General Science

Year 1

SECTION

1

CHARACTERISTICS OF SCIENCE

EXPLORING MATERIALS

Science and Materials In Nature

INTRODUCTION

Hello learner, welcome to an exciting adventure into the heart of science! In this section, we will uncover the secrets of nature by exploring its defining characteristics. Get ready to dive deep into the wonders of empirical evidence, consistency, objectivity, systematic, creativity, and community that shape the essence of scientific inquiry. This will enhance your critical thinking skills, encourage curiosity, promote healthy scepticism and foster lifelong appreciation for science and its role in society. We will further explore the exciting world where science and design intersect. We will discuss how scientific principles can enhance the quality and credibility of design projects and identify the characteristics of science, describe and provide examples of how these characteristics are applied in scientific inquiry. We will also apply scientific principles to a design project and formulate hypotheses related to their design project and design experiments or investigations to gather relevant data. Again, we will evaluate the impact of scientific design project for future design work and consider how scientific thinking can enhance the credibility and validity of design outcomes. Lastly, you will effectively communicate your project findings using scientific principles to explain your design process and outcomes. In this section we will identify and describe how characteristics of science are applied in both our everyday life and activities as well as other areas in health, agriculture, industry and among others. Let's embark on a journey of discovery unlike any other as we unlock the mysteries of science.

At the end of this section, you should be able to:

i. Explain the Characteristics of Science in Nature

ii. Design Project Using the Characteristics of Science.

iii. Apply the Characteristics of Science Where Appropriate

Learners at the end of this section will be able to:

- Explain the term science
- Identify at least three important aspects of science

- Explain the characteristics of science
- Identify the characteristics of science
- Apply scientific principles to a design project
- Evaluate the impact of scientific design on the design project
- Communicate the findings of the design project using scientific principles
- Identify areas where characteristics of science can be applied
- Describe with specific examples and illustrations how characteristics of science is applied in the home, school, health, education, industry, agriculture among others
- Evaluate how the characteristics of science are applied in the areas mentioned above.

Key Ideas

- Science is a body of knowledge and series processes that help us to understand the natural world and solve problems.
- Science is empirical (based on or derived from observations and data gathered through experimentation or observation of the natural world.).
- Scientific knowledge is replicable (the results of one study can be consistently reproduced by another study using the same methods and tools).
- Science is systematic (the scientific process follows a consistent approach, with clear steps for hypothesis testing, data collection, analysis, and interpretation.)
- Science is consistent (the ability of scientific findings to be reliable and repeatable over time).
- Science is tentative (scientific knowledge and understanding are not fixed or absolute but are subject to change and revision as new evidence, data, and insights emerge).
- Science is predictable: ability of scientific investigations to make accurate and reliable forecasts about future events or phenomena based on established scientific principles.

- Science is valid refers to how scientific observations, data, and measurements accurately reflect the phenomenon under study.
- Science is precise refers to the degree of accuracy, consistency, and reproducibility of scientific knowledge and ideas.
- Science is accurate refers to the correctness or truthfulness of scientific information or measurements.
- Design is the process of creating a plan or specification for the construction, production, or arrangement of an object, system, or structure.
- Scientific design refers to the application of scientific principles and methodologies in the process of designing experiments, studies, or research projects.
- A project is an endeavour undertaken to create a unique product, service, or result. It is a planned and organized effort with defined objectives, specific tasks, and a predetermined time frame.
- Application refers to how knowledge in the characteristics of science is used to produce ideas and/or manufacture products.
- Falsifiability is the capacity of a hypothesis or theory to be proven false if it is indeed incorrect.

WHAT IS SCIENCE?

Figure 1.1: Learners testing the magnitude of load their paper tower could carry using sachets of water.

Now, learner, look at figure 1.1 carefully and discuss what you see with your neighbours.

Activity 1

In pairs, use the activity in the picture to explain what science is. Note: suggested answers or conclusions for activities can be found in **Annex 1**.

Let us explore further with the following activity:

Activity 2

Home-made distilled water

Scenario: You are at a camp, and you need water to wash. The only water available is sea/salty water. As a scientist, how do you get the sea/salty water desalinated (water without salt) for washing?

What you need: A deep pot with a lid that is concave if turned upside side (i.e. it is domed if placed on the pot properly), Ice cubes, a bowl to collect your distillate, source of heat, heat towel or napkin, sea water or salty water, liquid soap (to test for the softness of water)

What to do:

You can perform this activity alone or in mixed group of not more than five (5) learners:

1. Watch this one-minute video to give you an idea **click here**
2. Design and conduct your own experiment by selecting your choice of materials from the list given.
3. Write a few sentences which summarise the experiment you conducted today. Remember to include:
   - A labelled diagram of your set up.
   - A numbered list of instructions (so it could be reliably repeated by another student)
   - A discussion of your results, and how these link (or do not link to the expected observations)

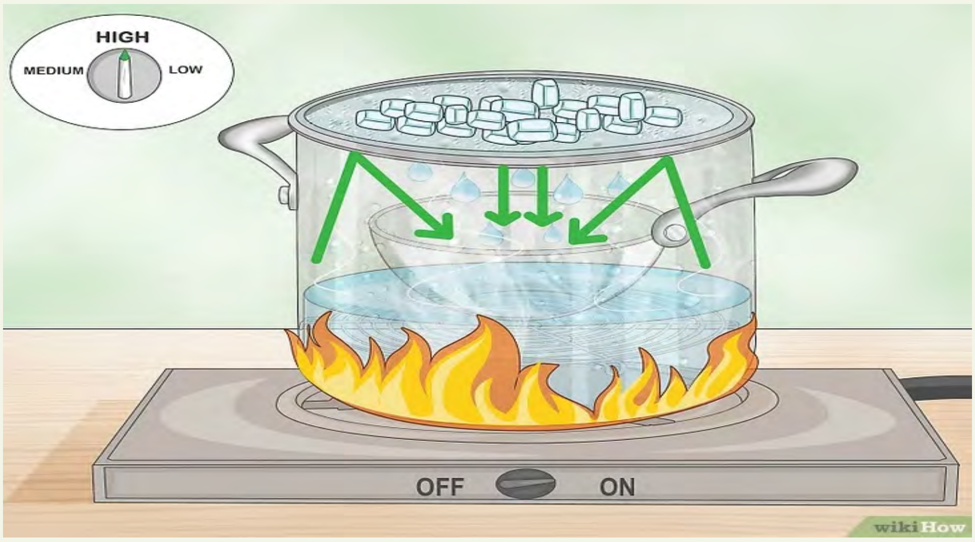


Figure 1.2: Simple distillation technique

Testing for softness and hardness of the distillate

1. Take equal amounts (about 100ml) of a sample of your distillate and sea/ salty water in separate plastic water bottles of same size and volume.
2. Add a teaspoon full of liquid soap to each sample.

