UNIVERSITY OF TWENTE.

Philosophy of Engineering: Science

Lecture 2: Scientific Reasoning and Methodology

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Introduction

1. What is Science?

- systematic, logical, rational, objective, explanatory, .., ‘methodological’,
- about the (physical) world (?),
- empirical (?),
- producing <u>true</u> knowledge (?).

2. What is Philosophy of Science?

Introduction

1. What is Science?

2. **What is Philosophy of Science?**

- systematic, logical, rational, (objective), explanatory, .., 'methodological',
- about '**how we reason in science**',
- about our presuppositions and beliefs
- usually not empirical but 'analytic' and 'conceptual',
- producing 'philosophical accounts'.

Last week:

What is philosophy (of science):

Philosophy (in science) is the non-empirical part of science. It investigates our beliefs, images and presuppositions (about science).

Doing philosophy of science involves: investigating (uncovering, articulating and analyzing) presuppositions about science.

General Aims:

1.Learning to critically think *about* Science, e.g.

a) Scientific <u>knowledge</u>: What is it? How to prove it?

b) Scientific <u>research</u>, e.g. Engineering sciences: How?

c) Science in <u>society</u>. How can claims be justified?

2.This requires learning content and skills:

a) Content: A <u>vocabulary</u> / ideas / concepts to think and talk *about* science (= philosophy of science theory).

b) **Skills**: Ability of <u>philosophical reflection</u>, including: articulation, analysis, argumentation, revealing presuppositions.

This week:

In philosophy of science, philosophers study how ‘we’ reason in science.

Philosophers do this in a very systematic, and often strictly logical way.

This very ‘straightforward’ approach can sometimes result into ‘shocking results.

Examples of important presuppositions and beliefs in science can be found in the <u>handout</u> “what is philosophy of science.” Examples are: “that there is structure in the world,” “that there are ‘laws of nature,’” “that every event is caused by something else,” “that everything can ‘in the end’ be explained by fundamental laws.”

Can we prove scientific knowledge?

1. Is it possible to prove scientfic knowledge?

   YES / NO

2. If YES: How? If NO: Why not?

Can we prove scientific knowledge?

1. Is it possible to prove scientfic knowledge?

   YES / NO

2. If YES: How? If NO: Why not?

1. Is it possible to prove scientfic knowledge? Yes = True; No = False

   (A) True **58 / 99 = 59 %**

   (B) False **41 / 99 = 41 %**

socrative
by MasteryConnect

If YES (it is possible to prove scientific knowledge: How?
If NO (it is not possible to prove scientific knowledge): Why not?

[redacted]

Because scientific knowledge has logical reasoning behind it, mathematical proofs, so it can be proved later on

[redacted]

it can be proved using scientific methodology and experiments

[redacted]

Yes, by giving a mathmatical proof, then you can show that the statement holds in any case.

[redacted]

it is not possible to test a theory in all cases

[redacted]

apply it to nature/society and see that it works

[redacted]

If certain natural laws + conditions are satisfied, then it is possible.

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If certain natural laws + conditions are satisfied, then it is possible.

12[redacted]

No, because there can always be another explanation that is not yet known. It is possible to disprove something

[redacted]

by doing measuremenst and experiments

S[redacted]

scientific knowledge is generated by following a logical method, which proves its credibility.

S[redacted]

yes: not all, but in a lot of cases if you would explicitly mention your assumptions and definitions it could become a valid proof.

S[redacted]

if you can say something which is true withouth a doubt because of some sort of prove. there are things that will be the same always and thus coukd be proben in a way

[redacted]

scientific knowledge can be proven through mathematics. whic is considered to be a universal language.

Is it possible to prove claims by means of scientific research?

Scientific methodology: **Epistemology** addresses the *justification* of methodologies.

Science talks about the (physical) world; it asks questions about the world: why, what, how questions. Philosophy of sciences talks about science; it asks questions about science: why, what, how questions.

What is Philosophy of Science?

I. **Epistemology**: How do we prove knowledge? ("Justified true believe." e.g., are claims made in science true?) => Justification of scientific method

II. **Metaphysics**: How is the world (e.g., which things exist)? Does science tell what the world is like (e.g., do things described in science really exist)? => Realism and anti-realism (e.g., instrumentalism, constructivism) about science. (see Ladyman part I and II)

I. Epistemology (16th-7th century)

They asked: What is the basis (solid ground) of knowledge? How can we be certain?

Rationalism	Empiricism
	
Rene Descartes	**Francis Bacon**

Rationalism: problem is underpinning first principles: how do we know the first principles are true.

e.g. rules of logic, mathematics, conservation laws, principle of evolution.

Associated with rationalism is the doctrine of innate ideas and the method of logically deducing truths about the world from “self-evident” premises. Rationalism is opposed to empiricism on the question of the source of knowledge and the techniques for verification of knowledge. René Descartes, G. W. von Leibniz, and Baruch Spinoza all represent the rationalist position, and John Locke the empirical. Immanuel Kant in his critical philosophy attempted a synthesis of these two positions. More loosely, rationalism may signify confidence in the intelligible, orderly character of the world and in the mind’s ability to discern such order. In the 18th cent. rationalism produced a religion of its own called deism

Empiricism: Knowledge can only be obtained through the use of the senses to find out about the world and not by the use of pure thought or reason.

