Nanyang Girls' High School
Secondary One Science
The Nature of Science

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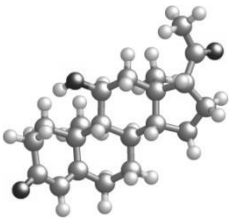

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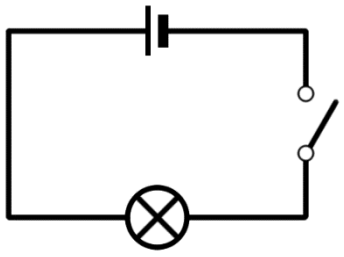
Name: …… **( )**

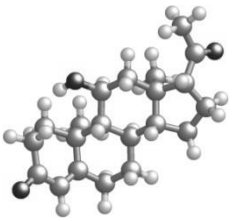
Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – People Bingo!

- Find someone in your class who…

1. Can name the scientist shown below:  • Sign ……	**2.** Can briefly explain how nutrients and oxygen are transported about the bodies of animals. • Sign ……	**3.** Can name at least four different forms of energy. • Sign ……
	4. Can recall the formula for water and the formula for carbon dioxide. • Sign ……	**5.** Can name the scientist shown below:  • Sign ……
6. Wants to be a veterinarian. • Sign ……	**7.** Can briefly explain differences between plant cells and animal cells. • Sign ……	
8. Can explain how to make the lightbulb in a circuit shine more brightly or more dimly by adding / removing more batteries, bulbs and / or wires.  • Sign ……	**9.** Can name some typical characteristics of a good scientist. • Sign ……	**10.** Can recall the test for carbon dioxide gas. • Sign ……
	11. Can explain what causes global warming. • Sign ……	**12.** Wants to be an astronaut. • Sign ……



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Class: ……

Date: …… **/** …… **/** ……

Students' Perceptions of Science

"*We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology*."

Carl Sagan (1934 – 1996), Director of Interplanetary Studies, NASA.

1. What do you think science is all about?

……

……

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2. Why is science important in your everyday life?

……

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3. Why do you think it is important to learn about science?

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4. Why do you think science is interesting and exciting?

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Continued…

5. How is science portrayed in the media (*e.g.* newspaper, advertisements and films)?

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6. Why do you think science might be difficult to study?

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7. What do you want to learn about science?

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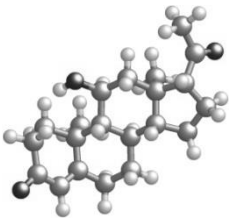

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Class: ……

Date: …… **/** …… **/** ……

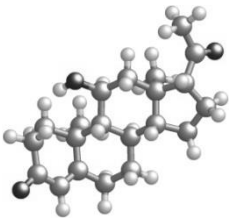
The Nature of Science – Survey

Instructions

Below are 25 statements describing science or things related to Science. Read each statement carefully and then place a tick in the appropriate box (☑) "Yes" if you are inclined to agree with the statement and "No" if you are inclined to disagree with the statement. Check your answers to the survey once again at the end of the Nature of Science unit to see if / how they have changed.

	Statement	Yes	No
1.	Science is primarily a method for inventing new devices.	☐	☐
2.	Science can prove anything, solve any problem, and answer any question.	☐	☐
3.	Science involves dealing with many uncertainties.	☐	☐
4.	Science is primarily concerned with understanding how the natural world works.	☐	☐
5.	Astrology (predicting your future based upon the arrangement of stars and planets) is a science.	☐	☐
6.	Science requires a lot of creative activity.	☐	☐
7.	Science always provides tentative (temporary) answers to questions.	☐	☐
8.	A "hypothesis" is just an "educated guess" about anything.	☐	☐
9.	Scientists can believe in God or a supernatural being and still do good science.	☐	☐
10.	Science is most concerned with collecting facts.	☐	☐
11.	Most engineers and medical doctors are practicing scientists.	☐	☐
12.	Something that is "proven scientifically" is no longer subject to change.	☐	☐
13.	Science can be done poorly.	☐	☐
14.	Scientific concepts and discoveries can cause new problems for people.	☐	☐
15.	Scientists have solved most of the major mysteries of nature.	☐	☐
16.	Science can study objects and events from millions of years ago.	☐	☐
17.	Knowledge of how science works is important for all educated people.	☐	☐
18.	Scientific experimentation usually involves trying something just to see what will happen, without predicting a likely outcome.	☐	☐
19.	Anything done scientifically can be relied upon to be accurate and reliable.	☐	☐
20.	Scientists assume that nature follows the same "rules" throughout the universe.	☐	☐
21.	Scientists often try to disprove their own ideas.	☐	☐
22.	Science can be influenced by race, gender and / or religion of the scientist.	☐	☐
23.	Different scientists may get different solutions to the same problem.	☐	☐
24.	Disagreement between scientists is one of the weaknesses of science.	☐	☐
25.	Any study done carefully and based on observation is scientific.	☐	☐

• Activity adapted from Indiana University Bloomington, http://www.indiana.edu



Sc!ence

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Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – Of Sunsets, Souls and Senses

Essential Questions

What questions can science answer? Are there any limitations to science? How does "doing science" require us to use our senses?

Instructions

1. For each item below, indicate with a tick in the appropriate box (☑) which items you think *can* be investigated by science, and which items *cannot*.
2. For each item below, indicate with a tick in the appropriate box (☑) which *senses* you would use to investigate those items.

Item	Can science study this item?		Senses that can be used to study the item…				
	Yes, it can	No, it cannot	Hear	See	Touch	Smell / Taste	Cannot be detected directly
1. Earthquakes	☐	☐	☐	☐	☐	☐	☐
2. Viruses	☐	☐	☐	☐	☐	☐	☐
3. Angels	☐	☐	☐	☐	☐	☐	☐
4. Cells	☐	☐	☐	☐	☐	☐	☐
5. Flying Carpets	☐	☐	☐	☐	☐	☐	☐
6. Stars	☐	☐	☐	☐	☐	☐	☐
7. Mind Reading	☐	☐	☐	☐	☐	☐	☐
8. Souls	☐	☐	☐	☐	☐	☐	☐
9. Blue Sky	☐	☐	☐	☐	☐	☐	☐
10. Rainbows	☐	☐	☐	☐	☐	☐	☐
11. Heart Disease	☐	☐	☐	☐	☐	☐	☐
12. Dinosaur Bones	☐	☐	☐	☐	☐	☐	☐
13. Tides	☐	☐	☐	☐	☐	☐	☐
14. Witchcraft	☐	☐	☐	☐	☐	☐	☐
15. Flowers	☐	☐	☐	☐	☐	☐	☐

