Nature of Science

Mohd Nor Syahrir Abdullah, PhD

Specialist (Science Education)

R&D Division

SEAMEO RECSAM

What is Science ?

https://padlet.com/mnsyahrir1/ihda6odcw9o

What is Science ?

- Science (Google)
- noun
- the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment.
- a particular area of science - "veterinary science, environmental science etc."
- a systematically organized body of knowledge on a particular subject.

Science (Oxford Dictionary)

- Knowledge about the structure and behavior of the natural and physical world, based on facts that you can prove, for example by experiment.
- A system for organizing the knowledge about a particular subject, especially one concerned with aspects of human behavior or society.






Science in 3 domains

1. Body of knowledge
   - facts
   - definitions
   - concepts
   - theories
   - Laws
   - etc.

Science in 3 domains

2. A set of methods and processes
   - observing
   - measuring
   - estimating
   - inferring
   - predicting
   - classifying
   - hypothesising
   - experimenting
   - concluding
   - etc.

Science in 3 domains

3. A way of knowing about nature
   - scientific knowledge is based on evidence.
   - scientific knowledge is tentative (subject to change).
   - creativity plays an important role in science.
   - background knowledge influences how scientists view data.
   - etc.

Activity 1

- Open your envelope.
- work individually.
- don’t share with your friends.
- How this activity is similar to “doing” science?

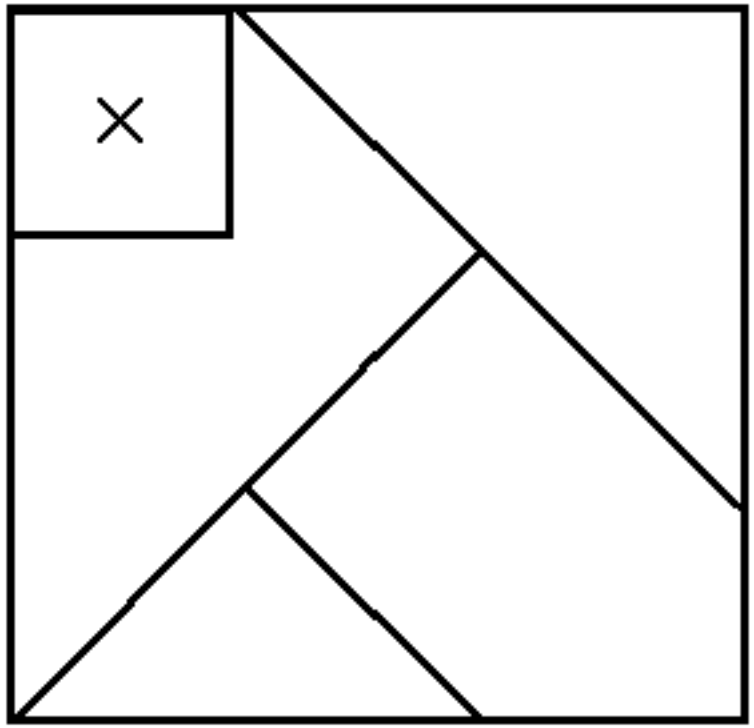


Figure 1

So, what is nature of science (NOS)?

- the epistemology of science, science a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Abd-El-Khalick, Bell, & Lederman, 1998).

NOS tenets (characteristics)

- **Science is an attempt to explain natural phenomena.**
- **Scientific knowledge is tentative (subject to change) – tentativeness.**

✓ All scientific knowledge is subject to change in light of new evidence and new ways of thinking. That does not mean that we shouldn't have confidence in scientific knowledge, rather that it may change in the future.

NOS tenets (characteristics)

- **Empirical evidence.**

✓ Scientific knowledge is derived from data and evidence gathered by observation or experimentation.