Empiricism requires principle of induction: when a large number of observations of Xs under a wide variety of conditions have been made, and when all Xs have been found to possess property Y, and when no instance has been found to contradict the universal generalization ‘all Xs possess property Y”.

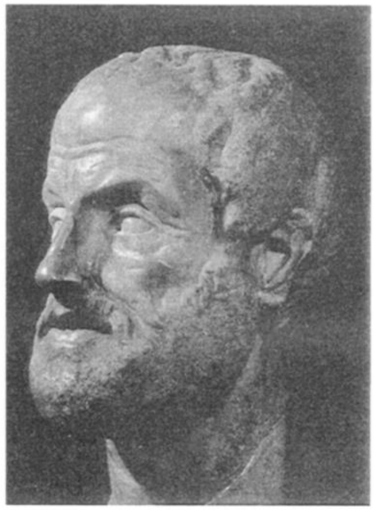
Problem of induction: when is it legitimate to infer a universal generalization from a collection of observations.

Scientific method: Rationalism

Aristotle (384-322 v. Chr.)

Organum

Deductive reasoning from first principles - which are universal and necessary. (e.g. logical principles)



Logical deduction:

P_1: All men are mortal.

$\underline{P_2\text{: Socrates is a man}}$.

C: Therefore Socrates is mortal

How do we get our first principles? Intuition.

Problem with logical deduction: conclusion says nothing new.

Note that ‘first principles’ play a role on two different levels:

1) The principle of deduction, which says that this logical form is valid.
2) The principle that “All men are mortal”. Why do we assume that this principle is true? Has it been derived by means of inductive reasoning, or can you give another kind of justification (e.g., what if we would find a person who is not mortal).

[Think of the important test: does its negation lead to a contradiction?]

Scientific method: Rationalism

Descartes (1596 – 1650)

Discours de la méthode

Ideal of mathematical proof:

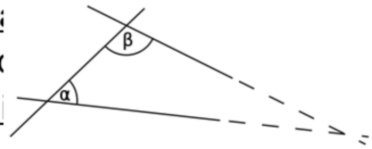
Scientific knowledge (e.g. laws of nature) must be proven by deductive reasoning from first principles similar to the proof of a theorem in mathematics.

Example of 1st principles — Rationalism

Euclidean geometry

An axiomatic system, in which all theorems ("true statements") are derived from a finite number of axioms. Near the beginning of the first book of the *Elements*, Euclid gives five axioms:

1. Any two points can be joined by a straigh line.
2. Any straight line segment can be extended indefinitely in a straight line.
3. Given any straight line segment, a circle can be drawn having the segment as radius and one endpoint as center.
4. All right angles are congruent.
5. Parallel postulate. If two lines intersect a
that the sum of the inner angles on one si
angles, then the two lines inevitably must i
that side if extended far enough.

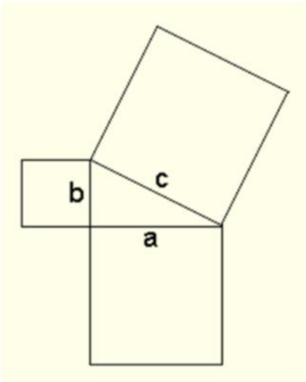


Are these principles (axioms) self-evident?

Other axiomatic systems happen to be possible in mathematics (e.g., non-Euclidean geometry http://en.wikipedia.org/wiki/Non-Euclidean_geometry). What do we learn from this situation about ‘self-evident’ principles? On what basis are (alternative) axiomatic systems accepted: self-evidence of the principles is important, but what else?

Example: Proof of Pythagoras' theorem

Suppose these three squares were made of beaten gold (thickness d), and you were offered either the one large square or the two small squares. Which would you choose?

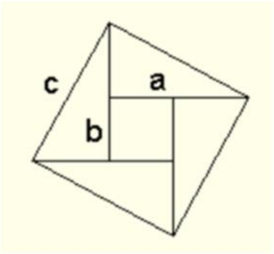


The *Pythagorean* (or *Pythagoras'*) *Theorem* is the statement that the sum of (the areas of) the two small squares equals (the area of) the big one.
In algebraic terms, $\mathbf{a^2 + b^2 = c^2}$ where **c** is the hypotenuse while **a** and **b** are the legs of the triangle.

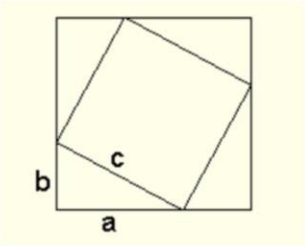
$$a^2 + b^2 = c^2$$

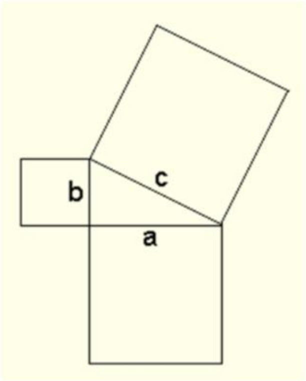
Example of proof by deductive reasoning

The square has a square-hole with the side (**a - b**). Summing up its area (**a - b**)^2 and the area of the four triangles, 4·**ab**/2, we get
$c^2 = (a - b)^2 + 2ab = a^2 - 2ab + b^2 + 2ab \Rightarrow c^2 = a^2 + b^2$



$$a^2 + b^2 = c^2$$





The area of the square **$(a + b)^2$** consists of the square **c^2** and the area of the four triangles (4·**ab**/2)
=> **$c^2 + 2ab = (a + b)^2$**.