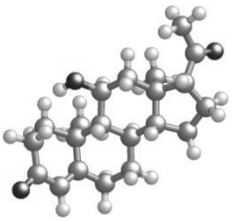
Continued…

Item	Can science study this item?		Senses that can be used to study the item…				
	Yes, it can	No, it cannot	Hear	See	Touch	Smell / Taste	Cannot be detected directly
16. Fairies	☐	☐	☐	☐	☐	☐	☐
17. Beautiful Music	☐	☐	☐	☐	☐	☐	☐
18. Love	☐	☐	☐	☐	☐	☐	☐
19. Ghosts	☐	☐	☐	☐	☐	☐	☐
20. Unicorns	☐	☐	☐	☐	☐	☐	☐
21. Beautiful Sunset	☐	☐	☐	☐	☐	☐	☐
22. Flying Saucers	☐	☐	☐	☐	☐	☐	☐
23. Atoms	☐	☐	☐	☐	☐	☐	☐
24. Pregnancy	☐	☐	☐	☐	☐	☐	☐
25. Weather	☐	☐	☐	☐	☐	☐	☐
26. Cancer	☐	☐	☐	☐	☐	☐	☐
27. Horoscopes	☐	☐	☐	☐	☐	☐	☐
28. Santa Claus	☐	☐	☐	☐	☐	☐	☐
29. God	☐	☐	☐	☐	☐	☐	☐
30. Origin of Life	☐	☐	☐	☐	☐	☐	☐
31. Extinct Life	☐	☐	☐	☐	☐	☐	☐
32. Murder not Seen	☐	☐	☐	☐	☐	☐	☐
33. Electricity	☐	☐	☐	☐	☐	☐	☐
34. Human Intelligence	☐	☐	☐	☐	☐	☐	☐

Reflection

- Which of the 16 Habits of Mind and which critical thinking skills did you use during this activity?
- At the end of the Nature of Science unit, review this activity once more and reflect on if / how your perception of science has changed.

• Activity adapted from Indiana University Bloomington, http://www.indiana.edu • Calvin and Hobbes © Bill Watterson.



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Name: …… **( )**

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Date: …… **/** …… **/** ……

The Nature of Science – CONPTT Grid

Is This Really Science?

Background Information – Science Defined

a) Science is limited to studying only the problems of the natural world that can be understood by using the process of science (the scientific method).

b) Scientists deal with natural phenomena (events) which can be observed, measured and tested by scientific methods. Scientists must be able to use their senses to observe (either directly or indirectly) and evaluate.

c) The processes of science are very successful in dealing with problems within the limits of science (within the limits of the natural world).

d) Scientific study is based upon the assumption that the universe is orderly, reasonable and testable.

e) A valid scientific theory offers a well-defined naturally occurring cause (mechanism) which explains how or why a natural event (phenomenon) occurs.

f) Scientific theories are always subject to change (tentative, uncertain).

g) Science does *not* have the answers to all of the questions in the universe, or the solutions to all human problems.

Introduction

For something to qualify as a science or a scientific statement, it must satisfy six criteria; **c**onsistent, **o**bservable, **n**atural, **p**redictable, **t**estable and **t**entative. If something satisfies most, but not all, of the criteria, then it may be classified as a protoscience (a newly emerging area of science). If something does not satisfy any of the criteria, then it is either a pseudoscience (something that is presented as scientific, but is supported by unprovable claims and does not follow the scientific method) or a non-science (something that may be logical and follow good reasoning, but falls outside the realms of science). The six criteria are listed on page 2, with a brief explanation about each one.

Criteria	Within the Realm of Science	Outside the Realm of Science
1. **C**onsistent	When observations and / or experiments are repeated under the same conditions, the results are reasonably the same.	When observations and / or experiments are repeated under the same conditions, the results are *not* the same.
2. **O**bservable	Phenomenon or evidence can be observed by human senses or an extension of those senses.	Phenomena or evidence *cannot* be observed by human senses or an extension of those senses.
3. **N**atural	A natural cause or naturally occurring mechanism is used to explain how or why an event happens.	A natural cause or naturally occurring mechanism *cannot* be used or is *not* used to explain how or why an event happens.
4. **P**redictable	Accurate predictions and conclusions are based on natural causes, not on presupposed or assumed information.	Accurate predictions and conclusions are *not* based on natural causes, but usually based on presupposed or assumed information.
5. **T**estable	Controlled experiments can be designed to test the natural cause of the event or phenomenon.	Controlled experiments *cannot* be designed to test the natural cause of the event or phenomenon.
6. **T**entative	Explanations (models, hypotheses, theories, laws) of the cause or mechanism of an event are subject to change when required by new evidence.	Explanations (models, hypotheses, theories, laws) of the cause or mechanism of an event are *not* subject to change.

Instructions

Take any statement that has been presented in class, or use a statement of your own, and qualify it as scientific or non-scientific based on the CONPTT criteria. Some examples of statements that you could use are given below:

- Green plants will grow towards a source of light.
- Walking under a ladder will cause bad luck.
- Storing food at a low temperature will keep it fresh for a longer period of time.
- An individual's personality can be deduced from their handwriting.

1. Write the statement that you are going to evaluate in the space provided below:

……...

……...

Before analysing the statement using the CONPTT criteria, indicate whether you think the statement is scientific or non-scientific:

☐ Scientific ☐ Non-scientific

2. Using the six CONPTT criteria, and referring to your statement, explain how each criterion is satisfied or is not satisfied as science, and indicate whether this puts the statement within or outside the realm of science.

Criteria	**Explain or demonstrate how each criterion is scientifically satisfied or not satisfied:**
1. **C**onsistent	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.
2. **O**bservable	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.
3. **N**atural	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.
4. **P**redictable	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.
5. **T**estable	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.
6. **T**entative	…… …… …… ☐ Within the realm of science. ☐ Outside the realm of science.

3. After evaluating your statement based upon the CONPTT criteria, how do you now classify your statement?

☐ Scientific ☐ Protoscientific ☐ Pseudoscientific ☐ Non-scientific

4. Just because a statement is not scientific, does that mean that the statement is not true? Explain your answer.

……...

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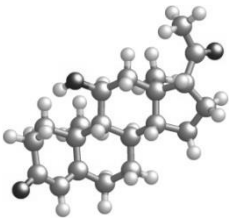
• Activity adapted from Indiana University Bloomington, http://www.indiana.edu



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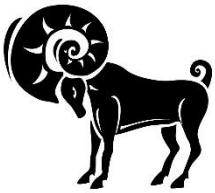
Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – How is Your Horoscope?

This activity is designed to help students recognise the difference between "*real science*" and "*pseudoscience*". A pseudoscience is something that is presented to the general public as a real science, but which is based mostly on assumptions and supported by unprovable claims.



Introduction

Is astrology a science, a pseudoscience or a non-science? A major premise of astrology is that a person's birth sign correlates with a particular collection of personality traits. In this activity, you will compare your own traits with standard astrological descriptions and then learn whether your actual birthday matches the corresponding astrological dates.