3. Shake the bottles with their contents and compare their reactions in them.
4. Record and discuss your observations.

Safety:

- Make sure that bowls for heating can withstand boiling water.
- The collected distillate should not be consumed, eating, or drinking in a laboratory is against lab safety rules.
- Use heat towel/napkin to prevent burns on the fingers.
- Only the water in the collecting bowl will have distilled water. The remaining water will contain all the impurities you removed from the distilled water.
- Always secure bottle caps tightly before shaking to avoid spillage."
- Clean up any spills immediately while following proper disposal guidelines for the materials used.

Conclusion: Only the water in the collecting bowl will have distilled water. The remaining water will contain all the impurities you removed from the distilled water.

Hello learners, I am sure you had an exciting time with activity 2. The knowledge from this activity can be used to explain the water cycle where evaporation (boiling of water) separates water from contaminants/impurities (salt and others in water) and condensation (on the lid) returns it to a liquid state, free from minerals and contaminants.

Interesting, isn't it? Great.

Let us explore the importance of science with the next activity.

Activity 3

The Egg Drop Challenge

Scenario: There is egg crisis in senior high schools in Ghana! The Ghana Education Service is organising a famous Egg Festival for senior high schools, which is just around the corner, and the Director General has ordered rare, delicate eggs from poultry farmers around the country for the festival's grand egg painting competition. However, during transportation, the delivery truck accidentally drove over a pothole, causing the eggs to be pushed and shaken. As a result, many of the eggs were cracked, leaving the students in a state of anxiety. The Director General has called upon the SHS 1 science classes to use their knowledge of science to salvage the situation. You are tasked to design and build a gadget to protect the remaining eggs from breaking when dropped from a height of 2.0m.

What you need: Raw eggs (enough for each group to have one), marker, various materials (e.g., straws, cotton balls, tape, popsicle sticks, rubber bands, balloons, paper cups, cardboard, bubble wrap, etc.) for building an egg protective structure, scissors, a designated dropping area (like a balcony, staircase, or simply a maximum height of 2.0m from which the eggs can be dropped).

Figure 1.3: Homemade materials for egg drop challenge

What to do:

Pair with a friend or form a mixed group of not more than 5 learners.

1. Generate ideas and agree on a design, select appropriate materials and build your egg protective structure.
2. Present your design to the class, explaining the scientific principles behind your choices of materials and construction.
3. Conduct the egg drop test: Each group takes turns to use their structure to drop an egg from a designated height (2.0m). If the egg breaks, the group is out of the challenge.

4. Discuss the results as a class, focusing on what worked well and what could be improved.
5. Analyse the scientific concepts involved, e.g. forces acting, etc.
6. Share your experience of the importance of science.

Through the Egg Drop Challenge, you have not only learned about scientific principles but also gained practical experience in applying those principles to solve real-world problems. You have also learned the importance of collaboration (teamwork) and repetition in the scientific process.

Thus learners,

What is the importance of science?

Take a moment here to reflect on how science has improved your daily life. Think about the experimentation that will have gone into all the aspects of your life touched by science.

Conclusion: Record here your thoughts of what the biggest achievements of science have been, and what you think they could be in the future. After producing your own share these with your neighbour and discuss what they have produced.

Science has a special role, as well as a variety of functions for the benefit of our society:creating new knowledge, improving education, and increasing the quality of our lives.

Good job learners, let us continue our exciting journey with a look at the characteristics of science.

The Characteristics of Science

Key Question

Why is it essential for scientists to base their conclusions on evidence?

Record your thoughts or those of the class here:

....

....

....

Let us look at the key characteristics of science, such as being empirical, reproducible, systematic, consistent, tentative, predictable, valid, precise and accurate. Let us discuss each of the characteristics and their application.

Are you ready?

Good!

Picture the first characteristic: 'Empirical'.

What does it mean then to say science is empirical?

Record the thoughts of the class here:

Empirical: This means it relies on systematic observations and data gathered through experimentation or observation of the natural world. These observations are used to formulate hypotheses and theories.

In science, we do not rely solely on speculation or hearsay. Instead, we embrace empirical evidence. It is like detectives gathering clues to unravel a mystery, except our mystery is the natural world itself.

I am sure you are eager to explore more.

Let us do an activity!

Activity 4

Experiment to show that science is empirical

Title: Determining the Boiling Point of Pure Water at Sea Level

Key Questions:

a. What is the boiling point of water?

b. How does altitude affect the boiling point of water?

c. Why is it important to know the boiling point of water?

d. How can you measure the boiling point accurately and reliably?

Aim: To verify that the boiling point of pure water remains constant at sea level.

Hypothesis: The boiling point of pure water at sea level is 100 degrees Celsius (212 degrees Fahrenheit).

Key Questions (record your thoughts alongside each question):

a. What materials do you need for this experiment?

b. How should you set up the apparatus to ensure accurate results?

c. Why is it important to use distilled water in the experiment?

d. What safety precautions should you take when conducting the experiment?

What you need

Heat source (e.g., Bunsen burner/electric stove/coal pot), a beaker or any suitable heat-resistant container, thermometer (that will measure up to 100 degrees Celsius), water (free from impurities), stopwatch or timer.

NB: rainwater should be collected from a height above the ground to prevent being contaminated by impurities.

Data Collection and Observation

Key Questions (In your view, suggest answers to these questions):

a. What are the signs that water is boiling?

b. How can you ensure that you accurately record the boiling point?

c. What factors might affect the accuracy of your measurements?

d. How can you maintain consistency in your observations?

Procedure:

1. Fill the beaker or container with a fixed volume of water (e.g., 100 ml).
2. Insert the thermometer into the water without touching the bottom of the receptacle.
3. Place the beaker or container on the heat source.
4. Gradually increase the heat and monitor the temperature using the thermometer.
5. As the water temperature rises, observe and record the changes in temperature.
6. When the water boils, note the temperature and start the timer.
7. Continue boiling the water and monitor the temperature every 30 seconds for a few minutes.

NB: Repeat the experiment using water from at least three different sources.

