Lesson 1: Introduction to science - what distinguishes scientific knowledge from other types of knowledge

Learning outcomes

LO1# - The student can distinguish and describe the different approaches in scientific theories and epistemological trends, and their scientific history-background (hermeneutical vs scientific, facts and observation, experimentation and falsificationism, induction vs. deduction).

LO#12 - The student is open to perceive and accept the diversity of cultural and social context of research systems and practices.

LO#13 - The student is open for different research methods and is committed to finding consensus in an interdisciplinary research setting.

What is this thing called science?

There is an abundance of evidence from everyday life that science is held in high regard, despite some disenchantment with science because of consequences for which some hold it responsible. It is due to science that humankind went to the moon, that human health longevity increased unprecedentedly in the last centuries, and from science that the solution to the Covid19 pandemics is expected to arise. However, science also generated technology necessary to build the atomic bomb. Good and bad are two sides of the same coin when it relates to the consequences of scientific discovery. Consider these definitions about what is science:

Oxford (2020) defines science as ‘the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment’, and technology as ‘the application of scientific knowledge for practical purposes’.

While the object of study of the natural sciences is the natural phenomena, including objects such as matter, earth and the human body; the object of study of the social sciences result from the social interaction of human beings, based on social phenomena and human behaviours. Moreover, King et al (1994) define social science as ‘an attempt to make sense of social situations that we perceive as more or less complex.’

Science is a method of inquiry—a way of learning and knowing things about the world around us. Contrasted with other ways of learning and knowing about the world, science has some special characteristics. It is a conscious, deliberate, and rigorous undertaking. (Babbie, 2010)

Despite these definitions originating either from the physical sciences or the social sciences, they illustrate a widely held belief that there is something special about science and its methods. The naming of some claim or line of reasoning or piece of research "scientific" is done in a way that is intended to imply merit or special kind of reliability. But what, if anything, is so special about science? What is this "scientific method" that allegedly leads to especially meritorious or reliable results? ALAN CHALMERS in his book “What is This Thing Called Science, 3. ed.” (Chalmers, 2013)

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addressees extensively this question in a simple and accessible way, with plenty of examples to illustrate the reasoning of several of the main philosophers of science.

Answering the question of What is Science? is by no means straightforward. Man and women have been trying to understand for centuries the distinctiveness of scientific knowledge in comparison to other types of knowledge, and there is a whole discipline of Philosophy of Science devoted to understanding science and its boundaries.

The **Philosophy of Science** inquires about the theoretical foundations, methods, and implications of science. The central questions of this discipline concern what qualifies as science, the reliability of scientific theories, and the ultimate purpose of science. However, the way science is practiced - which we will approach later - sometimes is different from theory, and from time to time this mismatch causes changes in the foundational theories. Thus, what is science in theory goes along with what is science in practice, in the sense that one has influenced the other long centuries.

Exploring the main ideas that have helped science philosophers to formulate theories to attempt to explain what distinguishes scientific knowledge from other forms of knowledge is important. Alan Chalmers book will be the main guide to this exploration.

Science is based on facts
It is claimed that science is special because it is based on facts. The facts are presumed to be directly established by a careful, unprejudiced use of the senses. Science is to be based on what we see, hear and touch rather than on personal opinions or speculative imaginings. If observation of the world is carried out in an unprejudiced way then the facts established in this way will constitute a secure, objective basis for science. The reasoning takes us from this factual basis to the laws and theories that constitute scientific knowledge.

The idea that scientific knowledge has a special status - because it is founded on the secure basis of solid· facts firmly established by observation - raises, however, some concerns.

One difficulty concerns the extent to which we rely on our senses which have physical constraints (for example: optical illusions). Also, perceptions are influenced by the background of the observer, so what appears to be an observable fact for one need not be for another example: a drawing in 3D may not be perceived as such from a tribe/community that was never exposed to or interpreted optical illusions).

Our perceptions depend to some extent on our prior knowledge, and hence on our state of preparedness, and our expectations, and the fact that observation statements presuppose the appropriate conceptual framework. How can we obtain significant facts about the world through observation if we do not have some guidance as to what kind of knowledge we are seeking or what problems we are trying to solve? There are facts that are more relevant than others to formulate theories, thus our search for relevant facts needs to be guided by our current state of knowledge (for example: in order to make observations that might make a significant contribution to botany, one needs to know botany to start with.)

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Another difficulty stems from the extent to which judgments about the truth of observation statements depend on what is already known or assumed, thus rendering the observable objects fallible as the presuppositions underlying them. (for example: the fact that the sun moves around the Earth before the discovery of Galileo that Earth moves around the sun). These difficulties suggest that the observable basis for Science, despite being a good basis, is not as straightforward and secure as is widely as traditionally supposed.

Consider the nature of observation, especially as it is employed in science. Observation is not a passive endeavour. There are different ways in which perceptions of the same scene can vary from observer to observer depending on their background, culture and expectations. Problems that eventuate from this undoubted fact can be countered to a large extent by taking appropriate action. There should be no news to the perceptual judgments of individuals that can be unreliable for a range of reasons. The challenge, in science, is to arrange the observable situation in such a way that the reliance on such judgments is minimised if not eliminated. (for example: size of the moon; simple observation, size changes, or taking different measurements at different sites and comparing them then one will conclude that size does not change).

An observation statement constitutes a fact worthy of forming part of the basis for science if it is such that it can be straightforwardly tested by the senses and withstands those tests. The emphasis on tests brings out the active, public character of the vindication of observational statements.

Nevertheless, observable facts are to some degree fallible and subject to revision: If a statement qualifies as an observable fact because it has passed all the tests that can be levelled at it hitherto, this does not mean that it will necessarily survive new kinds of tests that become possible in the light of advance in knowledge and technology.