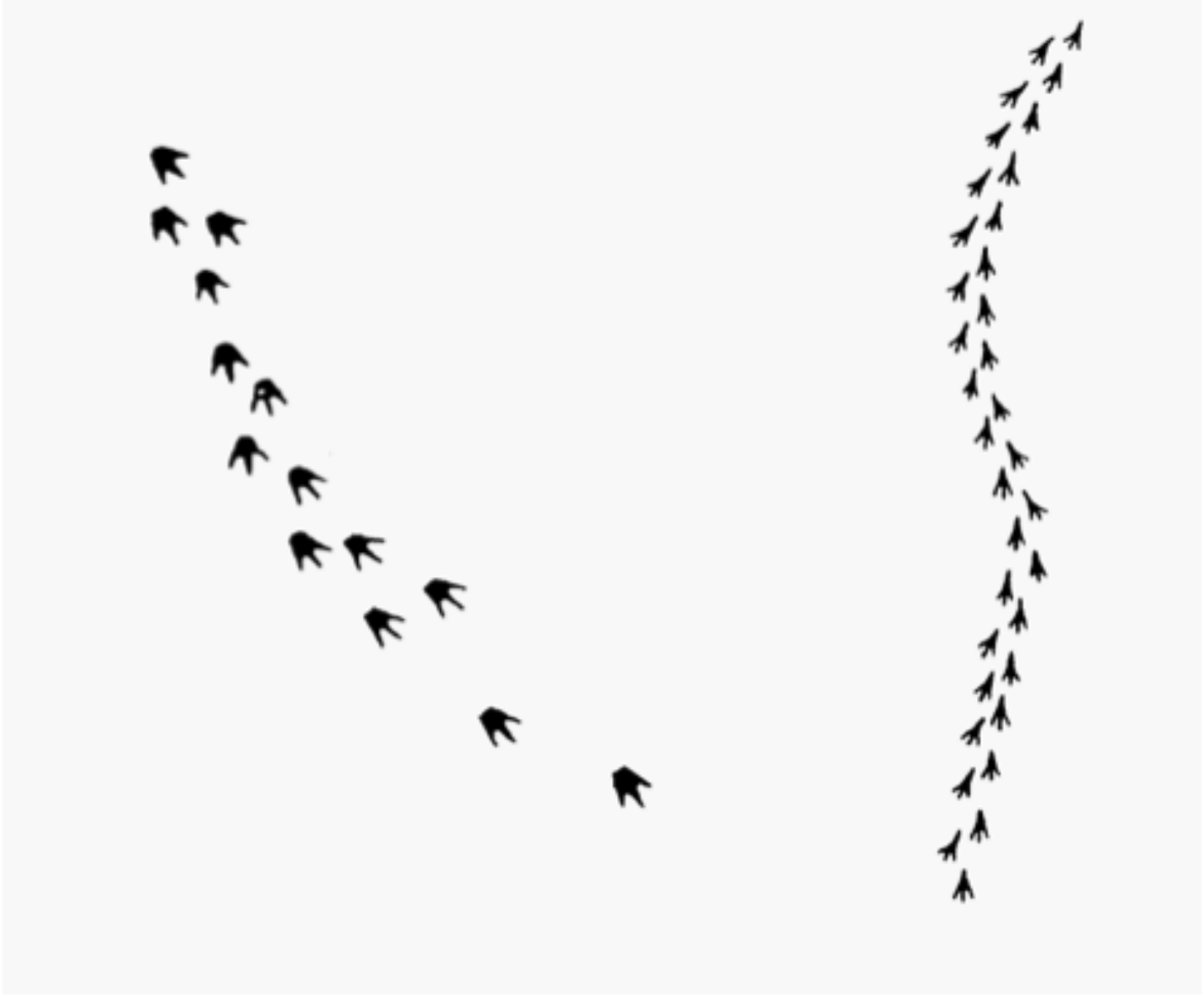
NOS tenets (characteristics)

- **science is observations and inferences.**

 - Observation involves gathering information using the five senses while inferences are explanations based on observation and prior knowledge.

