Philosophy of Science: An Introduction

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Why Philosophy of Science?

- Science is the most powerful tool that humanity has developed to understand and control the world around us.
- Most importantly, science provides the most reliable methods to approach the truth about the reality.
- How can we use experience to gain (scientific) knowledge or to alter our beliefs in a rational way?

Why Philosophy of Science?

- Why should we care about the philosophy of science?
- Science is like any complex phenomena; it needs to be studied and scrutinized carefully to be understood.
- Philosophy provides tools to resolve confusion and obscurity;
- Philosophy is an incubator of new sciences: science is just philosophy that worked.
- Some questions today still seem to overlap philosophy and science: "what is space?"

Philosophy of Science Issues

- What's the difference between science and pseudoscience? Astronomy/Astrology
- When is a scientific theory/hypothesis/generalization justified to be true? Coincidence/Natural Laws
- Are all sciences reducible to physics?
- Does science describe "reality" or is it just a useful tool? Quarks, electrons, etc.
- Is science "objective" or does it have an inherent perspective?

Outline

A Brief History of Science: Antiquity to 1900

- For most of human history, questions about the nature of the world were answered by religious authorities.
- Mathematics was born in Egypt, and the Babylonians were the first to apply it to astronomy.
- The pre-Socratic philosophers in Ancient Greece were the first to develop a systematic science.
- Thales of Miletus has been dubbed the "the father of science". 7th B.C.E., non-supernatural explanations for earthquakes, lightening, solar eclipse etc.

Pre-Socratic Science

- Anaximander: first to theorize that life came from water and mud, that humans evolved from lower life forms.
- Empedocles: discovered air using a straw and a glass of water.
- Democritus: first theorized that matter was made up of small "atoms"("uncutable" in Greek)
- Eratosthenes: accurately measured the size of the earth.

Antiquity: 3000 B.C.E. - 400 C.E.

- Pythagoras started a school dedicated to math and its application to nature. The term of philosophy, math.
- Hereclitus and Paramenidies' debate: what justifies knowledge, reason or experience? Is nature fundamentally permanent or changing?
- Chemistry consisted of five basic elements: earth, air, fire, water and ether. Hippocrates and Galen developed the first scientific approach to anatomy and medicine using experiments and records.

The Middle Ages: 400 - 1400 C.E.

- Science continued through the Roman Empire.
  - When the Empire fell and "Dark Ages" ensued science in the west ceased to progress.
  - While there were some European scientists in the middle ages, they were generally isolated and marginalized.
- Most scientific advancements from 500-1300 C.E. were made in the Islamic world. Medicine (Avicenna), astronomy, chemistry, etc.
- In the 12th century Europe, Scholasticism tried to reconcile ancient Greek thought with biblical dogma.

The Renaissance: 1400 - 1700

- St. Thomas Aquinas endorsed "natural theology" - knowing God, by studying His creation.
- Free discussion was demanded, weakening Church's sovereignty.
- Thus a renaissance or rebirth in Greek humanism. The universe was seen as a rational and comprehensible place.
- Francis Bacon's scientific method: careful observations and measurements, mathematical modeling.

New Theories and Technologies

- Boyle's theory of gases, laws of electricity, Harvey's theory of the circulation of the blood.
- The telescope, the microscope, thermometer, the printing press, gun powder, the compass, all lead up to the scientific revolution.
- There is a shift back to the idea that human reason, not faith has the power to discover ultimate truth.
- Nicholas Copernicus proposes a heliocentric view of the universe based on astronomical data: the Copernicus Revolution.

Issac Newton (1643-1727)

- The "Age of Enlightenment" was a golden age for "natural philosophers".
- They started looking for laws and mechanisms in nature, not the "purpose" or "Telos" of motion.
- This was epitomized by Sir Isaac Newton and his book *Mathematical Principles of Natural Philosophy*.

Darwin and Modern Biology

- Carl Linnaeus developed the first biological taxonomy. This inspired a young Charles Darwin to become a naturalist.
- While traveling, Darwin saw patterns in organisms and their environments, how they interbred, etc.
- Darwin's was not the first theory of evolution. But he was the first to provide a mechanism for it and a mountain of data to back it up.
- After the recognition of Mendel's discovery of genetics Darwinism was confirmed and the "neo-Darwinian synthesis" cemented the theory of revolution.

