the questions and suggestions below to help you write up your conclusion.

1. Look at the data gathered from the control sample. Write a short summary of the growth and condition of the seeds in the control sample at the end of the five days.

   Suggestion: Describe what you saw using your observation tables including length and colour.

2. Look at the data gathered from the acid samples. Write a summary of the growth and condition of the seeds after the five days in **comparison** to the control.

   Suggestion: Describe what you saw in the samples grown in acid and then compare this to what you saw in the control. Use language such as 'compared to', 'less than', 'the same as'.

3. Look at your graph and table. What general **trend** do you notice? Refer to each of the conditions the samples were grown in.

   Suggestion: Use the axes to help you. How does the dependent variable change with the independent variable?

4. Did you have any anomalous data? If so, where was this? Why might this have been?

   Suggestion: Describe any data that does not fit the general pattern and what conditions this occurred in.

5. Do your qualitative and quantitative results support your hypothesis? Explain your answer using your data.

   Suggestion: Look at your hypothesis and your data. Does your data show that your hypothesis is true? Prove this, using examples from your data.

6. Acid rain is a product of burning fossil fuels. Using your results, conclude your experiment and suggest the effect of burning fossil fuels on the environment.

   Suggestion: Relate your conclusion to what would happen to the seeds of other plants.

Worksheet A: Answers

Match each key word to a suitable description.

Mean	This is an average value calculated by finding the sum of all the data points, then dividing by how many data points there are.
Anomaly	A value that does not fit the pattern of data. It should be ignored when calculating a mean.
Estimate	Using a range or approximation to roughly calculate the value or number of something.
Dependent variable	A variable that you measure.
Independent variable	A variable that you change.
Control variable	A variable that you keep the same.
Quantitative	This type of data expresses a number range or quantity.
Qualitative	This type of data is observed and cannot be measured using numbers.
Observation	A description of what can be seen.
Measurement	Accurately recording quantitative data.

Worksheet C: Suggested answers

The answers provided here are just some of the many possible answers. The task is designed to be open-ended and to give learners the opportunity to be creative in their suggestions.

Key word	Example on Worksheet B
Estimate	The volume of water in the different size bottles. The number of woodlice in the tank. The number of gloves in the box. The mass of the plant.
Anomaly	The anomalous point on the graph. The result in one of the Petri dishes.
Mean	Adding the number of Petri dishes up and dividing by how many there are. Tally chart results could be averaged.
Dependent variable	Ruler to measure distance. Stopwatch to measure time. Universal indicator strips and pH scale to measure the pH of a substance. Measuring cylinder to measure volumes.
Independent variable	Species of fish. Growing conditions for plants. Volume/concentration of liquid in the bottles.
Control variable	Control the volume of distilled water. Control the distance of a sample to a lamp light source. Control the pH.
Quantitative	Number of fish. Time it takes woodlice to move from one area to another. Width of bacterial colony.
Qualitative	Condition of the plant. Colour of bacterial colonies. Behaviour of the fish. Colour of universal indicator paper.
Observation	Movement of the woodlice. Colour of the fish. Health of the plant. Colour of universal indicator paper.
Measurement	pH of the water. Rate of photosynthesis. Diameter of bacteria growth.

Worksheet D: Suggested answers

Scenario (a) Learners should be creative and will have many ideas.

What could be investigated?	How could this be measured? Include the type of variable and data involved.	What equipment would be needed?
Number of woodlice in light areas versus dark areas.	Set up one side of the habitat as a dark area and one side as a light area (**independent variable**). The substrate of the habitat (soil) should be the same across the tank as a **control variable**. Put a set number of woodlice in the centre of the tank, start the timer and wait for 20 minutes to allow the woodlice to choose the area. Count the number of woodlice in each area (**dependent variable and quantitative data**) and compare to conclude which condition they prefer.	A woodlice habitat; timer; a light source (lamp or set the tank up by a window); to create a dark area, a piece of cardboard, wood or leaves.
What pH soil woodlice prefer.	Set up a woodlice habitat with three different types of soil (**independent variable**). Light/water conditions should be the same across the habitat (**control variable**). Record the pH of the soil using litmus paper. Leave the woodlice for 20 minutes. Record the number of woodlice in each soil area every 30 minutes (**dependent variable and quantitative data**). Calculate an average. The soil with the greatest mean woodlice is the one the woodlice prefer.	Litmus paper; timer; three soils of different pH, a woodlice habitat.
Time woodlice spend in light or dark areas.	Set up a woodlice habitat with a dark and light area (as before). Have two timers. Place a woodlouse in the centre. Start one timer when a woodlouse enters the dark area and the other timer when a woodlouse enters the light area. Record the total time spent in this area (**dependent variable and quantitative data**). Repeat for 3 different woodlice. Record the mean time of all three woodlice. The greatest time will be the habitat the woodlice prefer.	A woodlice habitat; timers; a light source (lamp or set the tank up by a window); to create a dark area, a piece of cardboard, wood or leaves.
Test if woodlice prefer damp or dry conditions.	Set up one side of the habitat as damp by soaking the soil in water and one side as dry (**independent variable**). Type and pH of soil, and light conditions should be the same across the habitat (**control variable**). Put a set number of woodlice in the centre, start the timer and wait for 20 minutes to allow the woodlice to choose the area. Count the number of woodlice in each area (**dependent variable and quantitative data**) and compare.	A woodlice habitat; timer; dry soil and water to soak soil.