Activity 2

write down what you think might have happened

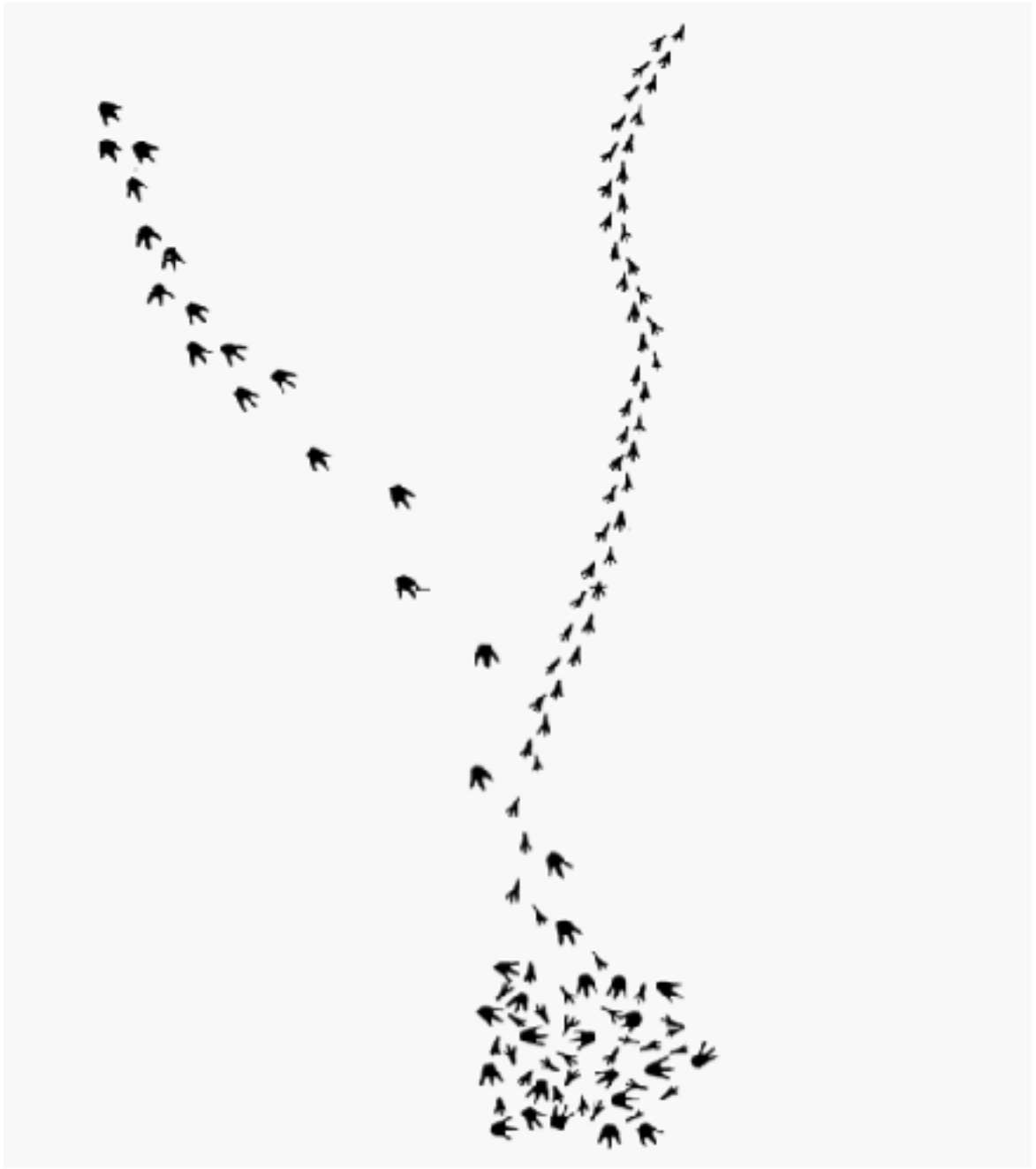


What do you observe?

Can you see the birds?