How does science work? Proposal One: Empiricism

- Science **works**, despite the many controversies within and surrounding science.
- But how exactly does science work?
- Proposal 1: empiricism. Science is a focused, organized and systematic version of how we know the world through **experience**.
- A counter-example (or not): Ignaz Semmelweiss and infection. Doctors washing their hands before delivering babies greatly reduced infections.

How does science work? Proposal Two: Math

- Galileo says that nature is written in the language of numbers. Science translates that language for us.
- What distinguishes science, what makes it successful is its use of mathematical models.
- Can this be combined with empiricism to make a more sophisticated view?
- For much of the history of philosophy and science, reason and experience were seen as competitors. Now it seems some combination would do. But what kind of combination?

How does science work? Proposal Three: Social Structure

- Many important scientific breakthrough required no real math at all.
- Science is a social endeavor, no individual can do it alone.
- Scientists are trained by and rely on the work of others, notably peer review. Cooperation and trust are essential.
- Scientists (among others) developed groups to police, control, check and coordinate scientific work.

How does science work?

- Experience, math, and social structure.
- How do we adjudicate when these elements are in conflict with each other?

Outline

A brief history of science: antiquity to 1900

When you learn about other cultures, you start to realize the variety of human customs. When you start to realize the variety of human customs, you tend to become more tolerant. Therefore, when you learn about other cultures, you tend to become more tolerant.

Logical Positivism

- Philosophy of science in the early part of the 20th century was dominated by "logical positivism" and its moderate descendant "logical empiricism".
- They were rejected decisively in the 1960's. We can learn a lot from their mistakes.
- Empiricism is the idea that all knowledge comes from and is justified by sense perception.
- The big three British empiricists: Berkeley, Hume and Locke.

Two Central Questions of Empiricism

1. How do you know? The only acceptable evidence for any claim has to refer back to some sort of experience.
   - Metaphysics of Plato and Descartes can't pass this test.
   - This mentality laid the groundwork for modern science.
2. What are the limits of knowledge? What kind of instrument is the human mind?
   - Can human mind grasp grand metaphysical truths about the true nature of reality?

Innate Ideas or Not

- Plato and Descartes both think that some ideas are innate, hardwired into the human mind. How do you know that any idea is innate?
- Locke claims that there is no idea that everybody shares.
- Instead, we are born with nothing in our mind, just a blank slate (Tabula Rasa) upon which sense experience imprints ideas.
- Sensations poured into the mind via the senses and the mind just absorbed them.

The Vienna Circle

- The academic group that founded logical positivism after WWI. They were very interested in scientific developments, mathematical logic, and philosophy of language.
- They hated German Idealism, which is the dominant philosophy of 19th century Europe.
- The Vienna Circle placed a high premium on reason, clarity, and the precision of language.
- They wanted to dispel mysticism, romanticism, and nationalism.

Two Ideas of Logical Positivism

- Logical positivism subscribed to a particular theory of language.
- The two main points were the analytic/synthetic distinction and the verifiability theory of meaning.
- Analytic propositions are ones that are true or false in virtue of their meaning alone: all bachelors are unmarried men; mathematical propositions.
- Synthetic propositions are ones that are true or false in virtue of how the world is. All bachelors are bald.
- The meaning of a sentence is how you verify it.

Logical Positivism and Philosophy of Language

- If there is no way to verify a statement, then it is meaningless. Only statements that are testable have any meaning.
- There are two categories of meaningful statements: observational/theoretical
- Do augmentations of ordinary perceptions such as telescope count as observation?
- Can we observed an electron?

Discovery/Justification

- The positivists distinguished between the context of discovery and the context of justification.
- Einstein said he knew relativity was true long before he could test it because "it was so beautiful it must be true."
- But what legitimizes science is not how the ideas are discovered, but how they are verified.
- The positivists ignored discovery or history. They focused on justifications.