Descartes' Rationalism

Scientific method: Deduction from First Principles:

1. Accepting as "truth" only clear, distinct ideas that could not be doubted (First Principles).
2. Breaking a problem down into parts (Reduction).
3. Deducing one conclusion from another (Deduction)
4. Conducting a systematic synthesis of all things (Universalization)

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Is it possible to prove claims by means of scientific research?

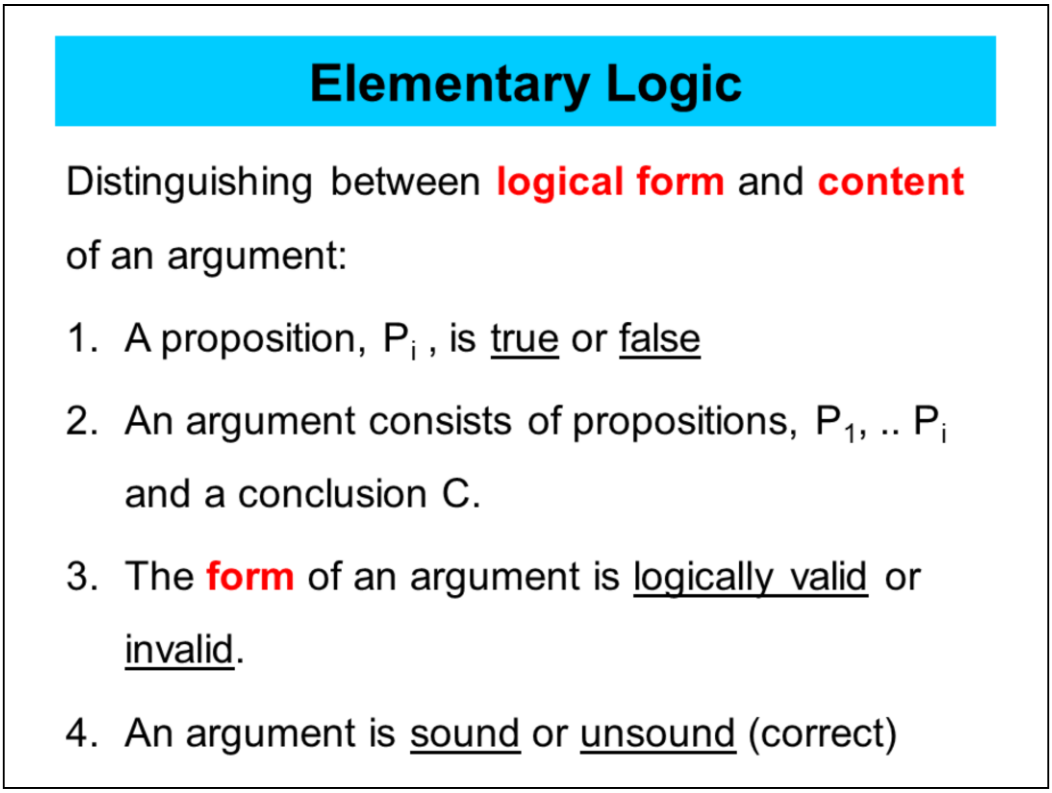
Scientific methodology: **Epistemology** addresses the *justification* of methodologies.

A. The role of **scientific reasoning** in scientific methodology, e.g.:

   1. Deductive reasoning (+ Falsification)
   2. Inductive reasoning (+ Problem of Induction)
   3. Causal reasoning (+ Manipulationism)
   4. Explanatory reasoning (IBE)

B. The role of **truth** in scientific methodology

Science talks about the (physical) world; it asks questions about the world: why, what, how questions. Philosophy of sciences talks about science; it asks questions about science: why, what, how questions.



In scientific reasoning we can distinguish between the (logical) form of an argument and its contents. With regards to the form, we distinguish between two logical forms: "deductive reasoning" and "inductive reasoning" .

To understand these we need to understand a bit of elementary logic; here we introduce some technical terms that will be used later. It concerns the distinction between (the use of) the qualifications: true / false , valid / invalid , and sound / unsound.

Let's look at the distinction between the (logical) form of an argument, and its contents.

1. Earlier we said that a sentence (a proposition) is either true or false, that is, when 'what the sentence says about reality' is or is not the case (Please note that the sentence is true, not 'the situation' itself).
2. (2-4) An argument is composed of a number of sentences (propositions) from which a conclusion, C, is drawn. In your assignments you can find a number of arguments. How do you tell whether these arguments are sound? For this, you make a distinction between the logical form of the argument (it should be valid) and the content of the sentences (these sentences must be true).
3. So you can determine separately whether the logical form of the argument

is valid, and whether the sentences are true.

