GSP 2203: SCIENCE, TECHNOLOGY AND SOCIETY

CHAPTER 1: THE SCIENTIFIC METHOD

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COURSE OUTLINE

- Science and Scientists;
- The Scientific Method

  (Observations, Hypothesis, Prediction, Experimentation, Analysis and Review);
- What of the Social Sciences;
- Scientific and Critical Thinking;
- Criticisms of the Scientific Method.

SCIENCE AND SCIENTISTS

What is Science?

- ***Science (from Latin scientia, meaning "knowledge") is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.***
- Modern science is typically divided into **three major branches** that consist of

i. the ***natural sciences*** (e.g., biology, chemistry, and physics), which study nature in the broadest sense;

ii. the ***social sciences*** (e.g., economics, psychology, and sociology), which study individuals and societies; and

iii. the ***formal sciences*** (e.g., logic, mathematics, and theoretical computer science), which study abstract concepts.

- Disciplines that utilize existing scientific knowledge for practical purposes, such as engineering and medicine, are described as ***applied sciences***.

FEATURES OF SCIENCE

- Science is both a body of knowledge and a process
- Science is exciting
- Science is useful
- Science is ongoing
- Science is a global human endeavour

DISCOVERY: THE SPARK FOR SCIENCE

- For a scientist, every day holds the possibility of discovery, coming up with a brand new idea or of observing something that no one has ever seen before.
- Discoveries, new questions, and new ideas are what keep scientists going and awake.
- In science, discoveries and ideas must be verified by multiple lines of evidence and then integrated into the rest of science, a process which can take many years.
- These activities all involve making observations and analyzing evidence and they all provide the satisfaction of finding an answer that makes sense of all the facts.
- Progress in science both involve making observations, considering evidence, testing ideas and holding on to those that work.

CHARACTERISTICS OF SCIENCE

- Science asks questions about the natural world
- Science aims to explain and understand
- Science works with testable ideas
- Science relies on evidence
- Science is embedded in the scientific community
- Scientific ideas lead to ongoing research
- Participants in science behave scientifically

SCIENTIST'S CODE OF CONDUCT

- Pay attention to what other people have already done.
- Expose your ideas to testing.
- Assimilate the evidence.
- Openly communicate ideas and tests to others.
- Fair play: Act with scientific integrity.

LIMITS OF SCIENCE: A FEW THINGS THAT SCIENCE DOES NOT DO

Science is powerful and it has generated the knowledge that allows thinking that the reach of science might seem to be endless, but it is not. Science has definite limits:

- Science doesn't make moral judgments
- Science doesn't make aesthetic judgments
- Science doesn't tell you how to use scientific knowledge
- Science doesn't draw conclusions about supernatural explanations

THE SCIENTISTS

- *A **scientist** is someone who conducts scientific research to advance knowledge in an area of interest.*
- In modern times, many scientists have advanced degrees in an area of science and pursue careers in various sectors of the economy such as academia, industry, government and non profit environments.
- The roles of "scientists", and their predecessors before the emergence of modern scientific disciplines, have evolved considerably over time.
- Scientists of different eras (and before them, natural philosophers, mathematicians, natural historians, natural theologians, engineers, and others who contributed to the development of science) have had widely different places in society, and the social norms, ethical values, and epistemic virtues associated with scientists and expected of them have changed over time as well.

Scientist	Discoveries/ Contribution(s)
Alessandro Volta (1745-1827)	An Italian physicist/chemist, the inventor of the electrical battery and discoverer of methane, is widely regarded as one of the greatest scientists in history.
Francesco Redi (1626-1697)	An Italian physician/naturalist/biologist. He is referred to as the "father of modern parasitology", is the founder of experimental biology.
Albert Einstein (1879-1955)	German theoretical physicist. He developed the general theory of relativity and made many substantial contributions to physics.
Enrico Fermi (1901-1954)	Italian physicist. He is credited with the creation of the world's first atomic bomb and nuclear reactor.
Niels Bohr (1885-1962)	A Danish physicist. He made fundamental contributions to understanding atomic structure and quantum theory.

