

Nature of Science

Unit 3

Nature of Science

- **Principles and Characteristics**
- **Science as Knowledge –**
 - Science as Empirical Knowledge
 - Science as Practical Knowledge
 - Science as Theoretical Knowledge
 - Science as Validated Knowledge

Principles and characteristics of Science

- **Objectivity:**

Scientific knowledge is objective.

Objectivity simple means the ability to see and accept facts as they are, not as one might wish them to be.

To be objective, one has to guard against his own biases, beliefs, wishes, values and preferences.

The results of science are objective.

Ex- Earth Rotates on its own axis.

- **Universal Basic Ideas:**

Science assumes that the universe is a vast single system in which basic rules are the same everywhere. Knowledge gained from studying one part of the universe is applicable to all other parts.

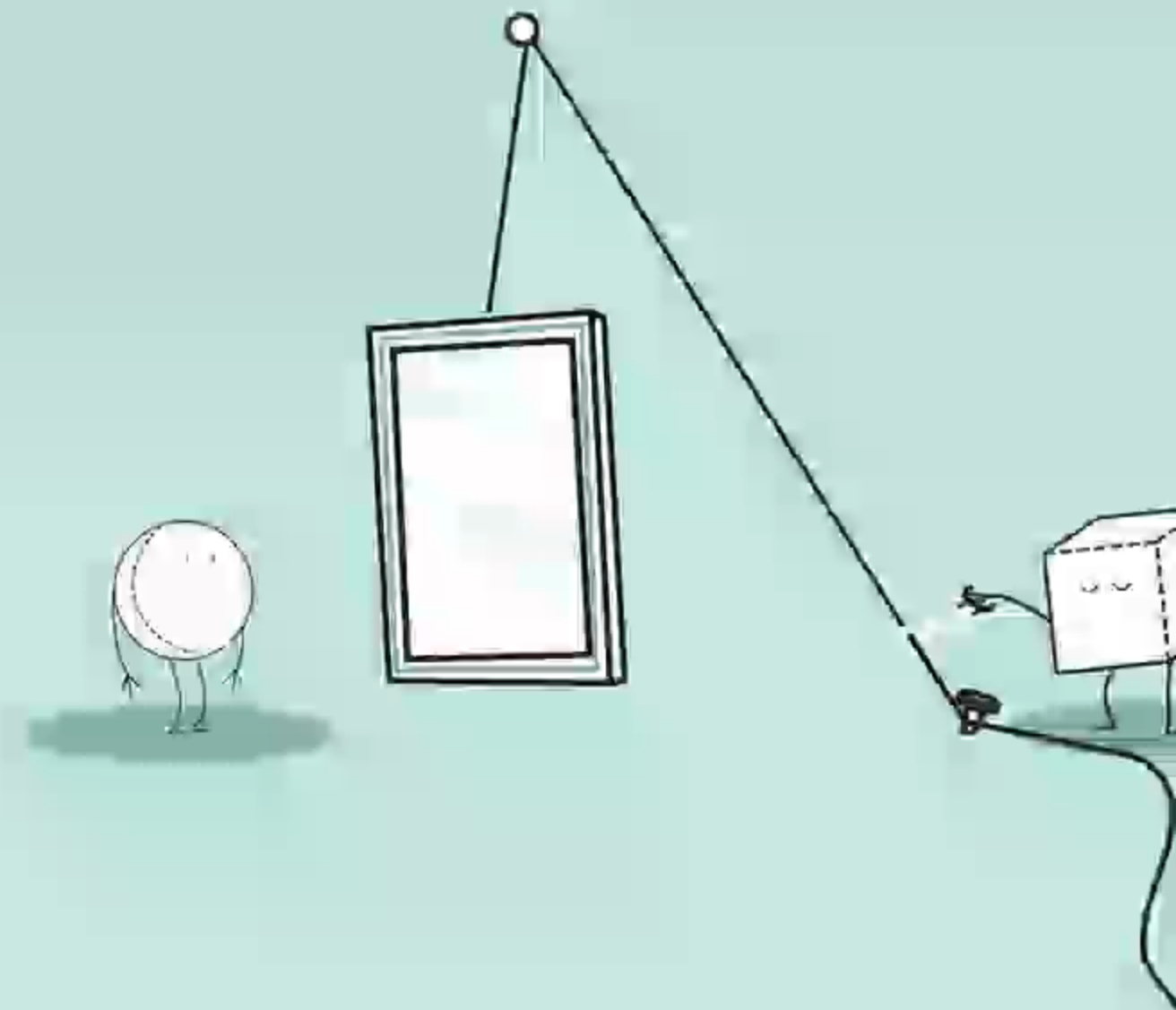
Ex – the laws of motion are applicable to all forms of forces such as vehicles , sailboats, massive stars, etc.

- **Progressive:**

Scientific knowledge , when corrected leads to new concepts, which may be one step ahead.

As more facts are tested and proved science progresses. This allows us to discard certain theories.