4. The idea is that only when the logical form of an argument is valid, *and* all propositions are true, the conclusion of this argument must also necessarily be true. In this case , the argument is sound. An argument is not sound if either one or more of the propositions is false and / or the logical form invalid. See summary on the next slide

Deductive Arguments (Truth**)**

- *If* a deductive argument is valid *and* propositions, P_1, .. P_i, are true, *then* the conclusion, C, MUST be true

- To evaluate deductive arguments:
  - Validity (logical correctness: only form).
  - Soundness (form + content).

Deductive Arguments (Logical form)

P_1: All men are mortal.

<u>P_2: Socrates is a man</u>.

C: Therefore Socrates is mortal.

Logical form of this argument:

All A's are B	If A then B (implication)
<u>x is an A</u>	<u>A .</u>
Therefore: x is B	Therefore: B

This slide shows the logical form of deductive reasoning. Deduction means deriving a specific statement of a general statement.

In the upper part you see form + content.

In the lower part the logical form is presented in abstracted form, separating out the content.

This deductive logical form is valid.

If you look at the example of "All men are mortal", the logical form is valid. But is this argument sound? For that, we have to look at the content.

The first sentence, "All men are mortal “, is true (at least that we assume because the contrary has never been proved).

The second sentence, "Socrates is a man" is false if Socrates for instance is not a man but my dog. In that case, the argument is not sound, and we can not conclude *on the basis of this argument* that (my dog) Socrates is mortal!

So the argument:

All men are mortal

<u>*Socrates is a dog*</u>

Socrates is mortal

Is not sound, as the logical form is not valid:

All A's are B

x is an H

Thus: x is B.

Note : It may still be true that my dog is mortal (it is in fact very likely!), but it does not follow from this argument!

Deductive Arguments (Soundness)

P_1: If today is Tuesday, then tomorrow is Wednesday.

P_2: Today is Tuesday.

C: Tomorrow is Wednesday.

- Valid
- Sound on Tuesdays
- Unsound on Mondays, Wednesdays, Thursdays, Fridays, Saturdays, and Sundays!

Scientific method: Empiricism

Francis Bacon(1561-1626)

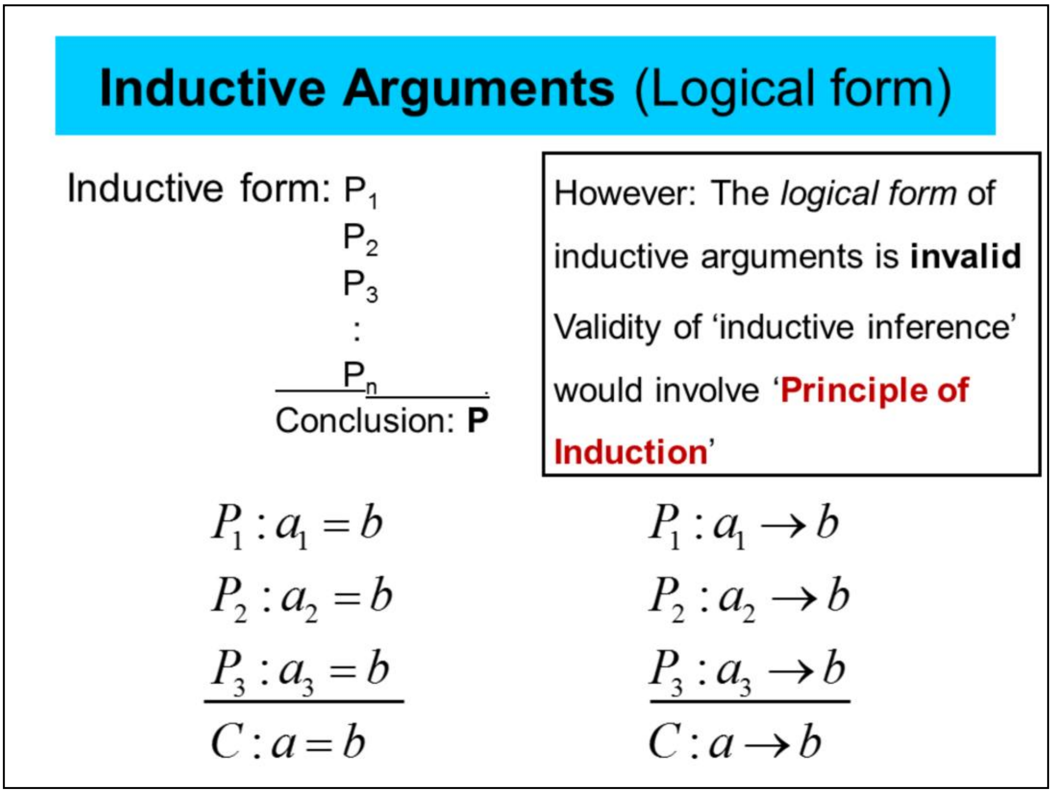
Novum Organum (1620)

Inductive reasoning and observation

Francis Bacon Empiricism

Scientific method: Observation + Inductive reasoning

1. Eliminating presuppositions ("idols of the mind").
2. Next, by gathering a mass of information about particular states of affairs and building step by step to a general conclusion (i.e. hypothesis).
3. Experiments allow us to ask "what would happen if…?" Experiments are supposed to be repeatable, so that others can check. Role of instruments is important since perception is unreliable.
4. Next tables are drawn. Studying information and finding something that is present in all instances. .. The thing to satisfy these conditions is to be found by elimination.
5. Following his method, one can discover the forms, which, although not directly observable, produce the phenomena that we can perceive with the senses.