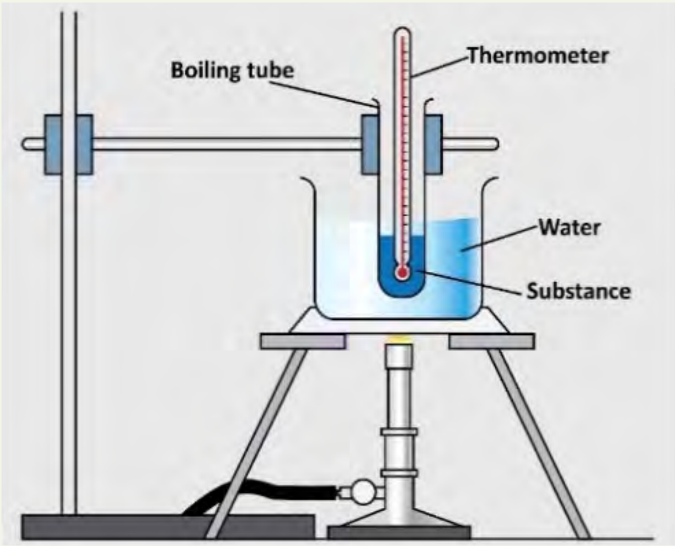


Figure 1.4: set-up to determine the boiling point of water.

Analysis and Conclusion

Key Questions (In your view, suggest answers to these questions):

a. What was the observed boiling point of water at sea level?

b. How does your experimental result compare to the standard boiling point of water (100°C or 212°F)?

c. What factors might have influenced any discrepancies in your results?

d. How can you improve the accuracy of your experiment in future trials?

Next is 'Consistency'. Nature is believed to operate according to consistent patterns and laws. Through scientific investigation, we strive to uncover these underlying principles, from the elegant laws of motion to the intricate principles governing genetics. This consistency allows you to make predictions and understand the Universe's inner workings.

Consistency, therefore, refers to the ability of scientific findings to be reliable and repeatable over time. It also means that other scientists can replicate experimental results using the same methods and procedures and that the findings are consistent with what is already known about the phenomenon being studied.

Why do you think that consistency is an important principle of Science? Imagine what science would be like without it. Record your thoughts and those of the class here:

Let us look at reproducibility as the next characteristics.

Reproducibility- Scientific research must produce results that others can repeat using the same methods and conditions.

Let us do an activity!

Activity 5

Experiment to show that science is consistent and replicable (reproducible)

Title: The Simple pendulum experiment

Aim: To conduct a simple experiment involving a pendulum to demonstrate that scientific results should be consistent and reproducible if the same methods are used, and factors are kept uniform.

Key Questions (Put your ideas on paper as you read each question)

i. What is the purpose of your experiment with the pendulum?

ii. How will you ensure that your experiment is reproducible by others?

iii. What factors do you need to consider and keep uniform throughout your experiment?

iv. How will you measure and record the variables involved in the pendulum experiment?

v. Why is it important to repeat the experiment multiple times with the same methods and conditions?

vi. What conclusions can you draw from replicating the experiment with the same methods and variables?

What you need

A sturdy string or thread, a small weight (e.g., a metal ball or a stone), a ruler or measuring tape, a stopwatch or timer, a stable point to hang the pendulum (e.g., a hook or a sturdy table edge or retort stand)

What to do

1. Attach the weight to one end of the string/thread securely.
2. Hang the other end of the string/thread from a stable point.
3. Measure and record the pendulum's initial length: Use the ruler or measuring tape to measure the pendulum's length (from the point of suspension to the centre of the weight). Record this length as "L" (initial length).
4. Hold the pendulum at a measured and fixed distance away from its resting position and release it from the same starting point each time.
5. Time the pendulum swinging to and fro ten times using the stopwatch or timer.
6. Record the time taken for the swings.
7. Repeat the experiment three times and compare the times taken for ten swings.
8. Change the length of the string (by shortening or lengthening it) and repeat the swinging process to and fro ten swings and record the time.

Analyse the data:

i. Compare the results for each repeat of the experiment.

ii. How do the results vary among the three repeats of the experiment?

iii. Are the results the same? If not, what reasons could account for the variability?

iv. Does changing the length of the string change the time taken for ten swings to and fro?

v. Compare your results with those of other groups in the class, do your findings agree with theirs?

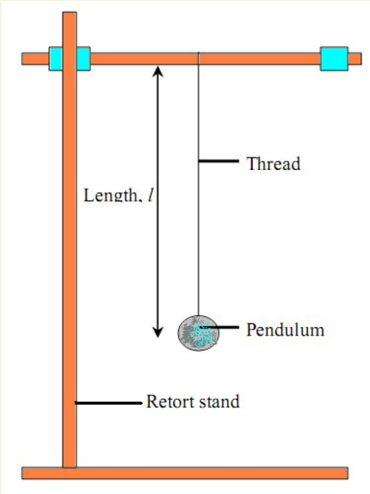


Figure 1.5: set-up for a simple pendulum experiment

Well done learners, let us turn our attention to another characteristic.

vi. What does it mean to say science is systematic in nature? Record your initial thoughts and those of the class here

Systematic methodology- This means scientific process follows an organized approach, with clear steps for hypothesis testing, data collection, analysis, and interpretation.

Let us do an activity!

Activity 6

Experiment to show that science is methodical (systematic)

Title: Investigating the presence of starch in plants.

Provide possible answers to key questions A, B and C.

Key Question A (record your thoughts alongside these questions):

i. What is starch, and what role does it play in plants?

ii. Why is it important to study the presence of starch in plants?

iii. How can you test for the presence of starch in plant materials?

iv. What are some common sources of starch in the human diet?

Aim: To test the presence of starch in plants.

Key Questions B (record your thoughts alongside these questions):

i. What materials do you need for this experiment?

ii. How should you prepare plant samples for testing?

iii. What reagents or chemicals are required to test for the presence of starch?

iv. How can you ensure that your experimental set-up is consistent and accurate?

What you need: Test tubes, test-tube stand, test-tube holder, heat source (e.g.electric kettle), dropper, filter paper, iodine solution, ethanol (alcohol), distilled water, green leaf.

Key Question C (record your thoughts alongside these questions):

i. What are the steps involved in conducting the starch test(s)?

ii. What are the expected results if starch is present in the plant samples?

What to do:

i. Gather leaves from plants exposed to sunlight for a minimum of 2 hours for testing.

ii. Pour boiling water from the electric kettle into a large beaker.

iii. Using forceps immerse a leaf in the hot water for three minutes.

iv. Remove the leaf from the boiling water with forceps and observe any changes. Record your observation in your science jotter.

v. Transfer the leaf to a labelled boiling test tube pushing it to the bottom with a glass rod.

vi. Fill the boiling test tube halfway with ethanol and place it in a hot water bath at 80 degrees Celsius for three minutes.

vii. Observe as the ethanol boils and record any changes observed.

viii. Remove the leaf from the boiling ethanol using forceps, rinse it under cold water.

ix. Gently place the leaf in a Petri-dish or a white tile and add iodine solution, ensuring complete coverage.

x. Record your observations.