Ex- it was stated that the earth was at the center and the stars and planets moved around the earth. (Geo Centrist) later on Copernicus changed this notion and scientifically advocated that earth rotates on its axis and revolves around the sun. In other words the sun was at the center and not the earth. (heliocentric) Further advancement of science made us understand that only the planets/ bodies of the solar system revolve around the sun not the other stars.



- **Observation and Inference :**

Scientific knowledge is the product of observation and inference.

- **Observations are made from information gathered with the five senses, often augmented with technology.**
- **Inferences are logical interpretations derived from a combination of observation and prior knowledge.**

Ex- we use observation and inference when we determine the distance to stars.

- **Verifiability:** Science rests upon Data gathered through our senses—eye, ear, nose, tongue and touch.

Scientific knowledge is based on verifiable evidence (concrete factual observations) so that other observers can observe, weigh or measure the same phenomena and check out observation for accuracy

SCIENCE

- **Reliability:**

Many scientific ideas have remained largely unchanged over long periods of time. Scientific knowledge must occur under the prescribed circumstances not once but repeatedly.

It is reproducible under the circumstances stated anywhere and anytime.

Conclusions based on casual recollections are not very reliable.

However, scientific knowledge change in the light of new evidence and new ways of thinking.

New scientific ideas are subject to skepticism , especially , if they challenge well established scientific ideas.

Once generally accepted by the scientific community, scientific knowledge is more or less durable.

Ex – The Solar System i.e. number of planets.

- **Scientific Knowledge is Empirically based:**

Empirical refers to the knowledge claims based upon observations of the natural world with the help of your 5 senses.

While some scientific ideas are theoretical and are derived from logic and reasoning , all scientific ideas must ultimately conform to observational or experimental data.

Empirical evidence in the form of qualitative and quantitative data forms the foundation for scientific knowledge.

- **Systematic exploration:**

A scientific research adopts a certain sequential procedure, an organized plan or design of research for collecting and analysis of facts about the problem under study.

Generally, this plan includes a few scientific steps—formulation of hypothesis, collection of facts, analysis of facts (classification, coding and tabulation) and scientific generalization and predication.

- **Scientific Methods:**

There exists no single scientific method used by all scientists. Rather, scientists use a variety of approaches to develop and test ideas and to answer research questions. These include descriptive studies, experimentation, correlation and so on.

The scientific method is a basic description of how experiments are done. As such, it should be seen as an important way, but not the only way that scientists conduct investigations.

Scientists can understand the natural world by using a variety of scientific methods.

- **Creative thinking :** Scientists don't rely solely on logic and rationality. In fact, creativity is a major source of inspiration and innovation in science. Scientists often use creative methods and procedures throughout investigations, bound only by the limitation that they must be able to justify their approaches to satisfaction of their peers.

Ex- Archimedes came up with the Archimedes principle while taking a bath.

THE SCIENTIFIC METHOD

- **Abstractness:**

Science proceeds on a plane of abstraction.

A general scientific principle is highly abstract. It is not interested in giving a realistic picture.

- **Ethical neutrality:**

Science is ethically neutral. It only seeks knowledge.

How this knowledge is to be used, is determined by societal values.

Knowledge can be put to differing uses.

Ex- Knowledge about atomic energy can be used to cure diseases or to wage atomic warfare.

- **Tentative :**

Scientific laws or ideas are subject to change.

Related to the tentative nature of science is the idea that regardless of the amount of empirical evidence supporting a scientific idea or scientific law, it is impossible to prove that the idea/ law holds for every instance and under every condition.

Ex- Einstein's modification to the well established Newton's law of motion



- **Laws and theories are different :**

A scientific law is a description of generalized relationship or pattern based on many observations. Scientific laws describe what happens in the natural world are often expressed in mathematical terms.

Scientific laws are simply descriptive , they provide no explanation for why a phenomenon occurs

Ex - the Boyle's law states that a constant temperature , the pressure of a gas is inversely proportional to its volume. The law expresses a relationship that describes what happens under specific conditions, but offers **no explanation for why** it happens.

Scientific theories are well supported explanations for scientific phenomenon.

Theories offer explanations for why a phenomenon occurs.

Ex - the kinetic molecular theory **explains the relationship** expressed by Boyles law in terms of the inherent motion of the molecular particles that make up gases.

Scientific laws and theories are similar in that both require substantial evidence before they are generally accepted by scientists. Also, either can change with new evidence.



- **Science has limitations:**

Science predicts and explains phenomena. However it cannot solve all problems with complete accuracy.

Ex - there are a few diseases which are not curable today like Aids, Cancer etc.

Thus, science is a subject that describes, finds solutions, prepares models and provides explanations to natural phenomena.

- **Science Explains and Predicts:**

Science has the ability to show the relationships among phenomena which normally could be treated as unrelated .

Ex - the theory of moving continents has emerged by relating various concepts like earthquakes like earthquakes , fossil types on different continents, shapes of different continents etc.

Scientists do not merely describe the phenomena being studied, but also attempt to explain and predict as well.

Validation of scientific claims by observation is not enough, it requires a bit of predictive power. It is typical of social sciences that they have a far lower predictability compared to natural sciences.