Background

According to astrologers, your horoscope is a map of the planetary positions at the time and place of your birth. Your Sun Sign is the constellation / sign of the Zodiac occupied by the sun on your date of birth. Although there are many factors typically considered when interpreting your horoscope, the Sun Sign is considered the most important factor, revealing your basic personality traits and potentials for growth and development.

Our research question / problem statement is therefore…

"*Do personality traits correspond reliably with birth dates*?"






Instructions

1. Study the following list of traits and interests until you find the particular combination that comes the closest to describing you.

Number	Key Positive Traits	Main Interests	Possible Negative Traits
1.	Action, initiative, enthusiasm, leader, competitive.	Self, challenge, leading, starting.	Arrogant, quarrelsome, easily bored, selfish, stubborn.
2.	Possessive, determined, practical, enduring, loyal.	Possessions, comfort, beauty, arts, family.	Stubborn, jealous, slow, lazy, greedy.
3.	Intelligent, witty, versatile, curious, popular.	Variety, travel, talking, reading.	Superficial, fickle, impatient, break rules.
4.	Tenacious, domestic, sensitive, emotional, shy, neat, protective.	Security, home, family, country, solitude.	Combative, moody, vain.
5.	Power, authority, romantic, idealistic, self-confident, generous.	Sports, being in charge, teaching, protective.	Egotistical, domineering, blunt, temperamental.
6.	Service, methodical, high standards, practical, neat, reliable.	Routine, details, perfection, travel, working alone.	Fault finding, worry, hurtful.
7.	Harmony, fair, cooperative, romantic, gracious, hard-working.	Companionship, social life, justice, beauty, arts.	Indecisive, extravagant, fickle.
8.	Resourceful, secretive, forceful, emotional, loyal, determined.	Solving mysteries, working hard, success.	Vengeful, cynical, sarcastic, jealous, argumentative.
9.	Hopeful, intuitive, honest, friendly, idealistic, easy going.	Freedom, travel, philosophy, religion, books.	Blunt, tactless, argumentative, not particular.
10.	Ambitious, organized, conservative, frugal, practical, neat.	Hard-working, business, being in charge, caution.	Worry, slave driver, stubborn, social climber.
11.	Independent, helpful, broadminded, tireless, generous.	Helping others, friends, politics, leader.	Dogmatic, rebel, impersonal, stubborn, blunt, argumentative.
12.	Compassionate, sensitive, generous, gentle, dreamy, imaginative.	Hospital, pets, thinking, peace, helping, arts.	Easily influenced, not ambitious, no self-confidence.

2. Write your birthday and the number of the combination of traits and interests that best describes you in the spaces given below:

Date of Birth: …… **Number:** ……

3. Now look at the list of dates presented to you by your teacher. Find the range of dates that includes your birthday, and note the corresponding number. Is the corresponding number the same as the number that you wrote down in answer to **Step 2**? If yes then tick "Hit", if no then tick "Miss".

☐ Hit ☐ Miss

4. What are the total number of "Hits" and "Misses" for the class?

- Total number of "Hits" ……
- Total number of "Misses" ……

Discussion Questions

1. **a)** What is the probability that a student would select the "right" number by random chance?

……...

b) What is the total of all these individual probabilities for the class?

answer to **1. a)** × total number of students in the class

……...

c) How many students in the class would you expect to choose the "right" number by random chance alone?

……...

2. If the total number of "Hits" obtained by the class is close to the number expected by random chance, then what does this tell you about the predictability of Sun Signs?

……

……

3. If the total number of "Hits" obtained by the class is significantly higher than expected, then briefly explain what could have caused this. How could you test for or control the cause?

……...

……...

4. If Sun Signs are fundamental to horoscope interpretation, then what do the class results suggest about the predictability and usefulness of horoscopes?

……...

……...

5. What problem(s) did you encounter trying to select the Sun Sign description which came closest to how you perceive yourself?

……...

……...

6. What other tests of astrology can you think of? Consider studying famous people who are experts in different fields.

……..

……...

7. Why might a person consider his or her horoscope to be true?

……..

……..

8. Astrology is the “oldest empirical science in the world”. Astrology is based on ancient beliefs about planets and stars, employing mysterious patterns and complex calculations to reveal details of individual personalities and potentials, and provide the basis for critical decisions in a person’s life. Repeated tests and challenges which could have provided support for astrology have consistently shown its predictions and descriptions to be unreliable. Furthermore, no mechanism to explain the supposed relationship between personalities, destinies, planets and stars has ever been demonstrated. Astrology allegedly continues to function due to “mysterious forces”. Explain why astrology is classified as a pseudoscience and *not* a science.

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9. Why do you think that people believe in pseudoscience?

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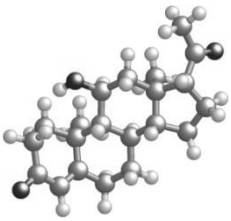
- Activity adapted from Indiana University Bloomington, http://www.indiana.edu



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

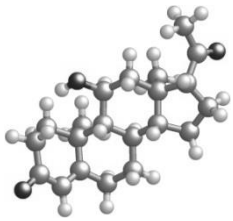
The Nature of Science – Brain-Break

Making Connections – Scientific Discoveries – The History of Science

Instructions

Draw a line connecting the name of each scientist to the discovery with which he or she is most closely associated.

	Scientist(s)	Discovery
1.	Robert Boyle •	• Radium
2.	Marie Curie •	• Atoms
3.	Nicolaus Copernicus •	• Electricity
4.	John Dalton •	• Air pressure
5.	Charles Darwin •	• Relativity
6.	Albert Einstein •	• Planetary motion
7.	Michael Faraday •	• Blood circulation
8.	Alexander Fleming •	• Evolution
9.	Galileo Galilei •	• Moons of Jupiter
10.	William Harvey •	• Chemistry of combustion
11.	Edwin Hubble •	• Penicillin
12.	Edward Jenner •	• Antiseptic surgery
13.	Alfred Wegener •	• Continental drift
14.	Antoine Lavoisier •	• Vaccination
15.	Joseph Lister •	• Expanding universe
16.	Gregor Mendel •	• Hereditary (genetics)
17.	Isaac Newton •	• Deoxyribonucleic acid
18.	Joseph Priestley •	• X-rays
19.	Wilhelm Roentgen •	• Gravitation
20.	Watson and Crick •	• Oxygen



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Scientific Method – Alienate This!