Problems with Logical Positivism

- The verifiability theory says that much language is meaningless. Poetry, ethics and theology are not verifiable.
- Testability is tricky: "Water is blue and Absolute Spirit is perfect."
- W.V.O.Quine: *Two Dogmas of Empiricism*. Testing and meaning were holistic. You can't test ideas in isolation, but all the ideas that are connected.
- Suppose we perform a test of hypothesis X and get a result we didn't expect. Is X falsified?

Problems with Logical Positivism

- Quine argued that there is no scientific way to make sense of the analytic-synthetic distinction.
- It seems like analytic statements are immune from tests, but they are just more likely to stay when challenged.
- Quine argued that we have a "web of beliefs" that all make contact with the world through experience. If we have the right experiences, we might evern revise analytic statements.
- Examples: non-Euclidean geometry and Schrodinger's cat.

Example

"Training poor farmers in developing countries how to use organic farming practices is an effective way to fight poverty. One organization, Harambee-Kenya, has trained hundreds of farmers to use natural farming methods, such as drip irrigation using buckets. These farmers have gone from food shortages to food security and even food surpluses. Some are using the cash they earn by selling their excess agricultural output to finance their children's medical and educational expenses." - Adapted from: Carol Carper, letter to the editor, Christian Science Monitor, Jul 19, 2010,

The Central Issue in the Philosophy of Science

- What is the evidential relation between observations and a scientific theory?

Two Examples of Confirmation

- This piece of copper conducts electricity - all pieces of copper conduct electricity;
- Khloe Kardashian is a third child - all people are third children.
- Maybe the first is "law-like", but the second is only "accidental".
- We need a way of distinguishing between "law-like hypotheses" and "accidental hypotheses."

The Problem of Induction

- Does science establishes "laws of nature?"
- We can only know what we have observed, but never the laws of nature.
- The justification of the inference from finite observations to general laws of nature is called "the problem of induction."
- Bertrand Russell illustrated this problem with his story of a chicken. How are we different from the chicken?

The Hypothetico-Deductive Method

- A scientific hypothesis is confirmed when its logical consequences turn out to be true. "Metal expands when heated."
- A logical consequence of any theory T is "T or S," where S is any statement. "Geocentrism and I am hungry".
- The end result of the HD method is that every statement confirms every other statement. The moon is made of rock and God exists.
- The Ravens Paradox: All ravens are black is confirmed, by the HD theory, by a white shoe.

Outline

Karl Popper

- Karl Popper is well-respected among actual scientists.
- Popper's principle concern is the problem of demarcation: how doe we distinguish between genuine science and non-science or pseudo-science?
- Popper's reply to the Problem of Induction: science is not based on induction, but deduction.
- In order to say two events are the same, we need to interpret the data: the theory ladenness of observation.

Conjecture and Refutation

- Popper claimed that we see repetition because we expect to see repetition. It is our natural psychological tendency.
- We impose regularities that we see on the world, it is the world that determines if the regularities are really there.
- The epistemology of science is a process of trial and error, or conjecture and refutation.
- Popper says the hypotheses come first. Otherwise we wouldn't even know where to look in the first place.

Conjecture and Refutation

- Our propensity to look for regularities breeds dogmatic thinking. We become committed to an idea and refuse to give it up.
- The willingness to abandon this dogmatic thinking and adopt a critical attitude is characteristic of science.
- Dogmatic thinking makes us look to confirm of our theories. If we look for confirmation, we will tend to find it. It is a self-fulfilling prophecy, or the "Oedipus effect."
- The critical attitude of science leads us to try to falsify our theories.

The Problem of Demarcation

- Popper is not asking when is a scientific theory true, or even good. Rather he asks "when should a theory be ranked as scientific?"
- Empirically verifiability is not enough to make a theory scientific. Example: Astrology vs. Einstein's theory of relativity.
- Einstein made a very specific, very radical prediction, that massive bodies would warp spacetime and bend light.
- A scientific theory is "incompatible with certain possible results of observation."

The Problem of Demarcation

- By contrast, Marx's "historical materialism" and Freud's "psycho-analysis" were mere "pseudo-sciences."
- No matter what data was discovered, Marxists and Freudians always saw their theories confirmed. Do you hate your job? Have you dreamed about your mother?
- Astrology is not a science because it is prophecies are too vague to be falsified.
- This does not mean that these theories are all false/worthless. They are just not science.