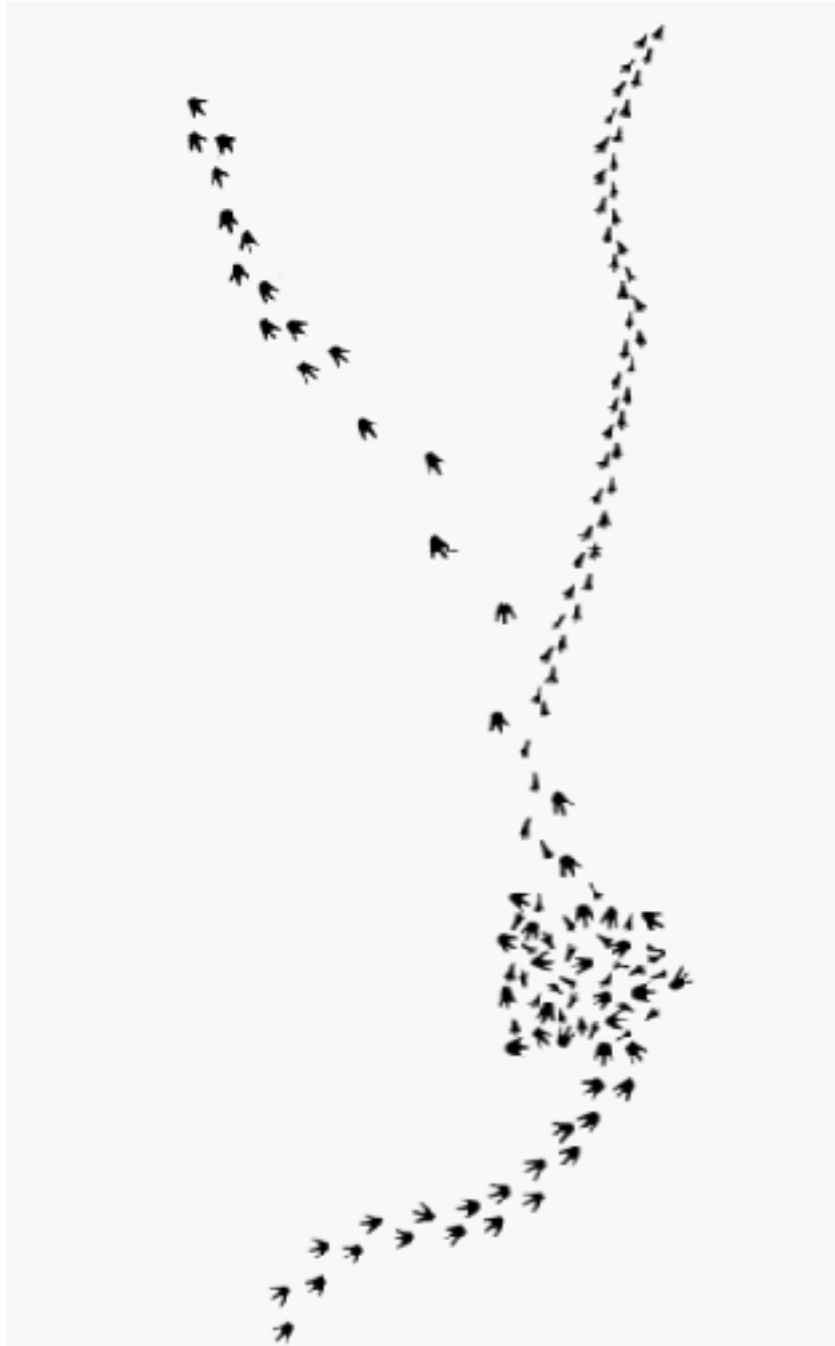
How can you tell that these tracks are left by the birds?

Why were the two animals heading towards the same spot?



What do you observe?

Data A Data B Data C



What do you observe?

What do you infer?

- What is the difference between observation and inference?
- scientists make similar inferences as they attempt to derive answers to questions about natural phenomena.
- no single answer (or story) may solely account for that evidence - several answers are often plausible.
- scientists may simply never find the answer as to what has really happened.

NOS tenets (characteristics)

- **Subjectivity, Social and cultural context.**

✓ Scientists are often portrayed being objective.

✓ Scientists are taught to set aside their personal prejudices, perspectives, and beliefs.

✓ Scientists strive to be objective and employ self-correcting mechanisms such as peer review.