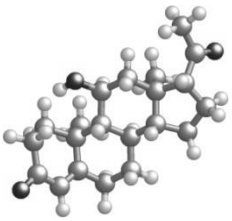
Imagine that an interplanetary spacecraft from Earth landed on a planet orbiting the star Betelgeuse, in the constellation of Orion. As astronauts from the spacecraft explored the planet, they came across a strange organism. In a record of their exploration, one astronaut wrote the following report about the organism:

	Astronaut's Report About the Organism	Observation	Inference
a)	The organism frowned to show that it did not like strangers.	☐	☐
b)	The organism is green, with brown spots.	☐	☐
c)	The organism lives near other small, colourful organisms.	☐	☐
d)	The organism moved away from us because it was afraid.	☐	☐
e)	The organism makes gurgling noises.	☐	☐
f)	The organism has four toes on each foot and each foot is webbed.	☐	☐
g)	The organism has one blue eye and two purple ears.	☐	☐
h)	The planet must be hot because the organism was perspiring.	☐	☐
i)	The organism can turn its head in a complete circle.	☐	☐
j)	The organism moves slowly, so it must be old.	☐	☐
k)	The organism can pick-up objects with its three fingers.	☐	☐
l)	The organism's arms are longer than its legs.	☐	☐
m)	The organism must like eating yellow plants because it is holding ten of them.	☐	☐
n)	The organism has no fingernails or toenails.	☐	☐

1. Show whether each statement is either an *inference* or an *observation* by placing a tick in the relevant box – ☑. Remember, an observation is something that you see, hear, taste, smell or touch. An inference is something you might decide about an object or an event after you have observed it. When were the astronauts observing? When were the astronauts deciding something they did not really observe?

2. In the space provided below, make a *drawing* of the organism. Your drawing should show only what the astronauts observed.

• Adapted from Gifted Education Branch, Ministry of Education, Singapore.



Sc!ence

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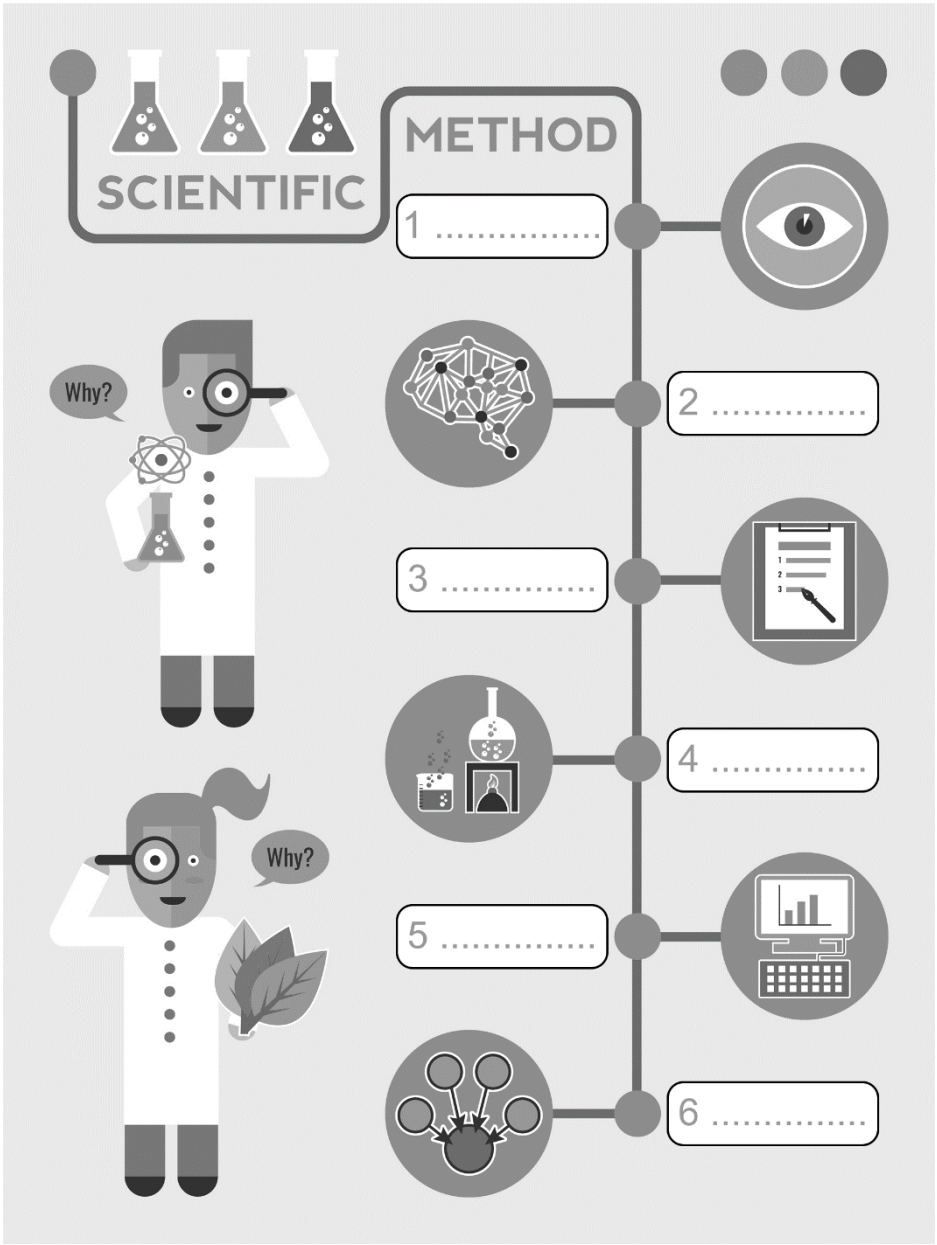
Class: ……

Date: …… **/** …… **/** ……

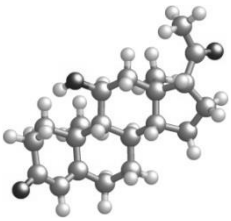
The Nature of Science – The Scientific Method

Instructions

- The diagram below shows six important stages in the scientific method. Use the symbols to help you decide the correct title for each of the six stages. Write your answers in the spaces provided below.



• Modified from an original image taken from ShutterStock, http://www.shutterstock.com



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – The Extra Piece

Background Information

In this activity, students assemble a tangram as a square and then reassemble the tangram incorporating an additional piece that they are given. Parallels are drawn to particular aspects of the nature of science.

Learning Objectives

By the end of this activity, students should be able to:

1. Use this tangram activity as an analogy to describe aspects of the nature of science, such as the tentative nature of scientific knowledge.
2. Explain several courses of action that scientists may take when confronted with an unexpected discovery.
3. Provide at least one authentic example of the tentative nature of scientific knowledge.

Introduction to the Activity

The activity is designed to explicitly teach ideas about the nature of science. It contains no specific scientific content knowledge. This means that students can learn about the nature of science without having to understand new science content at the same time.

Although it is reliable and durable, scientific knowledge is neither carved in stone nor perfect. Rather, it is subject to change in the light of new evidence or the new interpretation of existing evidence. Because of its tentative nature, we cannot claim “absolute truth” in science. The tentative nature of scientific knowledge also means that laws and theories may change.

Materials

Copies of the tangram template, cut into pieces. It is recommended to prepare one tangram for each student in the class, but students can also complete the activity working in small groups at the teacher’s discretion. For variety, the tangrams can be printed on different coloured paper. Printing the tangrams on card, and then laminating them, makes the tangrams more durable.