Scenario (b) Learners should be creative and will have many ideas.

What could be investigated?	How could this be measured? Include the type of variable and data involved.	What equipment would be needed?
How the pH of the soil affects the growth of plants.	Use an acidic, alkaline and neutral soil (**independent variable**). Record the pH of the three soils using litmus paper. Use the same species of plant for each test, and same light/water conditions as **control variables**. Plant the plants in the soil. Measure the starting number of leaves, average length of leaves and height of each plant (**dependent variable, quantitative data**). Observe the appearance of the leaves and plant (**qualitative data**). Leave for 3 days. Repeat the same measurements to see the effect of the soil on the plant.	Litmus paper; plant x 3; acidic soil; alkaline soil; neutral soil; ruler; plant pots.
How availability of water affects the growth of seeds.	Have six plant pots filled with soil. The soil type should be the same in each pot and have the same pH, as a **control variable**. Add the same number of seeds to each soil sample as a **control variable**. Feed each plant, a different volume of water (500 ml, 400 ml, 300 ml, 200 ml, 100 ml, 0 ml) is added every 6 hours for five days (**independent variable**). After 5 days, measure the number of leaves, average length of leaves and height of each plant (**quantitative data**) and compare.	Six pots; soil; seeds; water; Litmus paper; measuring cylinder and/or jug.
How light affects the growth of plants.	Keep one plant in light conditions and another in dark (**independent variable**). The same species of plant should be used, and the same age, as a **control variable**. The same type of soil should be used, and the pH compared to make sure it's the same (**control variables**). Measure the starting number of leaves, average length of leaves and height of each plant (**quantitative data**). Leave the plants in these conditions for five days. Repeat the same measurements and compare.	Lamp or access to window; dark space such as a cupboard or box (must be well ventilated) as control; plant × 2; ruler; Litmus paper.

Worksheet E: Suggested answers

1. What data could you collect to measure the effect of acids on the germination of cress seeds?

   Quantitative: length of shoots; number of germinating seeds.

   Qualitative: colour/condition of the shoots; colour of seed coats/seeds; presence/absence of leaves; condition of leaves.

2. Identify the variables in the experiment.

   Independent variable: concentration of acid.

   Dependent variable: number of germinated seeds; length of shoots; condition of seeds and seedlings.

   Variables to be controlled: volume of water and acid added to samples; number of seeds in each sample; location/conditions where samples are left to grow.

3. Describe a method for the experiment. Use the equipment list, and your answers to questions 1 and 2 to help you.

   Learners' answers should include the following ideas:

   - Have a sample for each of the different concentrations of acid.
   - Have a sample where no acid is added, water is added instead as a control.
   - Put same number of seeds in each dish.
   - Leave seeds to germinate/grow in the same place.
   - Count how many seeds have germinated in each sample.
   - Use a ruler to measure the length of shoots in seeds that have germinated.
   - Make observations about the appearance of the seeds and seedlings.

4. Complete a risk assessment.

Hazard	Risk	Prevention
Acid	Could be spilt onto skin, clothes or get into the eyes, and cause burns or irritation.	Take care when using the acid not to spill it. Tell the teacher immediately if spillage does occur. Wear eye protection. Wear lab coats if available. Wash hands after the practical.

5. Why is it important to have a control sample?

   Learners' answers should include following ideas:

   - The control shows what would happen without the independent variable, i.e. what the germination and growth of the cress seedlings would be when there is no acid rain.
   - Control allows comparisons to be made; any changes in germination or growth in the acidic conditions compared to the control are due to the change in conditions that are being investigated, i.e. acid concentration.

- Abnormal growth in the control indicates that a factor other than the independent variable, is influencing the results and a valid conclusion cannot be made; the experiment should be repeated.

6. What other factors could affect the experiment and how will you manage these?

   Access to water, light and a mild temperature.

7. Given your answer to question 6, what conditions should your samples be stored in over the five days? Why?

   The samples should be in a light room at a mild temperature, with good airflow. The same volume of water should be added to each sample each day to prevent the samples drying out. Water, light, carbon dioxide and mild temperatures allow photosynthesis and growth to occur. These conditions ensure that temperature, light, water and access to carbon dioxide are not limiting factors to germination and growth.

8. Why do you think you need to look at the sample again after five days?

   The practical should be reviewed after at least 24 hours to allow the cress seeds to germinate. It is unlikely that there will be much growth after just one day, especially not in the acidic conditions, so after 3–5 days is reasonable.

Worksheet K / L: Data summary

The results below are taken from the experiment carried out in the *Virtual experiment* video.