✓ But intuition, personal beliefs, and social values all play a role in the scientific enterprise.

NOS tenets (characteristics)

- **Subjectivity, Social and cultural context.**

✓ context is very important for making sense of what we observe.

✓ a mere collection of data or facts, lacking any context, may not make any sense.

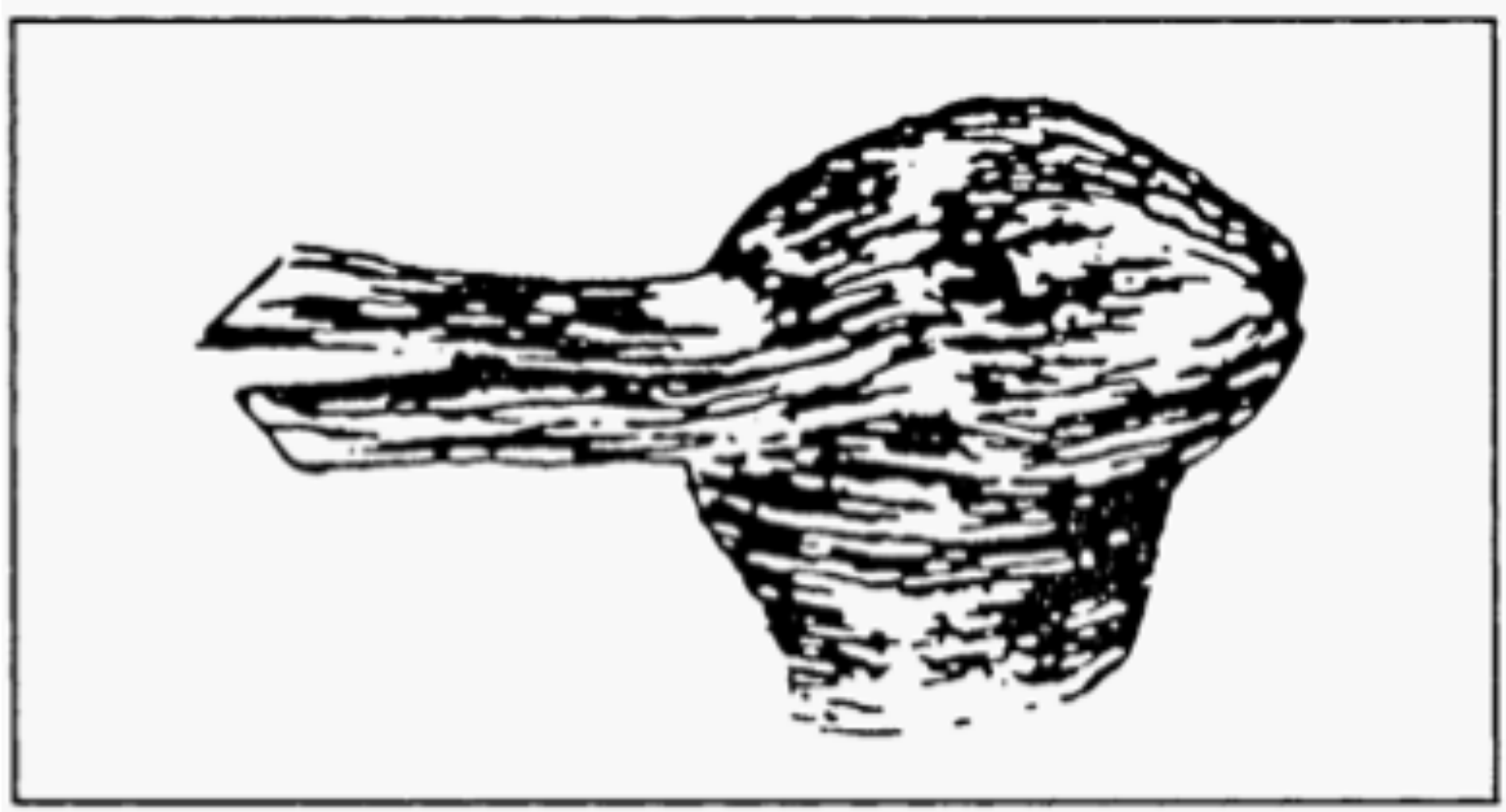
✓ prior knowledge, experiences, and expectations into a situation.