Relevant facts
One point that should be noted is that what is needed in science is not just facts but relevant facts. Most facts that can be established by observation. Which facts are relevant, and which are not relevant to science will be relative to the current state of development of that science? Science poses the questions, and ideally observation can provide an answer.

Experiments as an adequate basis for science
Many kinds of processes are at work in the world around us, and they are all superimposed on, and interact with, each other in complicated ways. A falling leaf is subject to gravity, air resistance and the force of winds and will also rot to some small degree as it falls. It is not possible to arrive at an understanding of these various processes by careful observation of events as they naturally occur. In general, it is necessary to intervene to try to isolate the process under investigation and eliminate the effects of others. In short, it is necessary to do experiments.

Experiments are adequate, and interpretable as displaying or measuring what they are intended to display or measure, if the experimental set-up is appropriate and disturbing factors have been eliminated.

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Deriving theories from the facts: inductive versus deductive inference
No matter which comes first, the facts or the theory, the question to be addressed is the extent to which the theory is borne out by the facts. The strongest possible claim would be that the theory can be logically derived from the facts. That is, given the facts, the theory can be proven as a consequence of them.

Inductive reasoning departs from specific events to test a general theory. Inductive reasoning represents generalized conclusions based on many observations - looking for a pattern. (for example: Premises: 1. Metal Xl expanded when heated on occasion t l .2. Metal X2 expanded when heated on occasion t2. n. Metal Xn expanded when heated on occasion tn. Conclusion: All metals expand when heated.)

Nevertheless, inductive reasoning is not a logically valid argument. It lacks the basic features of such an argument. This straightforward point is illustrated by an example attributed to Bertrand Russell. It concerns a turkey who noted on his first morning at the turkey farm that he was fed at 9 am. After this experience had been repeated daily for several weeks the turkey felt safe in drawing the conclusion "I am always fed at 9 am". Alas, this conclusion was shown to be false in no uncertain manner when, on Christmas eve, instead of being fed, the turkey's throat was cut. The turkey's argument led it from several true observations to a false conclusion, clearly indicating the invalidity of the argument from a logical point of view.

Arguments which proceed from a finite number of specific facts to a general conclusion, are called inductive arguments, as distinct from logical, deductive arguments. A characteristic of inductive arguments that distinguishes them from deductive ones is that they go beyond what is contained in the premises. General Scientific laws invariably go from the finite amount of observable evidence that is available to support them, and that is why they can never be proven right in the sense of being logically deduced from that evidence.

What are the characteristics of a good inductive argument? The question is of fundamental importance because it is clear that not all generalisations from the observable facts are warranted.

Under precisely what circumstances is it legitimate to assert that a scientific law has been "derived" from some finite body of observational and experimental evidence?

If an inductive inference roll observable facts to laws is to be justified, then the following conditions must be satisfied:

1. The number of observations forming the basis of a generalisation must be large.

2. The observations must be repeated under a wide variety of conditions.

3. No accepted observation statement should conflict with the-derived law.

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Any generalisation from facts about the observable world can yield nothing other than generalisations about the observable world. Consequently, scientific knowledge of the unobservable world (DNA, microscopic) can never be established by inductive reasoning.

Halperin and Heath (2012) define inference as *'the reasoning involved in the process of drawing conclusions based on facts or logical premises"*. King et al (1994) also state that scientific research is '*designed to make descriptive or explanatory inferences based on empirical information about the world*'.

Inference can be used in two opposite directions. **Inductive** reasoning departs from specific events to test a general theory, while **deductive** inference departs from a general theory to forecast or anticipate a specific event. Inductive reasoning represents generalized conclusions based on many observations - looking for a pattern; whereas deductive reasoning is based on testing a hypothesis based on observations.

The laws and theories that make up scientific knowledge are derived by induction from a factual basis supplied by observation and experiment. Once such general knowledge is available, it can be drawn on to make predictions and offer explanations.

(for example: Consider the following argument:

1. Fairly pure water freezes at about 0º (if given sufficient time). =General rule obtained by induction

2. My car radiator contains fairly pure water. = observation

3. If the temperature falls well below 0º, the water in my car radiator will freeze (if given sufficient time). = prediction obtained by deduction that is testable)

Karl Popper's falsificationism

Karl Popper was the most forceful advocate of an alternative to inductivism which is referred to as "falsificationism". He became suspicious of the way in which he saw Freudians and Marxists supporting their theories by interpreting a wide range of instances, of human behaviour or historical change respectively, in terms of their theory and claiming them to be supported on this account. It seemed to Popper that these theories could never go wrong because they were sufficiently flexible to accommodate any instances of human behaviour or historical change as compatible with their theory. Consequently, although giving the appearance of being powerful theories confirmed by a wide range of facts, they could in fact explain nothing because they could rule out nothing.

Popper drew the moral that genuine scientific theories, by making definite predictions, rule out a range of observable states of affairs in a way that he considered Freudian and Marxist theory failed to do. He arrived at his key Idea that scientific theories are falsifiable, that is a theory shouldn't be considered scientific if it cannot be proved wrong, at least in theory.

Once proposed, scientific theories are to be rigorously and ruthlessly tested by observation and experiment. The ones that fail to stand up to observational and experimental tests must be

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eliminated and replaced by further speculative conjectures. Science progresses by trial and error, by conjectures and refutations. Only the fittest theories survive. Though it can never be legitimately said of a theory that it is true, it can hopefully be said that it is the best available, that it is better than anything that has come before.

The falsificationist sees science as a set of hypotheses that are tentatively proposed with the aim of accurately describing or accounting for the behaviour of some aspect of the world or universe. However, not any hypothesis will do. There is one fundamental condition that any hypothesis or system of hypotheses must be falsifiable.

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