Scientist	Discoveries/ Contribution(s)
Rachel Carson (1907-1964)	American Marine Biologist. She was an author, and conservationist whose book *Silent Spring* and other writings are credited with advancing the global environmental movement.
Marie Curie (1867 –1934)	A PolishandnaturalizedFrench physicist and chemist who conducted pioneering research on radioactivity. She was the first woman to win a Nobel Prize, the first person and only woman to win twice, the only person to win a Nobel Prize in two different sciences, and was part of the Curie family legacy of five Nobel Prizes.
Auguste Comte (1798 – 1857)	A French philosopher. He was the first to coin the term "social science" in the nineteenth century. He believed in the concept of positivism, or that the collected senses made up all worthwhile information. .
Aristotle (384 – 322 BC)	An ancient Greek philosopher and scientist. Along with Plato, he is considered the "Father of Western Philosophy". Aristotle provided a complex and harmonious synthesis of the various existing philosophies prior to him, including those of Socrates and Plato,.

Scientist	Discoveries/ Contribution(s)
Auguste Comte (1798 – 1857)	A French philosopher. He was the first to coin the term "social science" in the nineteenth century. He believed in the concept of positivism, or that the collected senses made up all worthwhile information. He was also a prominent figure during the French Revolution in which he called for a doctrine based on science.
Max Weber (1798 -1857)	A German sociologist and political economist. He influenced many social scientists to come. He was one of the first to study methodological antipositivsm, or the belief that the findings that arise in social science cannot be fully interpreted by the scientific method and should focus on the meanings that social actions have.
Karl Max (1818 – 1883)	A German born social scientist. He was an advocate for workers or communism. After his work brought controversy, he sought refuge in Belgium where he theorized that "the nature of individuals depends on the material conditions determining their production." He would later join the Communist League and write the manifesto with Friedrich Engels, and it is still a hot topic of dispute today.