Activity 3

The procedure is actually quite simple. First arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity of this task in the immediate future, but then one never can tell.

After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

Activity 4



NOS tenets (characteristics)

- how can it be that some of us see only one face and not the other?
- scientists sometimes fail to ‘see’ (or perceive of) a certain set of evidence as relevant to their questions.
- tend to infer different things from the same set of data.

NOS tenets (characteristics)

- **Scientific laws and theories**

✓ A law is a concise description of relationships or patterns in nature based on observation and is often expressed mathematically.

✓ Scientific theories are broadly based concepts that make sense of a large body of observations and experimentation.

Examples of scientific laws

- ✓ Hubble’s Law of Cosmic Expansion • Universal Law of Gravity
- ✓ Newton's Laws of Motion
- ✓ Law of Superposition
- ✓ The Ideal Gas Law
- ✓ Archimedes Law of Buoyancy
- ✓ Bernoulli's Law

Examples of scientific theories

- ✓ Big Bang Theory
- ✓ Theory of Evolution
- ✓ Heliocentric Theory
- ✓ Cell Theory
- ✓ Atomic Theory
- ✓ Theory of Plate Tectonics • Germ Theory

NOS & Science Processes?

- Scientific processes - activity related to the collection and interpretation of data, and the derivation of conclusions.
- e.g.: observing & inferring
- NOS: epistemology commitments underlying the activities of science.

Why teach the nature of science?

- Research shows:
- it helps us better define the boundaries of science and non-science
- increased student interest
- developing awareness of the impacts of science in society

Why teach the nature of science?

- To help students develop a better understanding
- of:
- what science is
- the types of questions science can answer
- how science differs from other disciplines
- the strengths and limitations of scientific knowledge

The Myth of NOS

- **The scientific method.**
  - ✓ there is a universal scientific method, with a common series of steps that scientists follow. The steps usually include defining the problem, forming a hypothesis, making observations, testing the hypothesis, drawing conclusions and reporting results. In classrooms, students can be seen writing up the aim, hypothesis, method, results and conclusion.
  - ✓ In reality there is no single method of science. Scientific inquiry is not a matter of following a set of rules. It is fluid, reflexive, context dependent and unpredictable. Scientists approach and solve problems in lots of different ways using imagination, creativity, prior knowledge and perseverance.

The Myth of NOS

- **Experiments are the main route to scientific knowledge.**
  - ✓Science does involve investigation of some sort, but experiments are just one of many different approaches used.
  - ✓ geology, cosmology or medicine, experiments are either not possible, insufficient, unnecessary or unethical.
  - ✓science also relies on approaches such as basic observations (such as astronomy) and historical exploration (such as paleontology and evolutionary biology.

The Myth of NOS

- **Science and its methods can answer all questions.**
  - ✓ Science has achieved many amazing things, but it is not a cure-all for all the problems in society.
  - ✓ it can provide some insights that may inform debate. Science cannot answer ethical, moral, aesthetic, social and metaphysical questions.
  - ✓ clone mammals, but other knowledge is needed (cultural, sociological and philosophical) to decide whether such cloning is moral and ethical.
  - ✓ Not all questions can be investigated in a scientific manner.

The Myth of NOS

- **Scientists are particularly objective**
  - ✓We often assume scientists are always objective, but scientists do not bring empty heads to their research.
  - ✓Their background knowledge, experiences and the existing concepts they hold mean they can't be objective.
  - ✓they have a myriad of preconceptions and biases that they will bring to every observation and interpretation they make.