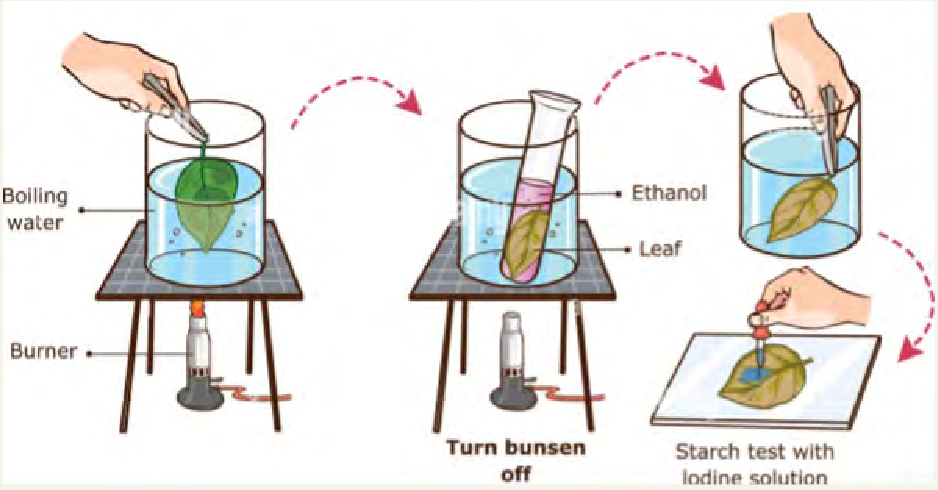


Figure 1.6: Steps for testing starch in green leaf

Safety:

- Keep the ethanol away from naked flames.
- Wear eye protection when working with ethanol or iodine solution to prevent chemicals from getting in contact with the eye.
- Take care with hot liquids.
- Be aware that plant sap may irritate the skin.

Observation:

After a few minutes, observe the development of a blue-black colour indicating the presence of starch.

Key Question D (record your thoughts alongside these questions):

i. What were the results of the starch tests for each plant sample?

ii. How do the results compare to your expectations?

iii. What factors might have influenced any differences in the results?

iv. How can you interpret the presence or absence of starch in different plant samples?

Consider now the concept of science being systematic. In the experiment just completed how did we determine beyond doubt that starch is present?

How did we ensure that our process was trustworthy? And that a casual observer would not think we were lying to them?

Well done learners. Let us discuss other characteristics

Tentative- This means that scientific knowledge and understanding are not fixed or absolute but are subject to change and revision as new evidence, data, and insights emerge. Can you think of any examples where this has happened? Either in recent memory or throughout history?

Predictability- refers to the ability of scientific investigations to make accurate and reliable predictions about future events or phenomena based on established scientific principles. Think of any unexpected events or findings that led to important changes, either in recent history or in the past?

Validity- refers to how scientific observations, data, and measurements accurately reflect the phenomenon under study. When scientific findings are valid, they are based on sound reasoning, empirical evidence, and rigorous scientific methods, with minimal influences from extraneous factors.

Let us consider two more characteristics, precision and accuracy! Let us read about them.

Precision- refers to scientific measurements' degree of accuracy, consistency, and reproducibility. Precise scientific measurements consistently produce similar results over multiple trials, with minimal deviation, error, or uncertainty.

Accuracy- refers to the correctness or truthfulness of scientific information or measurements. When scientific findings are accurate, they reflect the true nature of the phenomenon under study, with minimal errors, bias, or distortion.

Great learners, let us do an activity!

Activity 7

Experiment to determine whether given substances are acidic or basic.

What you need: red and blue litmus paper (you can also use red hibiscus petals/sobolo leaves to dye a filter paper, dry it and use as your home made litmus paper), orange juice, wood ash, vinegar, baking soda, unripe lemon, carbonated water, liquid soap, tomato juice, calcium carbonate (you can get it by grinding eggshells into powder), salt Petre. Milk of magnesia, calcium hydroxide powder (carbide waste from welder's shops can be used).

What to do:

Pair with a friend or in mixed group of not more than 5 learners.

1. Using red and blue litmus papers, test whether the following substances are acids or bases and present your findings in a table as shown below.

Test substances	Observation		Conclusion
	Red litmus	Blue litmus	
Orange juice			
Wood ash solution			
Vinegar			
Unripe lemon juice			
Carbonated water			
Bicarbonate of soda solution			
Liquid soap			
Tomato juice			
Calcium carbonate solution			
Salt Petre solution			
Milk of magnesia			
Carbide waste solution			

2. Identify the characteristics of science involved in this experiment and explain your answers.

Hello, learners. I hope you enjoyed the activity and can confidently explain the characteristics of science.

Activity 8: Creating a poster showing the key characteristics of science.

What have you learned in this session? Create a poster showing the key characteristics of science, explaining the significance of science and defining any terms used. Prepare your presentation for a whole-class gallery walk. (Note: see Annex 1 for some hints).

ANNEX 1 – POSSIBLE CONCLUSIONS

Activity 1

Science is not merely a subject to study or a collection of facts to remember; it is an exciting process. It is a way of thinking that encourages curiosity, questioning, and a deeper understanding of the world around us. All through your years at the basic level, you learnt about science by performing a number of experiments, recorded data and made inferences about natural phenomena. You will have gained deeper knowledge about the natural world and as a result can solve problems. Science is driven by curiosity, the insatiable desire to know and understand the natural world.

Thus, Science is the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena to widen people's understanding of nature and solve problems.

Activity 2

Expected Observations: The distillate is colourless, odourless and tasteless and easily forms lather with soap. Unlike the sea/salty water which does not easily lather with soap.

Activity 3

You will agree that from activity 3, you used your scientific knowledge to solve the problem in the real world. Your solution was made possible through creativity and innovation. Science is therefore an important channel of knowledge necessary for creation.

a. Similar to the above, scientific knowledge has brought some innovations like the creation of computers, satellites, x-rays, and cell phones which has proven invaluable. Other importance include:

b. Science enhances global understanding - being able to accurately predict the weather has enabled agriculture to flourish worldwide.

c. Scientific Research boosts health (yielding medications, vaccinations, and therapies) - extending lifespans and improving the quality of lives.

d. Science has improved diverse transportation modes in automobiles, aircraft, ships, and space exploration among others.