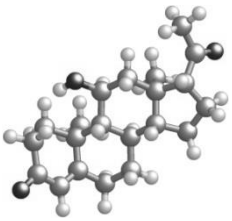
Instructions

1. Give each student their tangram pieces – all pieces except for the small square marked with a "×". Explain that the pieces represent current scientific data. Ask the students to arrange the four pieces into a square, which represents scientists understanding sets of data to produce a new model, theory or law (see **Figure 1** for the proposed solution).
2. Once all of the students have arranged the four pieces into a square, give each one the additional small square marked with a "×". Explain that a new scientific discovery has been made or a new piece of data has been found or that a new idea has been presented. Students must somehow incorporate this new information into their tangram to form a new square (see **Figure 2** for the proposed solution).
3. Encourage students to work individually at first, and then collaborate in groups if the level of frustration increases. Hints can be given by the teacher if necessary.
4. Once most or all of the students have arranged the pieces correctly, ask them to brainstorm and share how this activity is similar to really "doing" science. Some examples include:
    - Assembling the pieces into a square shape can represent scientists assembling data into evidence, ideas into an explanation or coming up with a model, theory or law.
    - Students assume that the pieces of the tangram fit together to form a square. Scientists assume that patterns, models, explanations, theories and laws can be made.
    - Trial and error can be an essential component of scientific research.
    - New information may require old models, theories or laws to be modified or discarded.
    - Our current information may be incomplete and therefore scientific knowledge, while durable, is always tentative and subject to change.
    - Serendipity has a role to play in science. Sometimes scientists are "lucky" and find the pattern or "answer" by chance.
    - Collaboration may be useful.
    - Once scientists arrive at "the answer", it makes perfect, elegant sense.

Extension

Discuss with students examples of how scientific knowledge has changed, for example, our knowledge of atomic structure.

- Adapted from an activity by Jason Choi, Sleepy Hollow High School, Westchester, New York, 2004.
- Additional information taken from Science Learning, New Zealand, http://sciencelearn.org.nz.



Sc!ence

Name: …… **( )**

Class: ……

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The Nature of Science – The Scrambled Sentence

Background Information

In this activity, students try to construct a meaningful sentence by successively turning over a set of word cards. Parallels are drawn to particular aspects of the nature of science.

Learning Objectives

By the end of this activity, students should be able to:

1. Describe aspects of the nature of science such as the self-correcting nature of science, the tentative nature of scientific knowledge and science as an ongoing human endeavour.
2. Give one authentic example of science as an ongoing human endeavour.
3. Give one authentic example of the tentative nature of scientific knowledge.

Introduction to the Activity

The activity is designed to explicitly teach ideas about the nature of science. It contains no specific scientific content knowledge. This means that students can learn about the nature of science without having to understand new science content at the same time.

In this activity, students gather information and work towards a closer approximation of the actual sentence. There is built-in ambiguity in the sentence, and several reasonable “correct” answers are possible.

Despite the artificial context of this activity, some aspects of the experience closely resemble real-life science. It can be used to teach students about the self-correcting nature of science, the tentative nature of scientific knowledge and science as an on-going human endeavour. For example, as the students turn over more cards, they will change their ideas of what the story might be about.

The parallel here to the way science works is that scientists will change their ideas, explanations, hypotheses or theories as they gather more information.

Materials

- One set of word cards for each group. For variety, the words can be printed on different coloured paper. Printing the words on card, and then laminating them, makes the words more durable.
- Copies of “What do you think the story is about?” for groups to record successive hypotheses.

Instructions

1. Divide the class into group of three-to-four students and give each group a set of the word cards and a copy of the worksheet “What do you think the story is about?” Instruct each group to spread-out their cards face-down on the table. Tell the class that the cards form one long sentence that also tells a story. The objective is for the students to figure-out the story from the words that they discover when they turn the cards over. Encourage students to keep their ideas within their group until the class discussion at the end.

2. Ask the groups to turn-over five cards at random and then write down a sentence that uses all five of the words (Hypothesis One). Ask the students if it would help to have more information.

3. Have each group turn-over five more cards. What do they think the story is about now? Have each group record their ten word sentence (Hypothesis Two) and their ideas. Ask the students if their idea of the sentence changed with the addition of more information. Discuss briefly with the class, but do not ask them to share their sentences just yet.

4. Have the groups turn over five more cards and record their fifteen word sentence (Hypothesis Three) and ideas. Allow groups to share with the class what they think the sentence says. Discuss the possible reasons why groups have different answers. Ask the students how this is similar to a palaeontologist digging-up fossils (the scientist uncovers information slowly, over a period of time). Ask the students why scientists may not agree on their explanations of things (scientists have different information or different ways of interpreting the same information).

5. Allow all of the groups to turn over all of the cards and revise their hypothesis (Hypothesis Four). Encourage the groups to share their “final” hypothesis. It is most likely that the groups will not have exactly the same sentences – even though they now all have the same information (words). Ask the groups why they have different sentences. Ask the students why scientists may not have exactly the same explanation for things even though they may have exactly the same information (the scientists may have different background knowledge, make different assumptions, have different points of view and so on). To illustrate this further, ask students to look at the drawing by Joseph Jastrow (**Figure 1**). Even though all students look as the same drawing, some will say they see a duck while others say they see a rabbit.

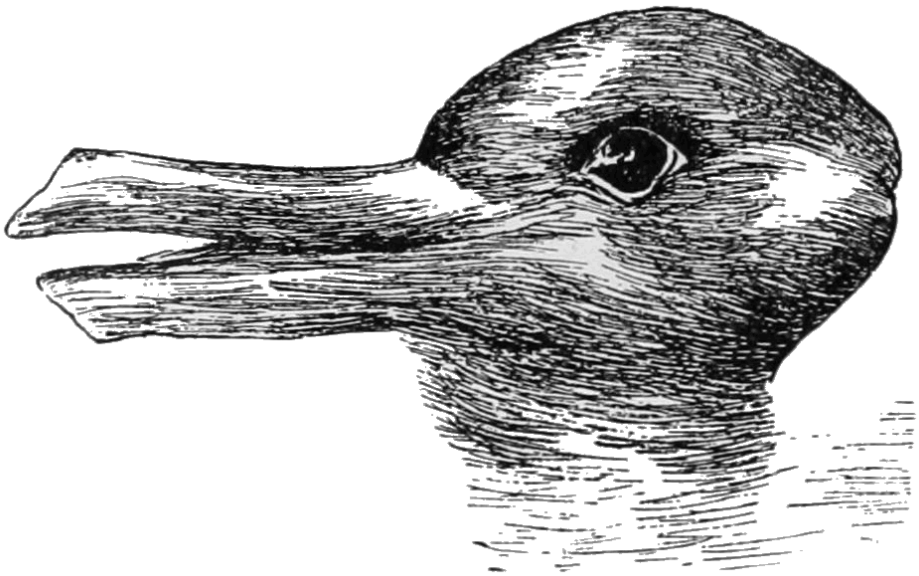
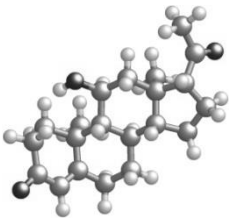


Figure 1. Drawing by Joseph Jastrow (1863 – 1944). What do you see?