Logical form of inductive arguments is **invalid** (also see Ladyman for further explanation).

Hence, the second problem of scientific methodology is that we cannot prove, say the law that “all A’s are B” by means of inductive reasoning.

Conclusion: Formal logic is extremely important for evaluating scientific reasoning. It also shows that we cannot prove much by logical reasoning. At the same time, deductive and inductive reasoning are crucial to scientific reasoning.

Note that inductive proofs are valid in mathematics! [Roughly, the structure of a proof by mathematical induction: you must prove that the statement holds for n=0, n=1, and for n+1), by means of which you have proven that it holds for all values of n.].

What is a law of nature?

(Q1-5): In your opinion, is the conclusion, C, of the inductive argument, -- in this particular example – which uses observations described by proposition P_1, P_2, …, P_n, a law of nature?

Multiple choice:

- This is a **law of nature**
- This is an **“accidentally true” generalization**
- None of the above

socrative
by MasteryConnect

Is the conclusion of this inductive argument a law of nature (choose one answer)

1. P1: Yesterday the clock stroke every hour

P2: Today the clock stroke every hour

P3: In the last 3 weeks the clock stroke every hour

....

Pn: ...

____

C: Tomorrow the clock will strike every hour

5/59 (A) This is a law of nature

23/59 (B) This is an accidentally true generalization

21/59 (C) None of the above

Is the conclusion of this inductive argument a law of nature (choose one answer)

2. P1: Raven 1 is black

P2: Raven 2 is black

P3: Raven 3 is black

...

Pn: ...

____

C: All ravens are black

5/59 (A) This is a law of nature

26/59 (B) This is an accidentally true generalization

27/59 (C) None of the above

Is the conclusion of this inductive argument a law of nature (choose one answer)

3\. P1: The day before yesterday the sun rose

P2: Yesterday the sun rose

P3: Today the sun rose

Pn: ...

C: The sun rises every day

31/59 (A) This is a law of nature

15/59 (B) This is an accidentally true generalization

15/59 (C) None of the above

Is the conclusion of this inductive argument a law of nature (choose one answer)

4. P1: Iron conducts electricity

P2: Copper conducts electricity

P3: Gold conducts electricity

...

Pn: ...

C: All metals conduct electricity

24/59 (A) This is a law of nature

17/59 (B) This is an accidentally true generalization

14/59 (C) None of the above

socrative by MasteryConnect

Is the conclusion of this inductive argument a law of nature (choose one answer)

P_1V_1 (at Ta) = k

5. P_2V_2 (at Ta) = k

P_3V_3 (at Ta) = k

...

C: PV = k(T)

33/59 (A) This is a law of nature

14/59 (B) This is an accidentally true generalization

9/59 (C) None of the above

What is a law of nature?

(Q1-5) Is the conclusion of an inductive argument a law of nature?

(Q6) Why do you think it is (or is not) a law of nature? and/or What is a law of nature in your opinion?

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by MasteryConnect

Why do you think it is (or is not) a law of nature? and/or What is a law of nature in your opinion?

[redacted]

There can always appear an exception when argumented using inductive reasoning. Those arguments were accidentally argumented true but there is a rational explanation of them that makes them absolutely true.

[redacted]

It is a law when you can prove that it always holds, so not by doing experiments and observe that it holds for those specific experiments.

S[redacted]

if something holds for n particular cases, it doesn't mean it holds for all the cases. a law of nature says something about ALL cases. therefore only the last one was a law of nature.

[redacted]

It is a law of nature because it is repeatedly observed and proved. A LON is universal, repeatedly observed and able to be proven.

[redacted]

a law of nature descrips a physical causal relationship

[redacted]

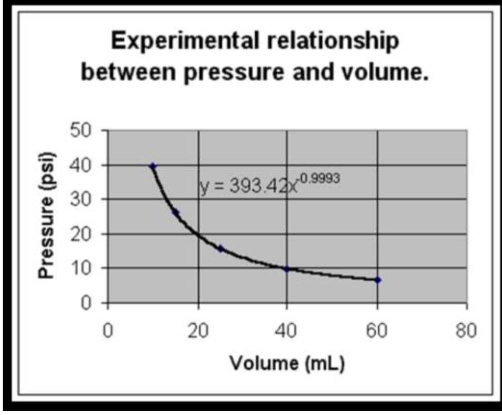
The last example showed a mathematical definition in which there is minimal ambiguity. This increases the probability of an observation to be a law.