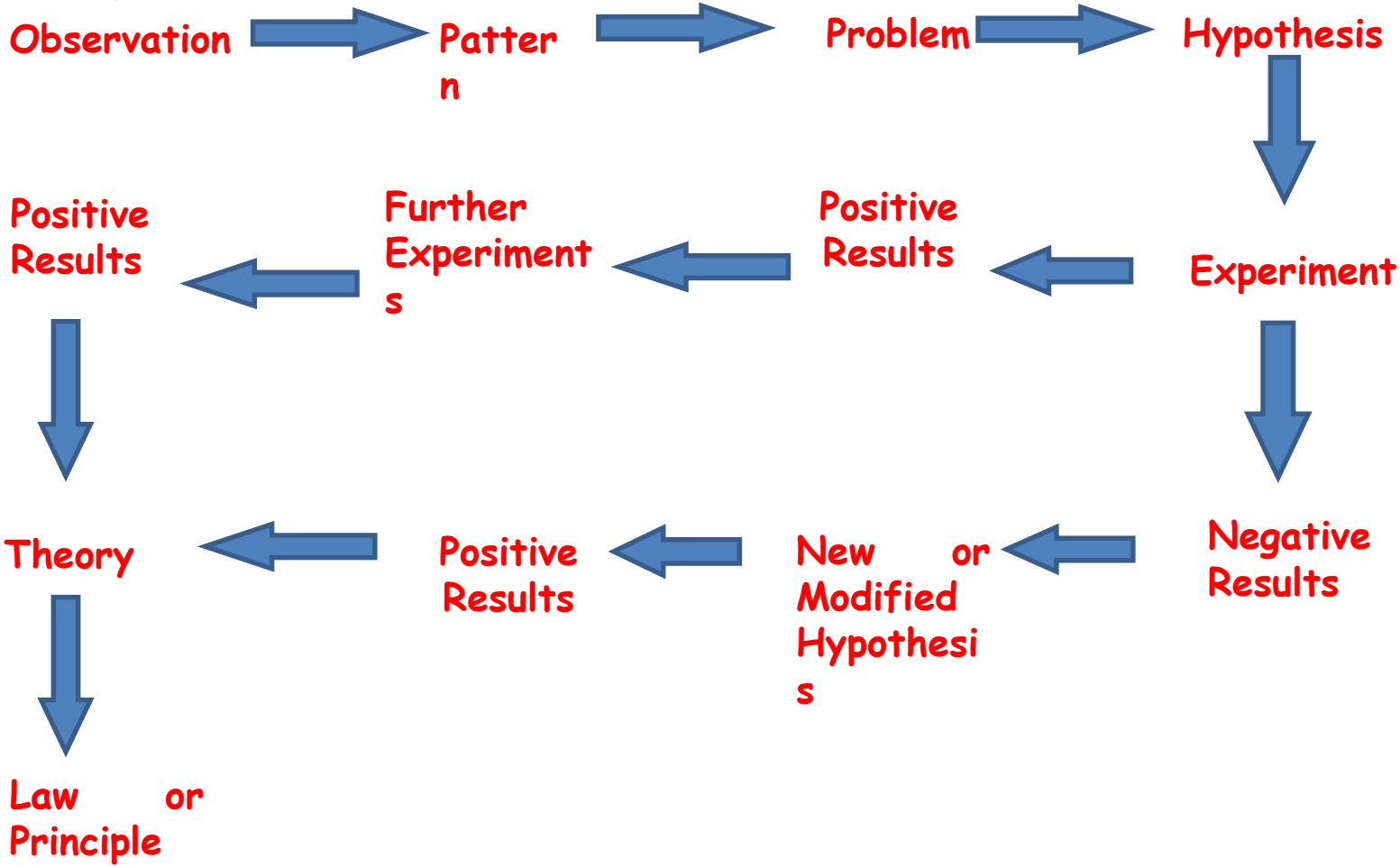
THE SCIENTIFIC METHOD

- *Scientific method simply means the series of steps that scientist use to answer questions and solve problems.*
- It can be said to be a mode of learning or a process of using comparative critical thinking.
- The scientific method in the actual sense is not a sequence of procedures that must happen, although, it is sometimes presented as such.
- Irrespective of how many method it has, a scientific method must contain elements that are applicable to most experimental sciences, such as Physics, Chemistry and is usually taught to aid students in their understanding of science.
- Scientific method is usually subjected to review and independent duplication in order to reduce the degree of uncertainty.
- It may include some or all of the following steps in one form or the other:

THE SCIENTIFIC METHOD
(The Sequential Steps)

- **Observation:** This comes as the first step in the scientific method; in making observation one makes use of the senses to gather information. Sometimes one may use instruments such as microscopes, and telescopes to extend the range of the senses.
- **Question:** Questions drive the scientific method. As one observes, one discovers that one has more questions than answers; the questions which need to be answered to satisfy human curiosity.
- **Hypothesis:** This is an educated guess about how things work. If I do this, then this will happen.
- **Experiment:** As soon as the hypothesis is established, the next step is to test it. The procedure of experiment is what sets science apart from other disciplines, through it, discoveries are made every day. An experiment is carried out to prove or disprove the hypothesis.
- **Evaluation:** Evaluation which is usually the last is integral to the process of scientific method. Here all evidences and conclusions are analyzed in a bid to ensure that biases or inadequate effort do not lead to incorrect conclusions. Qualitative and quantitative mathematical analysis may be applied. Scientific explanations should always be made public either in print or presented at scientific meetings.

MAJOR STEPS IN SCIENTIFIC METHOD



SCIENTIFIC PROTOCOL (REPORTING)

A critical first step in any scientific endeavour is to create a protocol that summarizes:

- Why are you performing your experiments (background information and reasoning) ?
- Precise experimental design
- Methods for data collection and analysis
- All possible outcomes of the experiment
- Potential pitfalls in experimental design, data analysis, or assumptions
- This document will serve as a template for the final presentation of experimental results and conclusions, which should take the form of a scientific paper.

STEPS IN SCIENTIFIC REPORTING

- **Introduction:** This should explain why the particular study being undertaken is relevant and interesting. The introduction should be enough to justify the experiment and its relevance.
- **Methods:** This should describe the experimental protocols that will be employed in the experiment.
- **Data Analysis:** The type of data collected and—if a statistical test is being used to analyze data—the type of statistical test must be stated before any data are collected.
- **Predictions and Interpretations:** All possible results/outcomes of the experiments to be performed should be discussed. Each outcome should be accompanied by an explanation of the most likely cause of this outcome.
- **Potential Problems:** As much as we like to think that our experiments are flawless, this often is not the case, especially in a lab with limited time and resources available. All possible sources of error, and especially note any assumptions being made that are not already supported by previous knowledge should be reported.