This is because of the complexity of the subject matter and inadequacy at control etc.

- **Precision:**

Scientific knowledge is precise. It is not vague like other disciplines.

Precision requires giving exact number or measurement. Instead of saying “most of the people are against

love marriages,” a scientific researcher would say, “ninety per cent people are against love marriages”.

Ex – Distance between the earth and sun.

- **Accuracy:**

Scientific knowledge is accurate.

Accuracy simply means truth or correctness of a statement or describing things in exact words as they are without jumping to unwarranted conclusions.

Ex – the computation of time.



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Science as Knowledge

Knowledge is facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject. It is the awareness or familiarity gained by experience of a fact or situation.

Science consists of a body of knowledge and the process by which that knowledge is developed. The core of the process of science is generating testable explanations, and the methods and approaches to generating knowledge are shared publicly so that they can be evaluated by the community of scientists.

- **Empirical Knowledge**
- **Practical Knowledge**
- **Theoretical Knowledge**
- **Validated Knowledge**

Empirical Knowledge

- Empiricism is a theory of knowledge that asserts that knowledge comes only or primarily from sensory experience.
- It emphasizes on the role of experience and evidence collected through sensory perception, that leads to formulation of new ideas over old ideas or traditions.
- Empirical knowledge means **knowledge gathered through sensory experience**, i.e. through touch, sight, sound, taste or smell.
- In science, all hypotheses and theories are tested against observations of the natural world. Along with reasoning experience is given importance.
- **Evidence derived from experiments become basis for knowledge.**

- For example, Aristotle one of the earliest philosophers said that knowledge of the natural world is based on its perception and thoughts based on what is experienced.
- Other notable philosophers associated with empiricism were Robert Grosseteste, Francis Bacon, Thomas Hobbes, Robert Boyle, John Locke, George Berkeley, David Hume and John Stuart Mill.
- The empirical data can be subjected to bias of the scientists. Verification of scientific data can help to avoid bias of the investigator. Only then can scientific knowledge be validated.

Theoretical Knowledge

- A **scientific theory** is a well-substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment. Such fact-supported **theories** are not "guesses" but reliable accounts of the real world.
- **Construction of valid theories is a major goal of science.**
- **A theory is built on one or more hypotheses as well as evidence and contains reasoning and logical connections based on it.**
- A scientist formulates a hypothesis means a calculated conclusion which he wants to prove right. To do this he conducts experiments and observes facts. The result of this process is a theory.
- A scientific theory can be proved wrong by testing it under various conditions. As new ideas develop and new evidences are found, theories improve accordingly.

- No theory is at any time completely proven, except in pure mathematics.
- Wrong theories are modified or completely discarded.
- For e.g. the **planetary theory of Ptolemy** remained true for around 1000 years till Copernicus gave his heliocentric theory.
- Similarly , **Newton's theory** of gravitation was challenged by Einstein's Theory of Relativity.
- However, **Darwin's** theory of evolution is self consistent.
- Scientists conduct research to verify theories, check their validity or sometimes to improve them. The theories should be able to predict. On the basis of existing theories new discoveries and experiments should be made.

Practical Knowledge

- Practical knowledge of science refers to the **application of scientific knowledge to increase human welfare.**
- Science is a body of knowledge about nature that has been gathered by man over the ages.
- With the help of this knowledge several useful things have been developed either for the purpose of comfort or happiness, for peace or for war.
- The technologist uses the knowledge of science to develop or design or to bring into being things that men want at a particular time whether it is a new industrial product, a weapon of war, or a new medical technique.
- For example, an engineer's job, in general, is not to discover new knowledge but to take the knowledge which has been discovered in past ages and use it to design better structures, better bridges, automobiles, computers, etc.
- Basic theoretical research is required for further technical research.

- Through application of scientific knowledge man has found **solutions** to several problems, increased efficiency of human life and has made many useful things.
- The application of studies in molecular biology, genetics and anatomical research has opened many new areas in medicine.
- Knowledge of space and astronomy has encouraged man to dream of exploiting resources from other planets for use on earth.
- Sciences such as psychology and neuroscience aim at understanding human thinking but there are practical motives such as treatment of mental illness.

Science as validated knowledge

- The essence of science is **validation by observation**. But it is not enough for scientific theories to fit only the observations that are already known.
- Theories should also fit additional observations that were not used in formulating the theories in the first place; that is, theories should have predictive power.
- Demonstrating the predictive power of a theory does not necessarily require the prediction of events in the future.
- The predictions may be about evidence from the past that has not yet been found or studied.

- **For example**, A theory about the origins of human beings can be tested by new discoveries of human-like fossil remains.
- This approach is clearly necessary for reconstructing the events in the history of the earth or of the life forms on it.
- It is also necessary for the study of processes that usually occur very slowly, such as the building of mountains or the aging of stars.
- **For example**, Stars evolve more slowly than we can usually observe. Theories of the evolution of stars, however, may predict unsuspected relationships between features of starlight that can then be sought in existing collections of data about stars.

Thank you