Empiricism - example

Boyle's law

Robert Boyle (1627-1691)
Induction: Inference from measured data to a law.

$$P_1V_1=P_2V_2$$

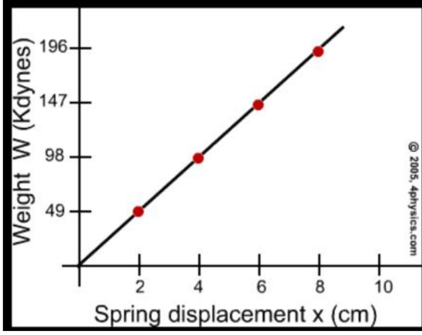


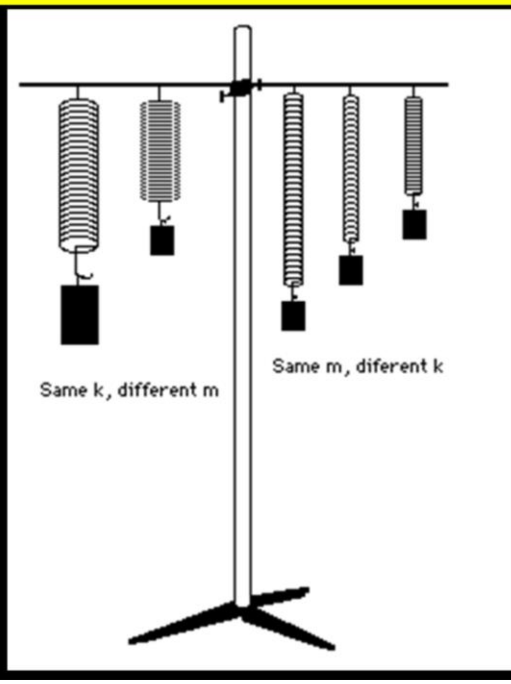
Empiricism - example

Robert Hooke's law (1635)

Induction: Inference from measured data to a law.

F=-k.x



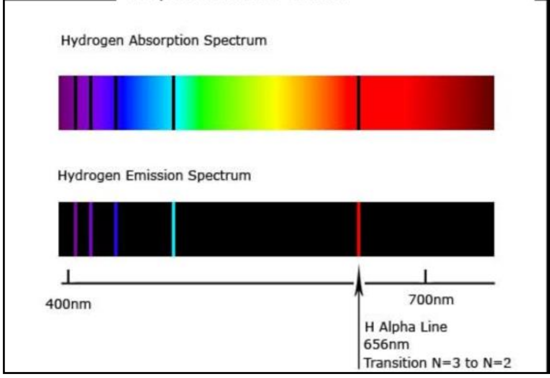


Empiricism - examples

Equipment

Number of set-ups available:

1 spectrometer/diffraction grating
1 hydrogen spectrum tube
1 spectrum tube power supply
1 flashlight
1 Handbook of Chemistry and Physics
1 cross hair illuminator
1 small lamp
1 spectrometer stand