CRITICISMS OF THE SCIENTIFIC METHOD

- Science Delusion/Misconception
- Scientific Taboos
- Science Does Not Incorporate the God-factor
- Government and Special Interest
- False Assumptions
- Not-yet-measured Equated to Non-existent
- Moral Decisions and the Scientific Method
- Science Deals with Hypothesis and Not Truth or that Science Sometimes Confuses Theory with Truth

CRITICAL THINKING AND THE SCIENTIFIC METHOD

- ***Critical thinking involves constantly asking questions, examining information and evidence, and figuring out conclusions.***
- Alternatively it can be defined ***as the application of logical principles, rigorous standards of evidence, and careful reasoning to the analysis and discussion of claims, beliefs, and issues.***
- With a scientific attitude, a person is armed for critical thinking.
- Critical thinking has led to many surprising conclusions.
- Critical thinking has also helped to combat commonly held beliefs, such as the idea that opposites attract.
- Scientific theories account for behaviour by linking and integrating observations and facts into a set of principles.
- These principles summarize information and should lead to testable hypotheses.
- Hypotheses are testable predictions that help guide research by providing a framework for the evaluation of research results.
- Results are said to either confirm or not confirm a theory. On the other hand, predictions can also be bias.
- After testing hypotheses, research usually leads to revised theories and additional research.

METHODS IN SOCIAL SCIENCES

- The methodological status of social science is seriously in doubt.
- Natural scientist's attitudes towards it are often suspicious or even hostile, and social scientists themselves are deeply divided over what constitutes a proper approach to social research.
- The uncertainty has been heightened by increasing doubts in philosophy about traditional views of scientific objectivity .
- Arguments about whether social science should be like natural science no longer take place on the basis of agreement about the nature and methods of the latter.
- However, recent developments in realist philosophy have offered new and productive perspectives in both areas that change the whole basis of discussion.
- How does social science relate to everyday knowledge in society and to natural science?
- Does it merely mystify or reproduce the former? Should it emulate the latter?
- Some of those who have attacked social science for the alleged triviality of its findings and for lacking relevance to practical matters have argued that this is due to its failure to use the 'proven' methods of natural science.

METHODS IN SOCIAL SCIENCES

- Others have argued that triviality is precisely the result of using such methods. There is disagreement about whether it should adopt a 'disinterested' stance with respect to practice or be actively involved in the process of social development.
- Some see social science as a natural science of society which can be applied through social engineering.
- Others see their role as having more in common with a therapist than an engineer, their aim being the development of greater self-understanding.
- Still others consider the role of social science to be the critique of society.
- Social scientific knowledge is primarily propositional or referential, rather than practical, and this should immediately provide some clues as to why it seems unable, except very indirectly, to help us decide how to live.
- No doubt the common fear of the alleged danger of 'value intrusion' in social science also inhibits its practical application.

SIMILARITIES BETWEEN NATURAL AND SOCIAL SCIENCES

The main similarities between natural and social sciences include the following:

- Both sciences employ the same scientific model in order to obtain information.
- Some branches of each science even employ both natural and social science components. Examples of natural sciences include biology and ecology, while economics and psychology are examples of social sciences.
- Both have general laws that have numerous applications.
- Both use empirical and measured data that is observable by the senses.
- Additionally, theories in both sciences can be tested to produce theoretical statements and general propositions.

DIFFERENCES BETWEEN SCIENCE AND SOCIAL SCIENCES

Natural science and social science are two types of science that share many things but are also different on many levels.

- Natural science is more concerned with studying nature, while social science is concerned with human behaviour and societies.
- Natural science is characterized by control, exactness, rationality, controlled variables, and predictability, while social science is the opposite, it is spontaneous, with unpredictable or uncontrollable variables, and it deals with human emotions and behaviours.
- The basis of natural science is experimental data, while social sciences rely on experiential data.
- The usual method of natural science (with respect to experimental data) is doing repetitive and conventional experiments in a laboratory, while social science, utilizing experiential data, usually involves alternative methods of observation and interaction with people within a community.
- Natural science work within a closed system, while social sciences work within an open system.

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