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Scientific Writing

Theory of Science

Table of contents

Lernziele

- Forschungsprobleme in die Wissenschaftliche Methodik formulieren

Basics of Scientific Work

Everyday knowledge is based on routine experiences of daily life and personal experiences.

- subjective (different people may reach different conclusions about the same fact)
- can be subject to uncontrolled changes

Science claims to produce knowledge systematically and methodically, which is

- objectively formulated
- free of contradictions
- intersubjective, and
- verifiable

Basics of Scientific Work

General working definition for theories (theory in the broader sense)

- a set of interconnected statements, of which at least one non-empty subset refers to empirically testable relationships between variables
- a theory must include at least one empirically testable hypothesis

Theory in the narrower sense

- more elaborated theories contain (1) **basic assumptions** (assumptions about empirically hard-to-test relationships and definitions of key concepts)
- (2) hypotheses derived from the basic assumptions, as well as rules for measuring variables
- a mathematically formalized theory is called a **model**

Scientific Method

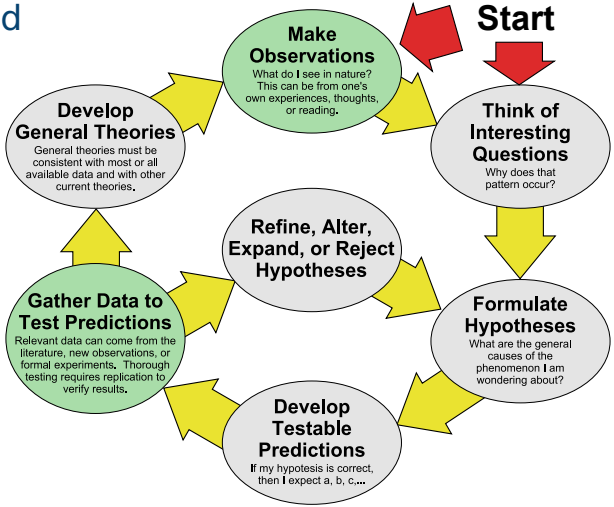


Figure: Based on “The Scientific Method as an Ongoing Process”, ArchonMagnus
https://en.wikipedia.org/wiki/Scientific_method

Theory Formation According to Critical Rationalism

Example in Computer Science

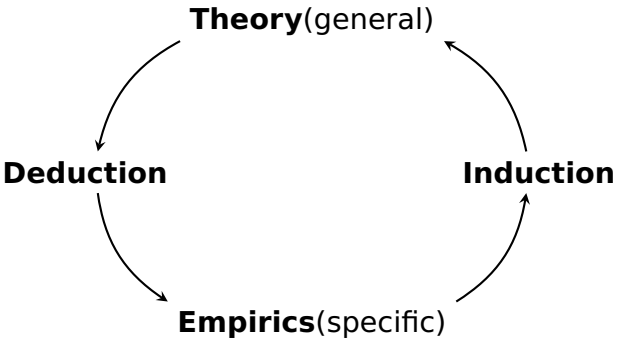
Step	Example (Computer Science)
0. Question	Is Code review beneficial for software quality?
1. Hypothesis about reality	“Code reviews improve software quality.”
2. Testable hypothesis	The number of code reviews is correlated to number of bugs.
3. Testing with data	Analysis of projects with different review frequencies.
4. Methodological critique	Other factors (e.g., team size) might influence the results.
5. Comparison with other theories	Perhaps automated tests are more important for quality.

Exercise: Scientific Method to a CS Problem

Group Task 15 Min

1. Give an example (e.g. use your thesis) for a CS problem

Two Central Ways of Scientific Reasoning



Deduction

- From general to specific

Induction

- From specific to general

Deduction and Induction

Deduction

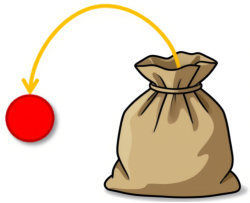
All balls from the bag are red.
$\rightarrow$ The ball is from the bag

Result: The ball is red.

$\rightarrow$ **Deduction**

Induction

The ball is from the bag.
$\rightarrow$ The ball is red.



Result: All balls from the bag are red.

$\rightarrow$ **Induction**

Deduction and Induction

- From the truth of the premises ("It is raining") logically follows the truth of the conclusion ("The ground will be wet").
- Besides deductive inferences, inductive inferences are often drawn.
- Example: From the empirical finding "The ground is wet" it is concluded: If the ground is wet, rain is always responsible.

Inductive inferences from individual cases to general cases can be correct but can also be false. Inductive inferences are not truth-transferring.

Counterexample in Science

- A **counterexample** occurs when an **empirical observation** or an **experiment** contradicts an existing theory.
- This shows that the underlying **assumption** or **theory** is **not universally valid**.
- A single contradictory observation can be sufficient to **falsify** a theory.

Consequence

If a counterexample is found, then:

$\rightarrow$ **The theory or assumption is refuted.**

What is a paradigm?

What is a Paradigm?

- Paradigm = Research approaches, ways of thinking
- For example:
  - Hermeneutics
  - Empirical and critical rationalism
  - ...

Research Paradigms – Hermeneutics

- Focuses on grasping comprehensive contexts
- **Interpretive understanding:**
  Meaning of a word from the sentence $\rightarrow$ meaning of the sentence from the paragraph $\rightarrow$ meaning of the paragraph from the chapter $\rightarrow$ meaning of the chapter from the book (or an era)
- *Knowledge gain* through uncovering meaningful connections

Hermeneutics – Example “Romeo and Juliet”

- **First impression:** You understand the plot: two young lovers from feuding families, whose love ends tragically.
- **Analysis of individual scenes:** You discuss individual dialogues, for example, the balcony scene. You pay attention to language, style, and emotions.
- **Expansion of understanding:** Through context (e.g., Elizabethan society, family honor, religion), you realize the play is not just a love story but also a critique of societal constraints.
- **Back-reference:** You reread earlier passages and recognize new meanings—such as how Juliet’s language already hints at the tragic ending early on.
- $\rightarrow$ **Hermeneutic Circle:** Your understanding of the *whole* (the play) changes your understanding of the *parts* (scenes, quotes)—and vice versa.

Empiricism and Critical Rationalism

Logical Empiricism

- Only statements that are **empirically verifiable** are considered meaningful
- Knowledge arises through **induction** (from the particular to the general)
- A statement is meaningful only if it is **verifiable**
- **Induction problem:** General statements can never be fully certain, as they refer to future observations

Critical Rationalism

- Rejection of pure induction as a principle of knowledge
- Knowledge arises through **falsification**: theories must be falsifiable
- Statements can never be finally proven, only **provisionally confirmed**
- Criticism: Makes theory comparison difficult and promotes reduction to measurable variables

Exercise: Induction and Deduction

Group Task 15 Min

1. Clarify the differences between the two types of reasoning.
2. Provide examples of induction and deduction in small groups.

Group Task 15 Min

1. Explain the concept of the hermeneutic circle in your own words.
2. Apply the hermeneutic circle to an example from your everyday life.

Discussion

Group Task 20 Min

- Share findings from group discussions.
  - Induction and Deduction
  - Hermeneutic Circle

Literature

- https://de.wikipedia.org/wiki/Hermeneutik_(Methode)
- https://de.wikipedia.org/wiki/Kategorie:Wissenschaftliche_Methode