Possible Objections

- We can never prove a theory inductively from the evidence.
- However, falsifiability is not sufficient for science.
- Holism about testing: anomalies are not counter-examples; Miscalibrated instrument, contaminated sample, etc.
- Popper did not specify exactly how to should we distinguish anomalies from counterexamples.

Possible Objections

- How could we falsify probabilistic claims: is this a fair coin?
- If we try to falsify a theory multiple times and fail every time. Can we say that the theory is more likely to be true than an untested theory?
- But what if we want to build a bridge and we have two techniques of the above two kinds?

Outline

Thomas Kuhn and the History of Science

- Kuhn focused on the historical development of scientific theories, and the "context of discovery".
- He found that most history and science textbooks tended to portray science as linearly progressive.
- But the history of science is filled with dead-ends, false-starts, contradictions.
- So Kuhn set out to draw a more accurate picture of how science develops: "*The Structure of Scientific Revolutions*."

Kuhn and Normal Science

- Most day-to-day science is peaceful, uneventful, problem solving practice. This is what Kuhn called "normal science."
- Normal science happens in terms of a broad set of presupposed, unquestioned assumptions that govern:
  - The sorts of questions that are asked
  - How those questions are investigated
  - How the results are interpreted
- This framework is called a "paradigm": Aristotelian/Newtonian/Einsternian physics.

Two Senses of Paradigm

- The narrow sense of the term paradigm refers to a specific achievement that exemplifies or illustrates a theoretical framework.
- The broad sense of paradigm refers to a pervasive theoretical framework in which people see and interpret the world.

Kuhn and Normal Science

- The average day in the lab involves slow, boring, tedious, repetitive labor. It is not like how Popper described it to be.
- A period of normal science is dedicated to solving "puzzles". Like a cross-word puzzle, we know there is a solution. We expect to find it following the scientific methods.
- As long as there are no real problems that threaten the paradigm, normal science continues.
- All paradigms develop "anomalies": results or observations that don't conform to or can't be immediately explained by the current paradigm.

Kuhn and Paradigm Shift

- Most of the time anomalies are ignored, set aside, relegated to another discipline, or simply explained away.
- But as the puzzles become more and more complicated, the anomalies begin to accumulate. Their combined strength pushes science out of "normal science" into a crisis.
- The current paradigm is not immediately rejected, but seen as inadequate. Only when a new paradigm emerges is the old one rejected.
- Example: Michelson-Morley experiment and Einstein.

Kuhn and Scientific Revolution

- Scientific progress is no longer a steady, consistent, accumulation of knowledge. This is a drastic departure from the previous Enlightenment idea.
- No one really contested Kuhn's basic challenge to the enlightenment picture. By and large, Kuhn's picture is superior.
- What makes Kuhn controversial is his suggestion that we do not rationally "choose" a paradigm: a paradigm shift is like a religious/political conversion.

Kuhn and Popper on Normal Science

- Popper claims that a good scientist is one who is open to criticism. Kuhn disagree.
- During a period of normal science, scientists are actually quite close-minded. They will hold on to their original paradigm.
- Kuhn argues that if scientists were as open as Popper wishes they couldn't do science at all. Science requires cooperation and consensus, which in turn require closing off debate about fundamentals.
- Accepting a paradigm requires a kind of faith. A good scientific education (within a paradigm) is a kind of brainwashing.

Kuhn and Popper on Scientific Change

- For Popper, all scientific change occurs via conjecture and refutation. Kuhn's proposal is more complicated (the circle).
- There are two kinds of change for Kuhn: change within a paradigm and scientific revolution.
- Within a paradigm, there are clear standards for what counts as progress, justification, etc. But scientific revolution has no such standards.
- Some further development interpret Kuhn as a relativist about truth. STS, the science war.

Reference

- David R. Morrow, Anthony Weston (2015). *A Workbook for Arguments: A Complete Course in Critical Thinking*, Second Edition. Hackett Publishing Company, Inc.