The Myth of NOS

- **Hypotheses become theories that, in turn, become laws**
  - ✓ Hypothesis, theory and law are three terms that are often confused. This myth says that facts and observations produce hypotheses, which give rise to theories, which, in turn, produce laws if sufficient evidence is amassed – so laws are theories that have been proved true.
  - ✓ Actually, hypotheses, theories and laws are as unalike as apples, oranges and bananas. They can't grow into each other. Theories and laws are very different types of knowledge. Laws are generalisations, principles, relationships or patterns in nature that have been established by empirical data. Theories are explanations of those generalisations (also corroborated by empirical data).

Changing theories about Mars

- With your friends share the ideas of what you have heard about the possibilities of life on Mars.
- Make a timeline on the changing theories of Mars. You may use other resources (e.g.: web resources and "The Story behind life on Mars"). Answer these questions:
  - Where have the ideas about life on Mars come from? Why did people think there might be life on Mars? How did scientists check those ideas out?
  - What is the same/different about the surface of Mars and of Earth?
  - Does Mars have an atmosphere that might support life?
  - What stories do you know about life of Mars?
  - What stories do you know about life on Mars?
  - Where do ideas about near-space objects, like Mars, come from?
  - What do you think it is actually like on Mars?
  - How do you decide which information to believe about Mars?
  - Do all scientific discoveries lead to an improved understanding about Mars?

Source: https://scienceonline.tki.org.nz/Nature-of-science/Nature-of-Science-Teaching-Activities

Reflection

- What evidence helped open-minded scientists change their minds over the last 20–30 years about what is on the surface of Mars?
- How was that evidence gathered?
- How easy do you think it has been for scientists to remain open-minded enough to shift their theories about Mars, when there were so many stories around that captured the popular imagination?
- Why do scientists now think life on Mars is unlikely?
- What conditions would be needed to support life on Mars?
- How does research about life in extreme environments on Earth help us with our understanding of the likelihood of life on Mars?

Conflicting theories for the origin of the Moon

Four theories for the origin of the Moon:	This theory proposes that …
A. Fission from Earth	The Moon was spun off from Earth when Earth was young and rotating rapidly on its axis.
B. Formation at the same time as Earth	The Earth and Moon and all other bodies of the solar system condensed independently out of the huge cloud of cold gases and solid particles that constituted the primordial solar nebula. Much of this material finally collected at the centre to form the Sun.
C. Formation far from Earth (the 'Capture' theory)	The Moon formed at a different place in the solar system and when the orbits of Earth and the Moon carried them near each other, the Moon was pulled into permanent orbit about Earth.
D. Giant impact	The Earth was struck by a body about the size of Mars, very early in its history. The catastrophic impact blasted portions of Earth and the colliding body into Earth's orbit, where debris from the impact eventually coalesced to form the Moon.

Source: http://scienceonline.tki.org.nz/Nature-of-science/Nature-of-Science-Teaching-Activities/Conflicting-theories-for-the-origin-of-the-Moon

- choose the pieces of evidence that support or refute that theory.
- give the reasons for your decisions about whether each piece of evidence (or combinations of evidence):
  - supports the theory
  - refutes the theory
  - has an uncertain/irrelevant relationship to the theory.
- discuss the pieces of evidence that seem to support two or more theories.
- decide which is most likely to be the leading theory for the formation of Earth’s Moon and why.
  - there are different views on the origin of the Moon.
  - investigation results can be interpreted in different ways - sometimes conflicting
  - critical thinking and matching evidence with theories are skills that highly valued in science.

Reflection

- Why can’t scientists tell how the Moon formed just by making careful observations?
- Why have scientists changed their minds in recent years about the most likely theory of the origin of the Moon?
- How did you go about sorting out, and making sense of, this massive amount of often conflicting or ambiguous evidence?
- Why is it important to consider alternative theories when analysing a new piece of evidence?
- Which theory of the origin of the Moon is currently the one that the majority of scientists favour? Why?

- In group, discuss and plan a lesson to get the students to think about the nature of science, and also, to show the importance of being an active participant in the learning process.
- Students have been given the definition of science in the past, but students should realize that science is dynamic, it is hands-on, and it changes as our knowledge of the world increases.

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Thank You

Mohd Nor Syahrir Abdullah

syahrir@recsam.edu.my