Activity 4

Expected Results:

According to the hypothesis, the boiling point of water at sea level is expected to be 100 degrees Celsius (212 degrees Fahrenheit). Therefore, during the experiment, you will observe that the water boils at this temperature and remains constant as long as it continues to boil.

Conclusion:

It can be identified that the boiling point of water without impurities at sea level remains constant at 100°C or 212°F. This allows you to accept your hypothesis. As the results are collected scientifically and agree with your hypothesis, you have demonstrated the use of empirical measurement in the testing and confirmation of the scientific hypothesis as a fact.

NB: Sea level refers to the level of sea at normal atmospheric temperature and pressure. These may differ from the conditions in our laboratory.

Activity 5

Conclusion:

The time taken for ten swings to and fro should be very similar for the three repeats of the experiments as long as the length of the string and the point of release are kept uniform. Thus, properly designed and executed experiments are consistent and replicable.

Any small variability in the results will be down to errors of timing or small inconsistencies in the height of release of the experiment. Increasing the length of the pendulum string should increase the time taken for ten swings.

Activity 6

Conclusion

The leaf turning blue-black is an indication that photosynthesis has taken place and starch has been prepared as a result.

Activity 7

1. Systematic, observation, empirical, verifiable, etc.

Activity 8

You have learned that:

1. Science is the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena to widen people's understanding of nature and solve problems.
2. The importance of science is that it helps us to understand the world better, improves our standard of living, and makes life easier and more comfortable.

The key characteristics of science include empirical, reproducible, systematic, consistent, tentative, predictable, valid, precise and accurate.

EXTENDED READING

The nature of science- http://www.project2061.org/publications/sfaa/online/chap1.htm

Explore the misrepresentation of the nature of science in the media, which we miss because we are not looking for it. You could do this by reading one of the myths in the article Myths of the nature of science or listing your own examples of occasions when you have seen or heard something through the media that could have reinforced this myth in your mind.

SCIENTIFIC PROJECT DESIGN

A scientific project design is a systematic plan for conducting scientific research or investigation. It outlines a particular scientific study or experiment's objectives, methods, procedures, and expected outcomes.

Activity 9: Discussing characteristics of science in the design of scientific projects

Key Questions (Note: solutions can be found in Annex 2)

1. Let's start by understanding what makes science unique. From the previous session, you discussed the characteristics of science that guided inquiry and helped generate reliable knowledge. List some of these characteristics.
2. What are some of the ways you can incorporate scientific principles into the design of a project?

Now, let us discuss the impact of scientific design on your project. When you incorporate scientific characteristics, such as empirical methods and falsifiability, you can make your project outcomes more reliable and credible.

3. How do you think scientific design can influence the quality of your project?

Lastly, you can effectively communicate your design project findings using scientific principles. It's important to present your work in a clear and structured manner, following scientific communication standards.

4. What other ways can you effectively communicate your design findings using scientific principles?

Examples of projects that require scientific designs are investigating the effects of different fertilizers on plant growth, relationship between the period of a pendulum and its length, investigating acid-base properties using hibiscus flower juice indicator, construction of solar oven for cooking and many more.

In the section, you performed various experiments to verify each of the scientific characteristics. In this section, you are using these characteristics to design scientific projects.

Project Design Activities

In this section, you will do activities to explore various designs that focus on specific characteristics. You will be engaged and have the chance to interact with them first-hand.

Now, in groups of six you are to design the following real-world projects and identify which of the characteristics relates to that project. You will find suggested answers in Annex 1.

NB: (The above instruction applies to all the activities in this section)

Activity 10: Investigating the effects of different fertilisers on plants growth

Title: A design for investigating the effects of different fertilizers on plant growth

Aim: To come out with a design to be used to apply the characteristics of science to investigate the effects of different fertilizers on the growth of plants.

The Design

1. Select sixty identical seedlings of the same plant species (e.g., tomato plants). All the seedlings must be of the same age.
2. Divide them into three equal groups.
3. Plant seedlings into soil.
4. Assign each group a different fertilizer treatment. For example, Group 1 could receive a commercial chemical fertilizer (NPK) of $20cm^3$, Group 2, an organic fertilizer of about 1kg (equivalent to $20cm^3$ of chemical fertilizer, and Group 3, a control group with no fertilizer.

Fig 1.7: Learners applying fertilizer on plants

NB: Ensure all groups receive the same environmental conditions (e.g., light, temperature, water).

Observation: Observe, measure and record the plants' height and number of leaves at regular intervals of three days over a set period (e.g., six weeks)

Table 10: Sample table

Day	Group 1		Group 2		Group 3	
	Mean Height	Mean Number of Leaves	Mean Height	Mean Number of Leaves	Mean Height	Mean Number of Leaves
0						
3						
6						
9						
12						
15						

Analysis and discussion

Analyse the collected data using statistical methods (for example, plot average values against time on the graph with a different line for each treatment) to compare plants growth patterns across different fertilizer treatments.

Discuss the implications of the findings, including potential applications in agriculture and areas for further research.

Conclusion

Draw conclusions based on the results obtained, considering the effects of different fertilizers on plant growth and any significant differences observed.

Activity 11: A project on a solar oven

Title: Produce a solar oven

Aim: Produce a solar oven to be used for cooking at home.

Material: cardboard box, Box knife or scissors, Aluminium foil, Clear tape, Plastic wrap, Black construction paper, Newspapers, Ruler or wooden spoon, Thermometer, chocolate, marshmallows, graham cracker

Fig 1.8 : Learners constructing solar oven

Methods:

i. Using a pizza box and knife cut a flap in the lid, leaving one inch between the edge of the box and where you cut. This is shown in **Fig.1.9**: stage 1

ii. Fold the flap out to stand up when the box lid is closed.

Fig 1.9 : Stage 1

iii. Cover the inner side of the flap with aluminium foil folding the edges of the foil over the flap to keep it in place. Tape down the foil and try to keep it as smooth as possible.

Fig 1.10 : Stage 2

iv. Lift the lid and line the inside of the box with aluminium foil – shiny side out.

v. Cover the opening made in the box lid by the flap with plastic wrap. The wrap should be as airtight as possible. Tape the plastic wrap in place.

Fig 1.11 : Stage 3

vi. Cut a piece of black construction paper so that it's 2 inches smaller along each edge than the bottom of the box. If you have a large box, you might need more than one piece of paper.

vii. Centre the construction paper in the centre of the bottom of the box, on top of the foil. Tape in place. This is shown in Fig.1.12; stage 4.