6. Encourage the groups to brainstorm and discuss parallels between this activity and how scientists work. Some examples are given below:

Possible Student Response	Parallels to the Work of Scientists
"We tried to make sense of the cads. We had data and tried to make sense of it."	Scientists try to make sense of the natural world. Scientific ideas are developed through reasoning. Scientists develop explanations using observations and what they already know about the natural world.
"As we were given more information (words) we came-up with new ideas. We changed our hypothesis (sentence)."	Science is on-going, tentative, subject to change with more evidence or with the re-interpretation of existing evidence. Science corrects itself.
"More information (words) made it easier to develop a hypothesis (sentence)."	The more data scientists have, the easier it is to develop a reliable hypothesis.
"We all had different ideas in our group."	Based upon the same data, two scientists can have different hypotheses or explanations.
"There was more than one possible sentence that fitted the data."	Science does not prove or conclude – science is always a work in progress.
"We used our existing knowledge to help construct the sentence."	Science is socially and culturally embedded and theory laden. For example, a person who did not know that flamingos are pink could not assemble the sentence that way. Scientists bring existing theories and background knowledge to any investigation – and this will affect how they interpret the data.

- Adapted from an activity by Al Janulaw and Judy Scotchmoor, University of California Museum of Palaeontology.
- Additional information taken from Science Learning, New Zealand, http://sciencelearn.org.nz.



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – The Scrambled Sentence

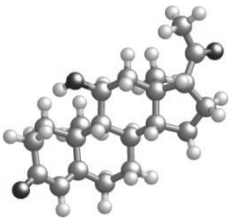
Student's Worksheet – "What Do You Think the Story is About?"

Hypothesis One
• What is your first sentence (hypothesis)? Five words.
……
• Elaborate on your ideas about the sentence – what do you think the story is about?
……
……

Hypothesis Two
• What is your second sentence (hypothesis)? Ten words.
……
• Elaborate on your ideas about the sentence – what do you think the story is about?
……
……

Hypothesis Three
• What is your third sentence (hypothesis)? Fifteen words.
……
• Elaborate on your ideas about the sentence – what do you think the story is about?
……
……

Hypothesis Four
• What is your fourth sentence (hypothesis)? Twenty-four words.
……
• Elaborate on your ideas about the sentence – what do you think the story is about?
……
……



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The Scientific Method – The Tale of the Other Dog

Read through the story of *the Tale of the Other Dog* and then answer the questions that follow.

The Tale of the Other Dog

Tang Ham Ma loved to tinker, trying to improve things, even paper clips and mousetraps. On his birthday his wife gave him a puppy, so he set out to make a better dog food. Pretty soon he came up with a mixture of special vitamins he was proud of, and he began feeding it to his puppy.

After a year Ham Ma was very pleased with the way the puppy had grown, and he showed his friends pictures of the dog. “That’s nothing,” one friend said. “What did the dog look like before you started giving it the special food?”

So Ham Ma produced pictures of the dog when it was a tiny puppy. By comparing the pictures, you could see that the puppy had indeed grown. “That’s still nothing,” the friend countered. “All puppies grow.”

Undaunted, Ham Ma set out to raise another puppy on his special food. Fortunately, it happened that his son had brought home a collie puppy just days before. Ham Ma went to the pound and brought home a second dog, a small mutt. Thus began his second experiment.

To prove that his dog food was better than standard dog food, Ham Ma added his special vitamin mixture to some commercial dog food and labelled it **A**. Then he labelled a second variety of dog food **B** and did not add his special mixture. His son’s collie received food **A** and the mutt received food **B**.

After a year of this, he brought the dogs to the company picnic and proudly displayed them both. The collie had grown nearly twice the size of the mutt. “You think you made some pretty good dog food, huh?” said Ham Ma’s rival at work, Johnny Lau. “You can’t say nothing about how good your special food is. Collies always grow more than little mutts.” Devi was sceptical too, “You never fed them the same stuff, Ham Ma. You have to feed them both the same stuff to prove anything.”

Ham Ma realized he had made two mistakes this time. And he vowed that the third time his conclusions would be so compelling that no one could doubt them.

So Ham Ma went back to work. He invested some of his savings in twin male beagles, identical puppies from the same litter. He restricted the puppies to a standard dry dog meal, and let

them drink only the water from his garden hose. He called them Dog **A** and Dog **B**. Dog **A** got Ham Ma's special vitamin mixture with its dog meal, and Dog **B** did not.

That year's picnic was quite a success. Ham Ma brought his dogs and a scale. From the dogs' identical collars hung brass letters of identical mass, saying "Dog **A**" and "Dog **B**." He even had brought the two bags of dog food, identical except for the addition of his vitamins to bag **A**.

"Hey, you have quite a thing going here," admitted Johnny Lau, smiling and petting Dog **A**. "Dog **A** sure did grow," said Devi. "But poor little Dog **B**. If you don't want it, I'll take it home."

Dog **A** weighed a full two kilograms more than its brother, Dog **B**, after only one year – and there wasn't a bit of extra fat beneath its glossy coat. Dog **B** was as delightful and sweet as Dog **A**, and its coat was shiny, but it was not any bit heavier than the average beagle.

Ham Ma had learned from his experiences, and he videoed the two beagles from the day that he bought them. When his boss, Mdm. Chan Chen Fen, called him in to congratulate him on his successful dog food work, Ham Ma showed her the video of the two dogs growing-up and she loved it.

One month later, Ham Ma had business cards identifying him as *Tang Ham Ma, Senior Canine Dietician*, and a six figure contract to market his special mix of vitamins worldwide.

Questions

1. What traits characterise a good scientist? How did Ham Ma demonstrate these traits?
Note: Refer to the *16 Habits of Mind* for guidance.

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……...
……...

2. What was wrong with Ham Ma's first dog food experiment?

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……...

3. What two mistakes did Ham Ma make in his second dog food experiment?

……...
……...

4. What was Ham Ma's hypothesis?

……...

5. What were Ham Ma's independent and dependent variables?

……...

6. What was Ham Ma's controlled experiment, and what did he control in it?

……...

……...

7. What is a control and why is it important in a scientific experiment?

……...

……...

8. What kind of record(s) did Ham Ma keep? What other records could / should Ham Ma have kept? Why?

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……...

……...

9. From the information given in the story, could you repeat Ham Ma's experiment? Why is it important to reproduce experimental results in science?

……...

……...

……...

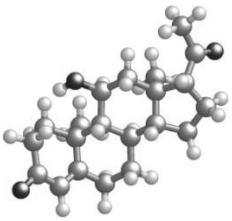
10. What other experiment(s) could you do to test Ham Ma's conclusion about the effect of his dog vitamins?