Sample	Number of germinated seeds	Average length / mm	Appearance
Control	15	over 15	White shoots with green leaves; brown seed coats.
0.1 M HCl	11	1 – 5	Stunted shoots; pale yellow seed coats.
0.5 M HCl	3	0 – 1	Shoots more stunted than 0.1 M sample, only just the tip emerging; pale yellow seed coats.
1 M HCl	0	N/A	There are no shoots; pale yellow seed coats.

Worksheet M: Answers

Continuous data	Data could take any value.
Categoric data	Data fits into distinct categories.
Valid	The experiment method measures what it sets out to investigate.
Reproducible	If the experiment was repeated again the same results would be obtained.
Trend	Describes a pattern in data.
Line graph	This graph is drawn using continuous data.
Anomalous data	This is data that does not fit the pattern or trend.
Bar graph	This graph is drawn using categoric data.

Worksheet P: Suggested answers

Please note the exact answers will depend on the outcome of the learners' investigation; these are based on the results in the *Virtual experiment* video and represent exemplar answers only.

1. Look at the data gathered from the control sample. Write a short summary of the growth and condition of the seeds in the control sample at the end of the five days.

   Suggestion: Describe what you saw using your observation tables including length and colour.

   In the control sample, all of the 15 seeds have germinated giving a percentage germination of 100%. The seedlings have grown significantly over the five days, with most shoots being greater than 15 mm in length. The stems are white and the leaves are a dark green colour.

2. Look at the data gathered from the acid samples. Write a summary of the growth and condition of the seeds after the five days in **comparison** to the control.

   Suggestion: Describe what you saw in the samples grown in acid and then compare this to what you saw in the control. Use language such as 'compared to', 'less than', 'the same as'

   In the 0.1M sample, most of the seeds have germinated, however not as many as in the control; 11 seeds germinated compared to 15, which is 70% germination versus 100%. The shoots are generally much shorter than in the control, with most shoots being between 1 and 5 mm long. None of the seedlings have leaves and the seed coat has turned a pale yellow colour compared to the control.

   In the 0.5M sample, only 3 of the seeds have germinated. This is much less than both the control and the 0.1 M sample; only 20% germination. The shoots are very stunted, with most being less than 1 mm in length. The shoots are a yellow colour with no leaves. Most of the seeds have not germinated at all and the seeds look a pale yellow colour compared to the control.

   In the 1M sample, no seeds have germinated. The seeds have changed to a yellow-brown colour compared to the control.

3. Look at your graph and table. What general **trend** do you notice? Refer to each of the conditions the samples were grown in.

   Suggestion: Use the axes to help you. How does the dependent variable change with the independent variable?

   From the graph, a general trend can be seen: as the concentration of acid increases, the percentage germination decreases from 100% to 0%. From the table, it is possible to see a trend of decreasing shoot length from over 15 mm to less than 1 mm as the concentration of acid increases to 0.5 M. It is also possible to see that the condition of the seedlings also deteriorates from white with green leaves to stunted and yellow as the acid concentration increases.

4. Did you have any anomalous data? If so, where was this? Why might this have been?

   Suggestion: Describe any data that does not fit the general pattern and what conditions this occurred in.

   In this experiment there were no anomalies. An anomalous point is one that does not fit the pattern. From our data it is clear to see that there is a smooth, curved line of best fit with no data points lying outside of this.

5. Do your qualitative and quantitative results support your hypothesis? Explain your answer using your data.

   Suggestion: Look at your hypothesis and your data. Does your data show that your hypothesis is true? Prove this, using examples from your data

   Yes, our results support the hypothesis that acidic conditions have a negative effect on the germination of seeds. This is because there is a reduction in the number of germinating seeds as the concentration of acid increases. For example, at 1M there are no germinating seeds whereas in the control (no acid) all the seeds have germinated. Also, when seeds have germinated in lower concentrations of acid (0.1M and 0.5 M) the seedlings were much shorter and did not have any leaves when compared to the control, suggesting that the growth and development of the seedlings was affected negatively.

6. Acid rain is a product of burning fossil fuels. Using your results, conclude your experiment and suggest the effect of burning fossil fuels on the environment.

   Suggestion: Relate your conclusion to what would happen to the seeds of other plants

   Our results show that increasing the concentration of acid has a negative effect on the number and quality of germinating seeds. In our control sample, where only distilled water was added, the most common shoot length was over 15mm whereas in highly acidic conditions (1M) we saw that there were no germinating seeds and the seeds appeared damaged and yellowed. Even in the weakest acid conditions (0.1M), the percentage germination of seeds fell in comparison to the control (100% to 70%) and the most common length of the seedlings fell to less than 5 mm compared to over 15 mm for the control.

   The graph shows a negative relationship between the increasing concentration of acid and the number of germinating seeds. This suggests that if an environment becomes more acidic it will have a detrimental effect on plant life. Burning fossil fuels contributes to acid rain and our results show that this could have a devastating effect on plants even at low concentrations. This could then severely damage the availability of food for wildlife and result in the destruction of habitats as plants are unable to grow in such conditions.

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