Fig 1.12 : Stage 4

viii. Take newspapers and make four rolled tubes of newspaper out of multiple sheets of paper. Each of these rolls will go along the edges on the inside of the box, creating a border. Tape the rolls in place. Be sure the rolls do not stop the lid from closing. This is shown is **Fig.1.13**: stage 5.

Fig 1.13 : Stage 5

ix. Using a pencil, create a "dent" in the box, where you can insert the pencil and use it as a "kickstand" for the lid to remain upright for cooking

Fig 1.14 : Stage 6

x. The solar oven is ready to be set outside on a sunny day while the sun is high overhead, between 11 AM and 2 PM when the sun's rays are the strongest. Put the graham cracker, topped with a piece of chocolate, and a marshmallow in the oven.

Fig 1.15 : Complete Solar Oven

xi. Close the lid. Prop up the flap you cut and lined with aluminium foil using the pencil.

xii. Let the sun do its work! It will take some time.

Discussion: With a peer or group of peers, discuss the design of the oven and consider improvements that could be made to make it more efficient. Consider how the efficiency of different solar ovens could be measured; write a brief method for your suggested investigation.

Activity 12: Building a balloon-powered car

Title: Balloon-powered cars

Aim: Design and build your own balloon-powered car

Suggested materials: Plastic bottle (empty and clean), Straws (plastic or paper), Balloon, Bottle cap, Rubber bands, Four bottle caps (for wheels), Tape (duct tape or masking tape), Scissors, Cardboard or foam board (for making the car body), Pen or marker.

See the picture below for an example of how your balloon-powered car may look, although you may choose a different design!

Hint:

Do some background research on balloon-powered cars. Do an internet image or video search for "balloon powered car" and you will see many different designs, made from different materials. This can inspire your design.

Think about what materials you want to use for your car, and how you will connect the different pieces together. For example, what do you want to use for wheels?

Make a sketch of your design on paper before you start building.

Observation:

It will be observed that the air escaping from the balloon will propel the car forward.

Suggest an alternative way to improve the performance of your car if it doesn't move as expected.

Activity 13: Tentative nature of science

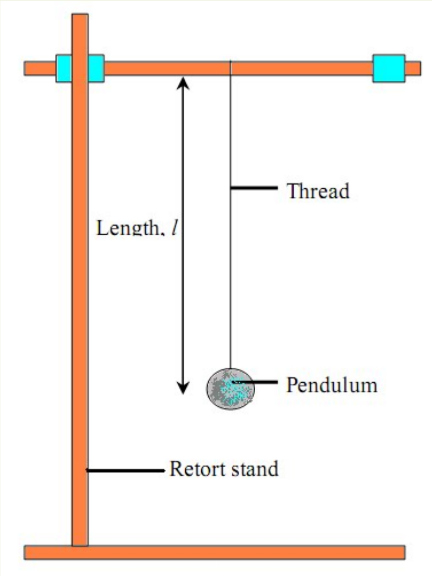
Title: The Pendulum Experiment - Demonstrating the Tentativeness of Science

Aim: To conduct a simple experiment involving a pendulum to demonstrate the tentative nature of science by observing how different factors can influence the pendulum's behaviour and how scientific conclusions may evolve based on additional data and analysis.

Materials: A sturdy string or thread, a small weight (e.g., a metal ball or a stone), a ruler or measuring tape, a stopwatch or timer, a stable point to hang the pendulum (e.g., a hook or a sturdy table edge)

Procedure:

1. Set up the pendulum:
   - Attach the weight to one end of the string/thread securely.
   - Hang the other end of the string/thread from the stable point.



2. Use the ruler or measuring tape to measure the pendulum's length (from the point of suspension to the centre of the weight). Record this length as "L" (initial length).

3. Conduct the pendulum swing experiment:
   - Hold the pendulum away from its resting position and release it from the same starting point each time.
   - Time the pendulum for a fixed number of swings (e.g., 10) using the stopwatch or timer.
   - Record the time taken for the swings.

4. Change variables:
   - Experiment multiple times while changing one variable at a time. For example, you can alter the pendulum's length (by shortening

or lengthening it) or change the amplitude (the angle at which you release the pendulum).

- Record the results for each variation, including the new length of the pendulum or amplitude and the corresponding swing time.

5. Analyse the data:

- Compare the results for each variation of the experiment.
- Look for patterns and relationships between the length/amplitude and the swing time.

Discuss how changing different variables affects the pendulum's behaviour and consider why scientists often revise their models as new investigations are carried out.

Activity 14: Experiment to demonstrate various characteristics of science

Choose one of the experiments that you carried out during week 2 and present your findings from the experiment to the class, including an analysis of how the experiment demonstrates various scientific principles and how the method could be adjusted in order to produce more reliable results.

Extended Reading

Access and use the following sources and resources to find out about designing scientific project and show which of the characteristics of science that have been involved.

1. Internet resources such as Massive Open Online Courses (MOOCs)
2. https://evolution.berkeley.edu/nature-of-science/characteristics-of-science/and
3. https://www.sciencebuddies.org/science-fair-projects/project-ideas/list)
4. https://evolution.berkeley.edu/nature-of-science/characteristics-of-science/and
5. https://www.sciencebuddies.org/science-fair-projects/project-ideas/list
6. https://evolution.berkeley.edu/nature-of-science/characteristics-of-science/and
7. https://www.sciencebuddies.org/science-fair-projects/project-ideas/list)
8. https://evolution.berkeley.edu/nature-of-science/characteristics-of-science/and
9. https://www.sciencebuddies.org/science-fair-projects/project-ideas/list)

ANNEX 2 – SOLUTIONS TO ACTIVITIES

Activity 9

1. Some of the key characteristics of science include empiricism, and replicability. These characteristics play crucial roles in ensuring the reliability and validity of scientific knowledge.
2. You can apply scientific principles by using empirical methods, such as collecting and analysing data, to inform your design decisions. You can also formulate hypotheses related to your design goals and create experiments or investigations to gather data that supports or challenges those hypotheses. By using scientific principles, you can make your design process more systematic, and evidence based.
3. It must be noted that scientific design helps you to gather accurate data, make informed decisions, and ensure that your design outcomes are based on evidence rather than assumptions. It also allows you to critically evaluate your design choices and make improvements based on the findings of your experiments or investigations. By applying scientific principles, you can create more effective and successful design solutions.
4. When communicating your design findings, you should use scientific terminology and concepts to explain your design process and outcomes. You should present your data, analysis, and conclusions in a way that others can understand and evaluate. By using scientific principles in your communication, you can ensure that your findings are transparent, credible, and accessible to others.

Activity 10

Examples of Characteristics of Science Applied in the above project

Empirical: The project will involve conducting experiments and collecting empirical data by observing and measuring the growth of plants.