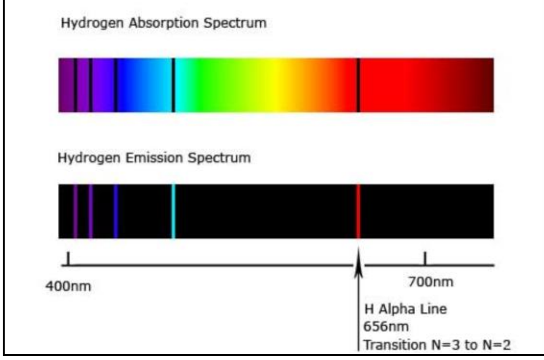


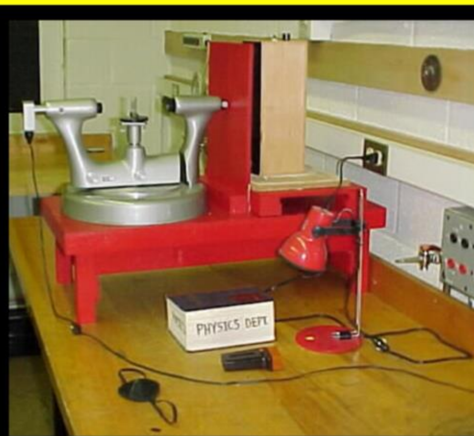
Empiricism - examples

Equipment
Num
1 sp
1
1
1
1
1
1
1 spectrometer stand

Balmer's equation

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$



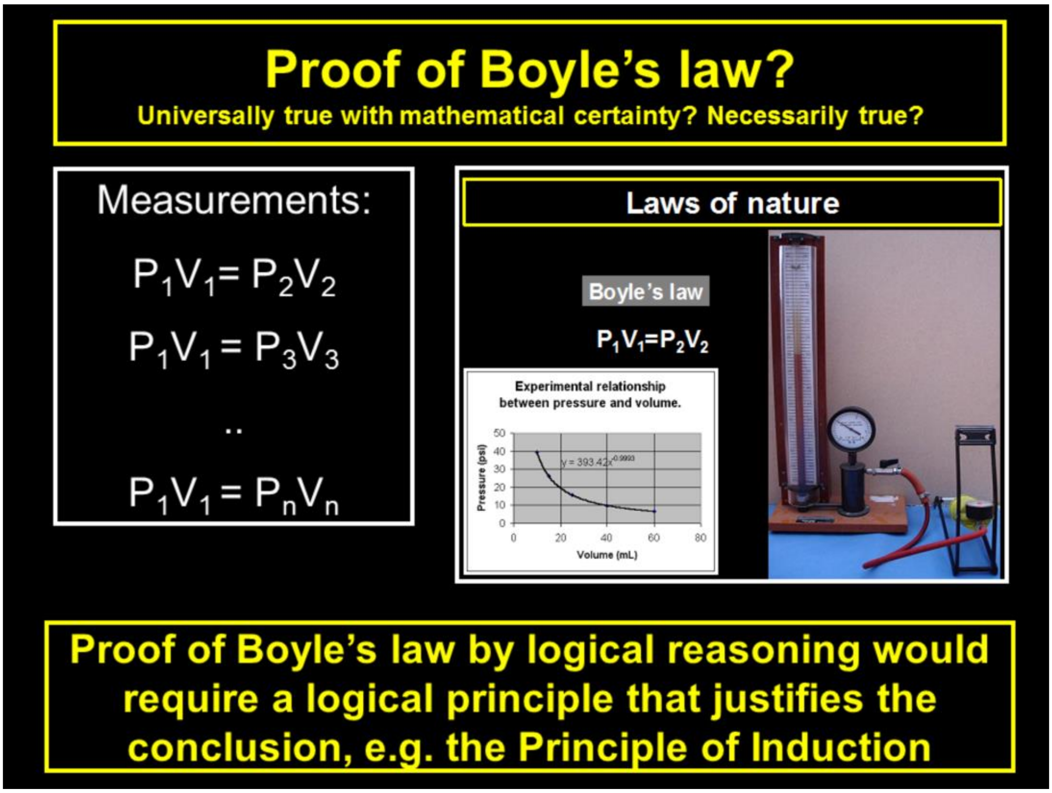


Proof of Boyle's law?

Empiricism

Universally true with mathematical certainty? Necessarily true?

1. Conclusions in all these examples result from inductive reasoning => Are the conclusions of an arguments true (or proven) if all propositions (P_1, ..P_n) are true?



Inductive form: P_1

P_2

:

P_n

Conclusion: P

1. Methodology needed to prove scientific knowledge (59% = 58 students: YES it is possible to prove knowledge; 41% = 41 students: NO it is not possible
2. **Methodology in *Empiricism*:** Observation + generalisation (logical form: inductive reasoning)
3. If correct, the **Conclusion, P** (e.g., All A's are B) of an inductive argument would be *logically* (= necessarily) true.

However: The *logical form* of inductive arguments is **invalid**

Validity of 'inductive inference' would involve '**Principle of Induction**'

Empiricism

Principle of Induction

Proof of Boyle's law would require a logical principle that justifies the conclusion, e.g. the **Principle of Induction**

David Hume: however, the principle of induction is logically invalid

But we talk about laws of nature, and inductive reasoning is a common way of reasoning?!

Proof of Boyle's law?

Empiricism

Universally true with mathematical certainty? Necessarily true?

1. Conclusions in all these examples result from inductive reasoning => Are the conclusions of an arguments true (or proven) if all propositions (P_1, ..P_n) are true?
2. How can we distinguish between conclusions from inductive arguments that are laws of nature and those that are not (= it is only a correlation or accidentally true generalization)?
3. Are there other scientific methods involved in proving a law of nature?

Proof of Boyle's law?

Empiricism

Universally true with mathematical certainty? Necessarily true?

3. Are there other methods involved in proving a law of nature?
4. Bacon's methodology: Observation and inductive reasoning.
5. Solution 1: "discover the forms, which, although not directly observable, produce the phenomena that we can perceive with the senses."
6. Solution 2: Law of nature is a causal relationship between two events.

David Hume (1711 – 1776)

An enquiry concerning Human Understanding

1. **Problem of Induction**:
   Principal of induction is logically invalid.
2. **Problem of Observation**:
   Connection (causal relationship, ‘hidden force’) cannot be observed.

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David Hume (1711 – 1776)

An enquiry concerning Human Understanding

Problems of Empiricism:
- Induction (logically invalid)
- Causality (cannot be observed)
- Necessary connection (,,)

Hume says that "We suppose that there is some connexion between them; some power in the one, by which it infallibly produces the other, and operates with the greatest certainty and strongest necessity." -- but there is no legitimate basis in our experience for this additional claim. Instead, that claim is derived simply from the habit of the mind "upon the appearance of one event, to expect its usual attendant, and to believe that it will exist.

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Hume's problem with causality is that 'the causal connection' (e.g., a force) cannot be observed. Think for instance of the following example. You see to circles on a screen. The number 1 moves and touches number 2, and at the same instance number 2 starts to move. Would you conclude that the movement of number 2 is caused by 1? How would you make the distinction between occurrences in which we see that two events (movement of 1, movement of 2) immediately follow up on one another, accidentally, or causally?

Important in experiments, is that we examine causal relationships by direct intervention with the cause. This is the manipulationist account of of causality. (So, rather than by passive observation, we learn about causal relationships by active experimental interventions).

Can we prove Boyle's law?