……...

……...

……...

• Adapted from Gifted Education Branch, Ministry of Education, Singapore.



Sc!ence

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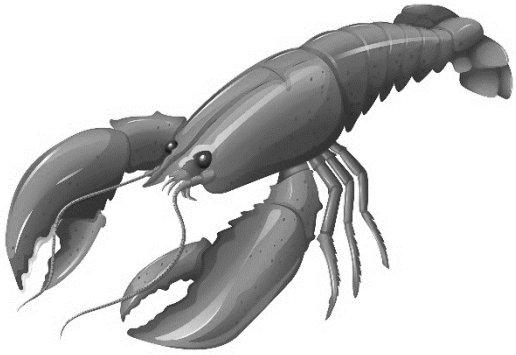
The Scientific Method – Analysing Experimental Results using Graphs to Interpret Data

Anne was looking for a project for the school science fair. She had read an article in a science magazine about feeding antibiotics to chickens. The chickens that were fed antibiotics grew at a faster rate than those that were fed none. Anne thought about the chicken experiment for a long time. After more reading in the library, she decided to design an experiment using red crayfish. Crayfish grow to a maximum size of about 10 cm and mature in 6 to 8 weeks. Female crayfish produce between 100 and 400 eggs that hatch in 2 to 3 weeks. Anne's teacher helped her order 144 crayfish from a science supply store. Anne obtained *Aureomycin**, an antibiotic, from her doctor.



- Crayfish

When the crayfish arrived, Anne divided them into 6 groups. Each group contained 12 males and 12 females. She placed each group in an identical glass container, fed them the same food, and changed the water in each container every seven days. All six groups were treated the same way except that *Aureomycin* was added to five of the containers after each water change according to the following schedule:

Group Number	Mass of Aureomycin Added After Each Change of Water / mg
1	0
2	25
3	50
4	100
5	200
6	300

* Aureomycin is the trademarked name of the drug chlortetracycline, an antibiotic used to treat many bacterial infections and some viral infections. Aureomycin has the formula $C_{22}H_{23}ClN_2O_8$, and is obtained from the bacterium *Streptomyces aureofaciens*.

Each week, before the water was changed, the length of each crayfish was measured and the average length was calculated for each group. The following data was obtained:

Group Number	Average Length of Red Crayfish after Number of Weeks Indicated / cm					
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
1	1.5	3.1	4.0	4.6	6.0	6.8
2	4.0	6.1	7.2	7.3	7.4	7.5
3	2.8	5.0	6.6	7.5	7.6	7.7
4	4.4	6.5	8.0	9.0	9.5	10.0
5	1.6	3.1	4.2	4.5	4.7	4.8
6	1.5	1.9	2.6	2.8	2.9	3.0

Questions

1. What was Anne's hypothesis?

……...
……...
……...
……...

2. Describe the control that Anne used in her experiment.

……...
……...
……...
……...

3. Explain why Anne used so many crayfish in her experiment.

……...
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……...
……...

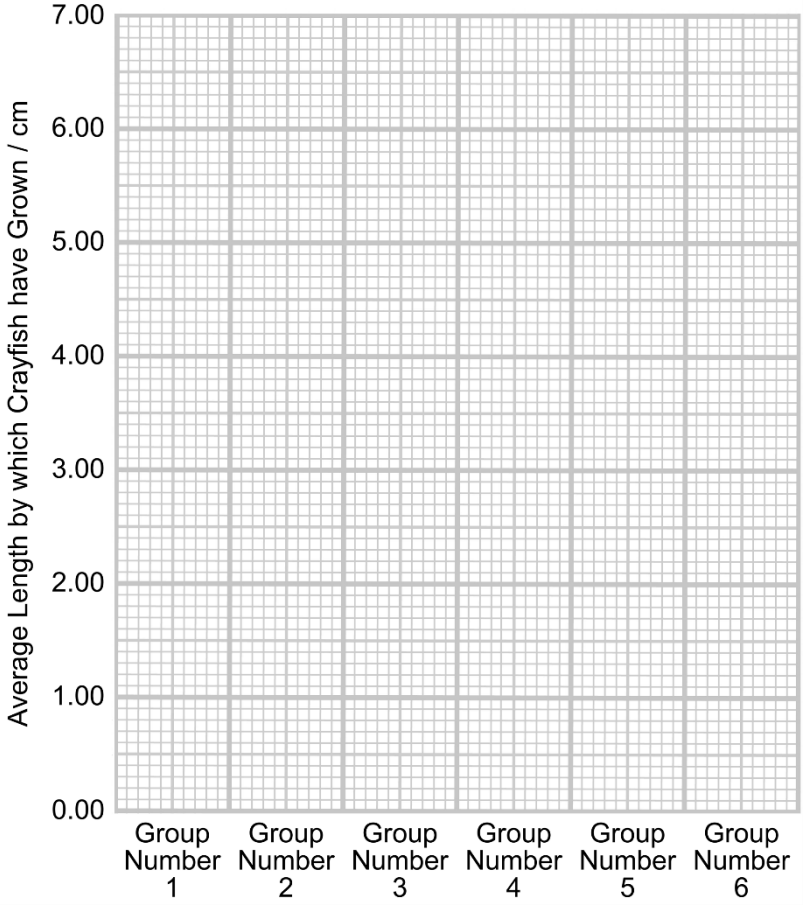
4. What did Anne do to ensure the accuracy of her experiment?

……...
……...
……...
……...

5. Scientists use many different types of graphs to present and communicate the results to their experiments, for example, bar graphs, histograms, line graphs, pie charts and scatter plots. The data from Anne's experiment is best presented as a series of line graphs, but for this introductory activity, you will present her results as a series of histograms. Complete the table below to calculate the average length by which the crayfish in each group have grown:

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Average length by which the crayfish have grown / cm (length week 6 – length week 1)						

Present the results to Anne's experiment as a histogram on the graph paper provided below. You may use a different colour for each group.



6. What conclusions can be drawn from Anne's experiment?

……...

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7. If you were to repeat Anne's experiment, what would you do to improve it further?

……...

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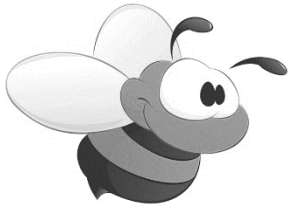
• Adapted from Gifted Education Branch, Ministry of Education, Singapore.



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Scientific Method – Experimental Design

Instructions

Design an experiment to determine whether honey bees are attracted more towards regular cola or diet cola.

1. What is your *hypothesis* for this experiment?

……...

……...

2. What *assumptions* (if any) are you making about this experiment?

……...

……...

3. What is the *independent* variable (input variable) for this experiment?

……...

……...

4. What is the *dependent* variable (output variable) for this experiment?

……...

……...

5. What is your *control* variable for this experiment?

……...

……...

6. What variables need to be kept *constant* throughout this experiment?

……...

……...