Objective: The project will follow standardized methods of experimentation to minimize bias and subjectivity. Care will be taken to ensure accurate and unbiased measurements and observations.

Verifiable: The project will formulate testable hypotheses regarding the effects of different fertilizers on plant growth. The results obtained will help determine if the hypotheses are supported or contradicted.

Replicable: The experimental set-up and procedures will be documented to enable other researchers to replicate the study and verify the findings. The project will provide detailed instructions and guidelines for replicating the experiment.

Cumulative: The project will contribute to the cumulative body of scientific knowledge by adding new data and insights to the current understanding of the effects of fertilizers on plant growth.

Tentative: The project recognizes that scientific knowledge is tentative and subject to revision. The findings will be interpreted within the context of current understanding and may lead to modifying or refining existing theories or practices.

Predictive: The project will analyse the data collected to predict the effects of different fertilizers on plant growth. These predictions can serve as a basis for further experimentation or practical applications in agriculture.

Activity 11

Examples of Characteristics of Science Applied in the above project

Empirical: Through experiments and observations, students can gather empirical evidence to support the effectiveness of their solar oven design.

Systematic: The design and construction of a solar oven follows a systematic approach. Students need to develop a clear plan, consider different variables, and organize their experiment in a logical manner. They will systematically test and modify their design to optimize its performance.

Testable and Falsifiable: The experiment to construct a solar oven involves formulating hypotheses about how different design elements will affect its cooking efficiency. These hypotheses are testable by conducting experiments and measuring the oven's performance. If the results do not align with the predictions, the hypotheses can be revised or rejected.

Replicable: The experiment should be replicable, meaning that other individuals should be able to follow the same instructions and construct a similar solar oven. Replicability allows for the validation of results and the verification of the oven's cooking capabilities.

Tentative: The knowledge gained from the experiment is tentative in nature. Students may discover new insights, encounter unexpected challenges, and make adjustments to improve their solar oven design. The experiment's outcomes can lead to further revisions and refinements in the understanding and construction of solar ovens.

Cumulative: The experiment contributes to the cumulative knowledge in the field of solar energy and cooking. The findings from the experiment can be shared with others, building upon existing knowledge and inspiring further research and innovation in solar oven design and applications.

Activity 12

Examples of Characteristics of Science Applied in the above project

Empirical: Constructing a balloon-powered car involves empirical observation and experimentation. Students test different designs, materials, and configurations to determine how they affect the car's performance. They gather empirical evidence through observations and measurements to support their conclusions.

Systematic: The experiment follows a systematic approach. Students develop a plan, identify variables, and design controlled experiments to test specific hypotheses. They systematically vary factors such as balloon size, car weight, or wheel material to understand their impact on the car's speed and distance travelled.

Testable and Falsifiable: Hypotheses can be formulated and tested in balloon-powered car experiments. For example, a hypothesis might be that increasing the size of the balloon will result in greater propulsion and increased speed. The hypothesis can be tested by constructing cars with different balloon sizes and measuring their performance.

Replicable: The experiment should be replicable by others. Detailed instructions and specifications should be provided so that other students or researchers can construct similar balloon-powered cars and reproduce the results. Replicability allows for validation and verification of the experiment's findings.

Tentative: Knowledge gained from the experiment is tentative and subject to revision. Students may discover unexpected results or encounter challenges that require them to revise their initial hypotheses or redesign their cars. The experiment promotes a willingness to revise and refine understanding based on new evidence.

Cumulative: The experiment contributes to the cumulative knowledge in the field of balloon-powered vehicles. Students' findings can be shared with others, building upon existing knowledge and inspiring further experimentation and innovation in the design and performance of balloon-powered cars.

Activity 13

By conducting the pendulum experiment and analysing the data, participants will realize that scientific conclusions are tentative and subject to change based on various factors and evidence. They will understand the importance of considering different variables and the limitations of a specific experiment in drawing scientific conclusions. This experiment is a tangible example of how science is an ongoing process of learning and refinement.

Examples of Characteristics of Science Applied in the above Project

Empirical Evidence: The experiment relies on direct observation and measurement of the relationship between pendulum length and period.

Systematic Observation: The experiment follows a systematic procedure, changing one variable (length) while keeping others constant to observe its effect.

Predictive Power: By analysing the relationship, you can predict how changing the length of the pendulum will affect its period.

Objectivity: By ensuring the mass of the weight used is constant, the type and length of string is kept constant and there is an agreed protocol for measuring the length o the pendulum, bias is removed, and the experiment can be considered objective.

Testability: The hypothesis that the length of a pendulum depends on its length is testable through experiment. By conducting this experiment and analysing its results, you can gain a deeper understanding of the characteristics of science within the realm of physics.

APPLICATION OF CHARACTERISTICS OF SCIENCE IN OUR EVERYDAY LIFE

We engage in various activities in our everyday life. Sometimes you argue with friends, bring out ideas or options for how to solve a problem and then finally agree on the option you believe will work. With your knowledge on characteristics of science from your previous discussions, we will discuss how they are applied in areas like the home, school or education, health, agriculture and industry. *In your small groups, you can list other areas of your community you think these scientific characteristics are applied.*

Application of Characteristics of Science in Health and Medicine

Activity 14: Discussing characteristics of science in medicine

Discuss with your friends how the characteristic of science were applied in medicine, for example in discovering vaccines for COVID-19 during the pandemic. You can use your search engine to surf the internet to help you with the facts.

Fig. 1.16: Scientists discovering vaccines in the laboratory

Application of Characteristics of Science in the Home

We apply characteristics of science in our everyday life including the home. Let us go through the following activity and point out which of these characteristics are applied.

Activity 15: Application of characteristics of science in cooking

In your small group

i. Use Fig. 1.17 to help you Identify a meal of your choice.

ii. Discuss where and how you will get the ingredients to prepare the meal.

iii. Describe among yourselves the steps involved in cooking that meal.

iv. Analyse the scientific characteristics were applied in the process of your discussions (Note: suggested answers are in Annex 1).

v. Present your findings to the class.

Fig. 1.17: A woman cooking

Application of Characteristics of Science in School or Education

Formal education like learning General Science occurs in the school.

Activity 16: Application of characteristics of science in school

Describe what you see in Fig. 1.18, and consider which of the scientific characteristics are involved in school.

Fig. 1.18: Learners performing experiment in the science laboratory.

Application of Characteristics of Science in Agriculture

Having gone through application of the characteristics of science in the home, let us discuss how it applies in agriculture.