Universally true with mathematical certainty. Necessarily true

3. Are there other methods involved in proving a law of nature?
4. Bacon: Observation and inductive reasoning.
5. Solution 2: Law is a causal relationship between two events.
6. Hume: Causal relationship ('hidden power') cannot be observed.
7. Can this be solved?
8. (a) How do we know that an inductive generalisation is a law of nature?
   (b) How can we prove the principle behind it?

Summary of Problem of Induction

How can we justify inductive reasoning?

Or, how can we justify generalizations "If A then B"?

I. Is there a (logically) necessary relation between A and B?

- What do we mean by logical necessity?
- How do we 'test' logical necessity?

By asking: Does the denial of "If A then B" lead to a logical contradiction?

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Summary of Problem of Induction

II. Is there a causal connection between A and B?

- What do we mean by a causal connection?
- How do we test that there exists a causal connection? (We cannot observe it).

III. Does “If A then B” describe a law in nature?

- What is a law of nature?
- How do we know that it is a laws of nature and not just an ‘accidentally true generalization’?

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Problem of Induction

Is the problem of induction relevant for doing scientific research and using scientific knowledge?

1. Go back to how the law was experimentally produced.
2. Find out about other relevant circumstances.
3. Decide whether these circumstances are ‘sufficiently similar’ to your situation.
4. Find out about further scientific explanation of why the law holds.

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Manipulationism: another solution to the induction problem

We can find out whether there is a causal relationship between two events (‘cause’ and ‘effect’):

Interventionist or Manipulationist

‘account’ of causality

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In current philosophy of science, one of the proposed solutions is the so-called interventionist or manipulationist account of causality. Roughly, the idea is that we know of causal relationships in case of (physical) interventions such as in experiments. Does this solve the Hume’s problem?

Helmet therapy / Aspirin / Smoking / and Manipulationism (or Interventionism):

1. It has been observed that in many cases skull deformation gets better after wearing a helmet. Does the manipulationist criterion for determining whether there is a causal relationship [**A causes B**] between "wearing the helmet" (A) and "curing deformation of the skull" (B) apply? (Choose one answer). YES/NO
2. Taking aspirin / paracetamol for headaches. YES/NO
3. Smoking and lung cancer. YES/NO

1. It has been observed that in many cases skull deformation gets better after wearing a helmet. Does the manipulationist criterion for determining whether there is a causal relationship between "wearing the helmet" (A) and "curing deformation of the skull" (B) apply? (Choose One answer).

28/57 (A) No, because we do not understand what the cause really is.

13/57 (B) Yes, because there is an intervention (wearing the helmet) and an effect (the deformation of the skull gets better).

7/57 (C) None of the above

2. It has been observed that in many cases headaches get better after taking an aspirin. Does the manipulationist criterion for determining whether there is a causal relationship between "taking an aspirin" (A) and "curing headaches" (B) apply? (Choose One answer).

23/57 (A) No, because we do not understand what the cause really is.

20/57 (B) Yes, because there is an intervention (taking an aspirin) and an effect (headache gets better).

3/57 (C) None of the above

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3. It has been observed that in many cases people get lung cancer when long-life smokers. Does the manipulationist criterion for determining whether there is a causal relationship between "smoking" (A) and "lung cancer" (B) apply? (Choose One answer).

24/57 (A) No, because we do not understand what the cause really is.

25/57 (B) Yes, because there is an intervention (smoking) and an effect (lung cancer).

6/57 (C) None of the above

HElmet therapy: It has been observed that in many cases skull deformation gets better after wearing a helmet.

“HElmet therapy cures skull deformation”

Does this account work for the Helmet therapy? The intervention seems to result into an improvement of the skull.

Helmet therapy / Aspirin / Smoking / and Manipulationism (or Interventionism):

1. It has been observed that in many cases skull deformation gets better after wearing a helmet. Does the manipulationist criterion for determining whether there is a causal relationship [**A causes B**] between "wearing the helmet" (A) and "curing deformation of the skull" (B) apply? (Choose one answer). YES/NO
2. Taking aspirin / paracetamol for headaches. YES/NO
3. Smoking and lung cancer. YES/NO
4. [Open question] **What method would you propose for distinguishing between correlations (accidentally true generalizations) and causal relationships?**

Question four is introduced on the tape.

4. What method would you propose for distinguishing between correlations (accidentally true generalizations) and causal relationships?

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Testing if the intervention does or does not have an effect.

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Observarion of the cause, understanding it.

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You can never be sure whether a relation is causal or there is just a (strong) correlation. But often you don't need to be sure to get something useful.

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Also test what happens if no helmet/aspirine/sigarete is used, will the effect be the same, or different?

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Making a testgroup, keep all other conditions constant and test on both groups

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For example, have a group take the medicins and an other group not. If the group with medicins performs significantly enough better than the control group, than the medicine works.

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In causal relationship the cause and effect are fully correlated, with correlation they are not.

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Epistemology: Scientific method

Rationalism	Empiricism
Science starts with finding first principles (axioms) ⇒True knowledge by means of deduction from first principles	Science starts with observation ⇒ True knowledge by means of induction ⇒ Laws of nature