

Theory and Methodology of Science

Lecture 1: The Aim of Science

Different ways of Justifying Method Choice:

1. Conventional 2. Consequentialist 3. Reason-based

Classical Definition of Theoretical Knowledge:

X knows P only if: 1. P is true. 2. X believes that P.

3. X is justified in believing that P.

Two Types of Knowledge: Knowledge of facts; Action knowledge

Two ways of Justifying Belief:

Foundationalism: "Basic" belief \Rightarrow Theoretical belief.

Coherentism: Theoretical beliefs \Leftrightarrow Rational intuitions

\Downarrow
Belief in sensory experiences

Justification as a Social Enterprise:

* Collaboration * Discussion * Evaluation

Lecture 2: Inference

Types of inferences:

Direct Inferences: In sample \Rightarrow In population

Projection: Some \Rightarrow Next

Generalisation: Some \Rightarrow All

Modus Ponens: Assumptions A_i , if A_i then T \Rightarrow Accept T.

Modus Tollens: if H then C, C false \Rightarrow Reject H.

Inductive and Deductive Inferences

* Direct Inference } Inductive inference rules
* Projection } Amplify knowledge
* Generalisation } Fallible

* Modus ponens } Deductive inference rules
* Modus tollens } Explicate knowledge

Necessary true

Hume's Problem: No inductive inference rule can be justified

The Hypothetico-Deductive Method

1. Formulate a hypothesis H.

2. Deduce observable consequences $\{C_i\}$ from H.

3. Test whether $\{C_i\}$ is true or not.

4. If $\{C_i\}$ is false, infer that H is false.

5. If $\{C_i\}$ is true, increase confidence in H.

* Popper's Falsificationism

{ 4. If $\{C_i\}$ is false, decrease confidence in H }.

Lecture 3: Observation and Measurement

Different scales types and transformations

Nominal scale: identifying numbers: non-identity

Ordinal Scale: Mohs scale of hardness: positive monotone

Interval Scale: temperature in $^{\circ}\text{C}$: positive linear

Ratio/quotient scale: temperature in K: positive scalar

Absolute scale: counting objects: unique

Construct validity: check that the operationalization accurately reflects the intended concept.

* Convergent validity: Different ways of measuring should give rise to similar results.

* Divergent validity: Different ways of measuring different intended concepts should give rise to dissimilar results.

Lecture 4: Experiments

Three Characteristic Feature

* Control * Intervention * Observation of difference

Non-Experimental Empirical Practices

* Observational studies

- No manipulation - No intervention - No control

* Nature experiments

- No manipulation - No intervention - With control

Internal Validity: Without

(i) Failed intervention (ii) Failed control (iii) Failed observation

A Feature of Inferences, not experiments.

Lecture 5: Modelling

Model vs. Theories:

* Similarities: Representation

* Differences: Specific vs. Abstract and general

Model vs. Experiments

* Similarity: Control, Manipulation, Observation.

* Difference: External validity problem vs. Internal problem.

Lecture 6. Statistics

Lecture 7. Explanations and Causes

Deductive - Nomological

Lecture 8. Philosophy of Technology

Technical artefacts.

Lecture 9. Social Science

Qualitative methods vs. Quantitative method.

Holism.

Lecture 10. Science at Risk

Risk assessment \Rightarrow Risk management

Neyman-Pearson Hypothesis Testing

	H_0 true	H_0 false
Accept H_0	Correct decision	Type 2

Reject H_0	Type 1.	Correct decision
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In theoretical science: minimize type 2.

In practical decision: minimize ~~cost~~ of severe consequence

Principle of Insufficient Reason: Equal probability

Maximin or Minimax: Choose the least worst.

Precautionary principle: proof not harmful

Lecture 11. Research Ethics

Three Frameworks of Ethics

- * Consequentialism: Best consequence.
- * Deontology: Actions are right or wrong in themselves.
- * Virtue ethics: Developing good character traits.

Informed Consent:

Informed, Voluntary, Decisionally-capacitated.

Scientific Misconduct

- * Fabrication: making up data or results.
- * Falsification: Manipulation so that research record not accurately represented.
- * Plagiarism: To appropriate another person's idea.

"The Art of Doing Science"

C1.

- * Intersubjectivity: Common to all humans.
- * Empiricism: an opinion that puts much weight on empirical observation and draw strict limits for how much can be achieved with reason alone.
- * Episteme: Knowledge of facts
- * Techne: Action knowledge
- * Scientific corpus: everything that is taken for true in science until we obtain a good reason to doubt it.
- * Intersubjective: the conclusions one draws should resist the critical assessment of others.
- * Rationalism: More emphasis on the exercise of rational reasoning and argumentation.

C2.

- * Vagueness: No sharp limit
- * Definiendum: to be defined.
- * Definens: by which it is defined.
- * Lexical definition: common usage
- * Stipulative definition: how the author intends to use the word.
- * Ambiguity: a word has many meanings
- * Value-laden: value in the word.

C3.

- * Experiment: A planned observation. Manipulation.
- * Controlled observation: A planned observation. No manipulation.
- * Ordinal scale: higher number corresponds to a higher degree of a given property

- * Interval scale: constant measurement unit.
- * Ratio scale: interval scale where the zero point corresponds to total absence of the measured property.
- * Tendency: Judged according to the informant's purpose.

C4.

C5.

- * "hypothetic-deductive method": deducting consequences from the hypothesis, and then testing these consequence.
- * Vienna school: a sentence cannot be at all meaningful unless it is possible to verify.
- * Karl Popper: Not possible to verify if something is real.
- * Mass correlation: correlation of random variations in data
- * Individual asymmetry: one of the statements is more suitable as a scientific hypothesis.
- * Verification asymmetry: one of the statements is practically easier to verify.
- * Crucial experiments: it alone tells whether a theory should be accepted or rejected.
- * "Occam's razor": no unnecessary multiply the entities.

C7.

- * Reduction: explaining complex phenomena in terms of simpler ones.
- * Functional explanation:
- * "post hoc ergo propter hoc": after this, thus because of this.