Fig. 1.19: Agriculture research

Activity 17: Discovering characteristics of science in agriculture

Observe the image in fig.1.19

i. describe what you see with your friends

ii. which crops do you think go through a similar process in the image?

iii. explain among yourselves the types of characteristics of science that is applied in the process above.

Application of Characteristics of Science in Industry

Activity 18: Explanation of characteristics of science.

Explain the types of characteristics of science that are applied in industry.

Extended Reading

Posterpicturesshowingscenariosinwhichthecharacteristicsofsciencearedisplayed.
https://evolution.berkeley.edu/nature-of-science/characteristics-of-science/
https://www.sciencebuddies.org/science-fair-projects/project-ideas/list

REVIEW QUESTIONS

Review Question 1

Exercise 1

Crossword Puzzle

Use the clues to fill in the words below.

- Words can go across or down.
- Letters are shared when the words intersect.

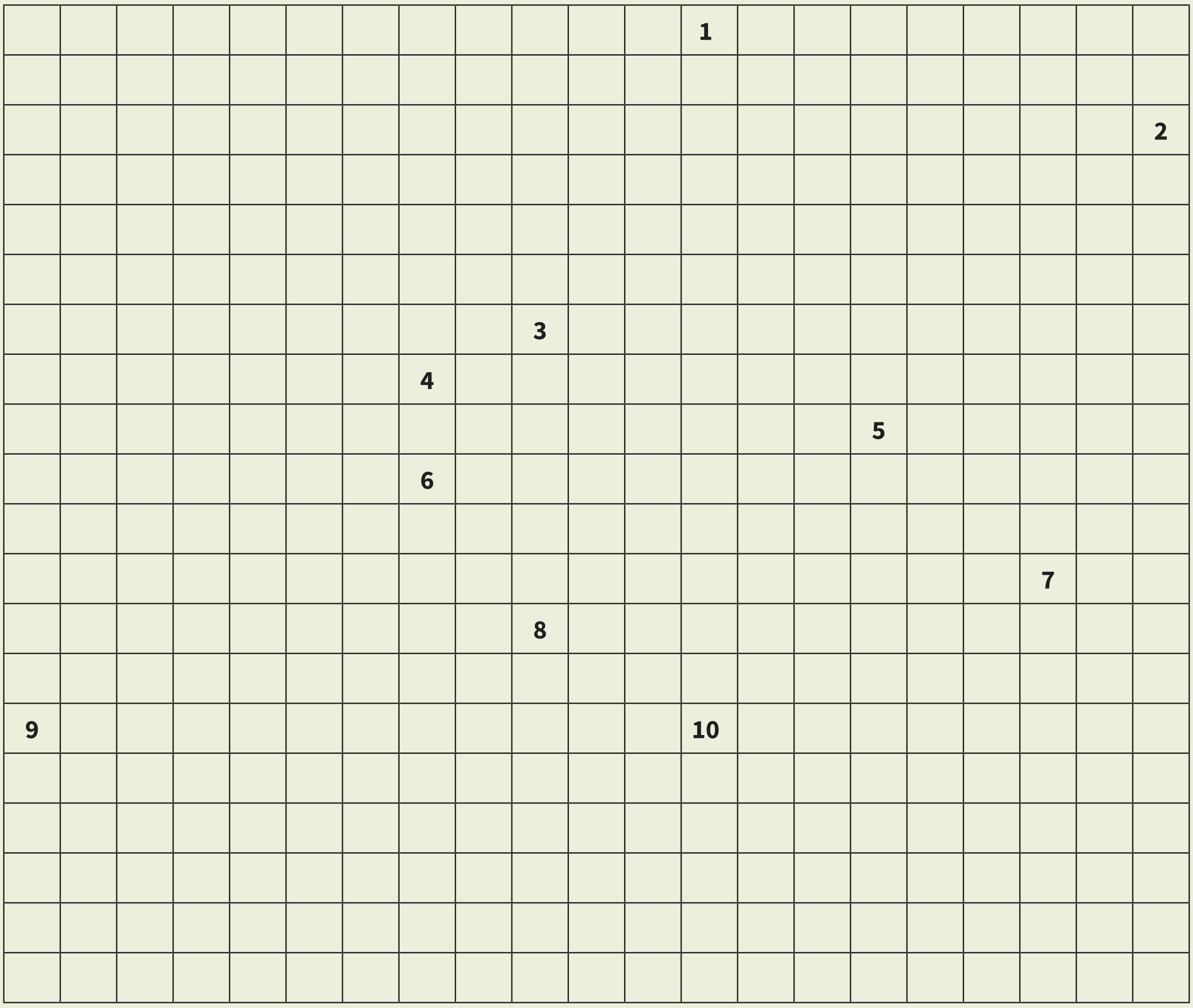
Across

3. means that scientific knowledge and understanding are not fixed or absolute but are subject to change.
6. refers to the ability of scientific investigations to make accurate and reliable predictions about future events or phenomena based on established scientific principles.
9. refers to the scientific process that follows an organized approach, with clear steps for hypothesis testing, data collection, analysis, and interpretation.
10. relies on observations and data gathered through experimentation or observation.

Down

1. refers to the ability of scientific findings to be reliable and repeatable over time.
2. refers to how scientific observations, data, and measurements accurately reflect the phenomenon under study.
4. means scientific research must produce results that others can repeat using the same methods and conditions.
5. means seeing and accepting facts as they are, not as one might wish them to be.
7. refers to scientific measurements' degree of accuracy, consistency, and reproducibility.

8. refers to the correctness or truthfulness of scientific information or measurements.



Exercise 2

Answer the following questions

1. How would you explain six characteristics of science to your younger student?
2. How would you explain six characteristics of science to your younger student?
3. Ali looks on as his parents make tea using teabags every morning before they go to work. This is to enable him to prepare tea in the future as he grows. As a learner of science identify and discuss the characteristics of science involved in this daily process.

4. An SHS 1 learner is required to use 150cm^3 of water in an experiment. As a learner of science show how to measure 150cm^3 of water using a measuring cylinder and identify any characteristics of science applied.

Research Work

Use the internet and other resources to search for more information about one of the characteristics of science. Think about a historical or current experiment or practice where this characteristic is key. Explain how the experiment or practice you have chosen exemplifies the characteristic and it’s role in Science. Present your report which should include posters, diagrams and charts about your findings to the class.

Review Question 2

1. Name two ways of applying characteristics of science in
   i. education
   ii. health and
   iii. agriculture.
2. People living in a town realised that most the children and some adults were frequently getting ill. The medical reports of those who visited the clinic pointed to malaria infection. As a student of science, how will you apply the characteristics of science to identify the causes?

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