7. What do you need to *measure* during this experiment (what *data* / *evidence* do you need to collect)?

……...

……...

8. How will you *interpret* the data that you obtain from this experiment in order to check whether your hypothesis is right or wrong?

……...

……...

9. How will you clearly *present* / *communicate* the data that you obtain from this experiment?

……...

……...

10. What *apparatus* will you need in order to complete this experiment?

……...

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11. Draw a *diagram* of this experiment.

12. Write a clear step-by-step *description* of this experiment.

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Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

The Nature of Science – Using Models to Communicate and Understand Science

Biggest Ever Crystal Built in Vienna

The world's biggest crystal structure model – a 3D chemical illustration made from little balls and sticks – is being assembled in Vienna's city hall. It replicates the repeating lattice of sodium ions and chloride ions found in a crystal of table salt, NaC*l*.

Standing more than 3 m tall, the model was built by Dr. Robert Krickl from nearly 40 000 balls and 10 km of sticks.

The world record attempt will be adjudicated by the Guinness Book of Records on 23rd November. It will be on public display until 30th November, and has already been commemorated on an Austrian postage stamp.

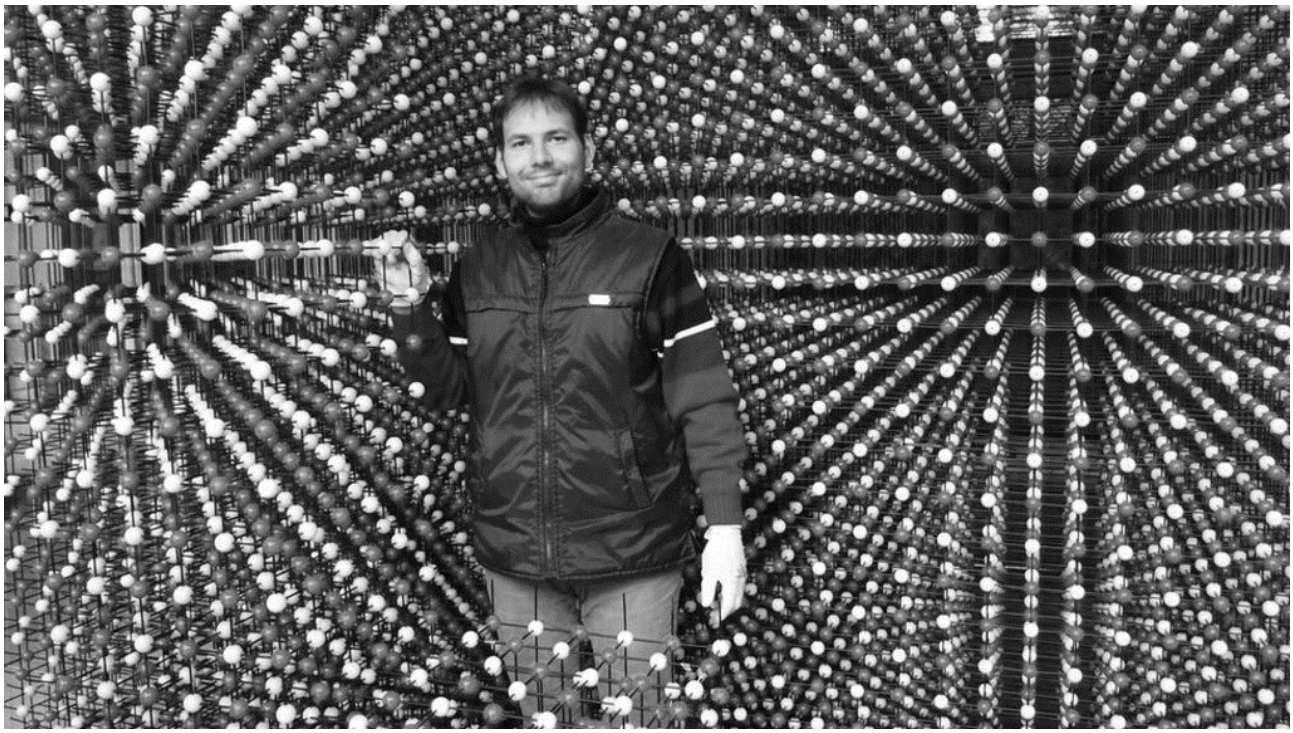
- The model appears on an Austrian postage stamp.

"I want to show – to visualise – how our world looks when it's magnified about a billion times," Dr. Krickl, a crystallographer turned science communicator, told Science in Action on the BBC World Service.

Because of the regular pattern it is built-up from, which causes hundreds of the sodium ions and chloride ions to form precise lines from multiple angles, the huge model has a rather dazzling appearance.

It also has particular significance this week, Dr. Krickl said. "This week is the 100th anniversary of the Nobel Prize for discovering what I show with this model: the arrangement of atoms in crystals." The British father-and-son team of William and Lawrence Bragg won the Nobel Prize for Physics in 1915 for originating the technique that is now known as x-ray crystallography.

"This discovery really had a major impact on science and our understanding of the world," Dr. Krickl said. "It led to the determination of the structure of DNA, of viruses, of proteins – and on the other hand, of materials used in our daily lives, for technology to build faster, better lighter machines."



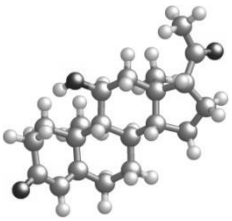
- Dr. Krickl constructing the model of sodium chloride. The dazzling model shows the ionic structure that would make up a crystal of table salt just 0.0000096 mm across.

Essential Questions

- Why must scientists communicate their ideas with clarity and precision?
- Why do scientists often use models to communicate their ideas?
- Apart from physical models, what other types of models do scientists use?
- How do models help scientists understand complex ideas and theories?
- What are the limitations of using models to communicate ideas?

Article taken from http://www.bbc.com/news/science-environment-34796501

Downloaded on 14th November 2015



Sc!ence

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

Answers to Selected Nature of Science Worksheets

- Please scan the QR codes given below to view the suggested answers to each assignment.

People Bingo

www.nygh.sg/nature_of_science/worksheets/1_people_bingo_ans.pdf

What is Science? - Survey

www.nygh.sg/nature_of_science/worksheets/3_what_is_science_ans.pdf

Sunsets, Souls and Senses

www.nygh.sg/nature_of_science/worksheets/4_sunsets_ans.pdf

Making Connections

www.nygh.sg/nature_of_science/worksheets/7_connections_ans.pdf

Alienate This!

www.nygh.sg/nature_of_science/worksheets/8_alienate_this_ans.pdf

The Scientific Method

www.nygh.sg/nature_of_science/worksheets/9_scientific_method_ans.pdf

The Tale of the Other Dog

www.nygh.sg/nature_of_science/worksheets/12_the_other_dog_ans.pdf

Analysing Experimental Results

www.nygh.sg/nature_of_science/worksheets/13_crayfish_ans.pdf