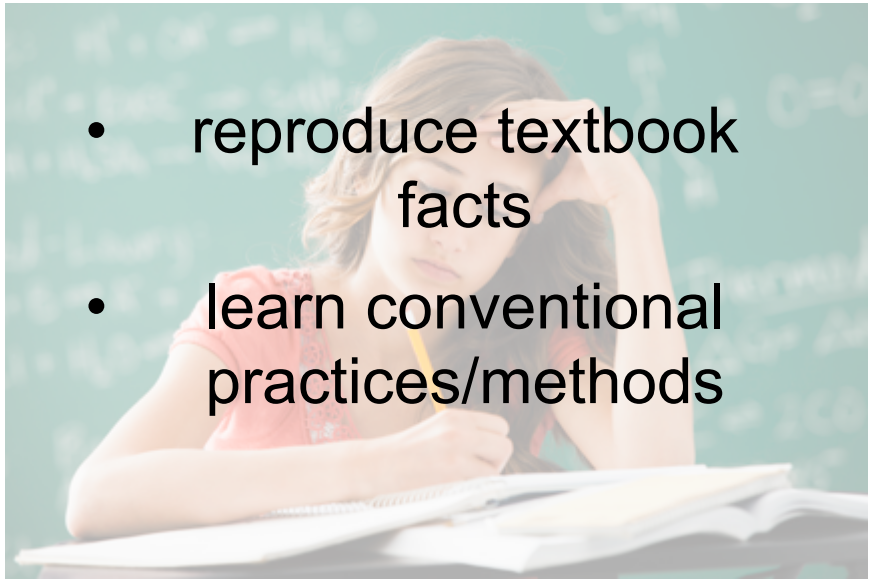
Theory and Methodology of Science

Introduction Lecture

Till Grüne-Yanoff

An Important Transition

Student → Scientist/ Professional

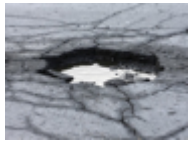


- reproduce textbook facts
- learn conventional practices/methods

- choose best method for your goals
- justify method choice

Method Choice – Examples from MSc Theses

1. Your task is to identify improvements in the energy performance of a type of buildings. Should you do this by…
   - FE simulation, or …
   - a case study, or…?



2. Your task is to investigate wear of a new road cover. Should you do this by…
   - laboratory experiment, or..
   - field experiment, or…?

3. Your find a negative correlation between cell phone use and learning performance. To argue for the causal relevance of this finding, should you…
   - search for better data, or..
   - run more statistical tests, or…?

Different Levels of Discussing Method Choice

General philosophy of science

Methodology of science

Methods of science

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General philosophy of science

Methodology of science

Methods of science

FE simulation X-ray spectroscopy Questionnaire
Temperature measurement Pen-and-paper-models
Significance testing Optimization under constraints
Process tracing Regression analysis

Different Levels of Discussing Method Choice

General philosophy of science

- How is it possible to acquire knowledge of the world?
- Are our best theories true, or are they merely useful?
- Everything we observe is interpreted on the basis of our beliefs and expectations; how is it possible to overcome this and be *objective*?

Different Levels of Discussing Method Choice

General philosophy of science

Methodology of science

- Which of the available methods shall I choose for my goals?
- What justifies this choice of method?

The Focus of TaMoS

General philosophy of science

Methodology of science

Methods of science

The Focus of TaMoS

Methodology: investigates assessment and justification of *method choice*

Methodology ≠ Collection of methods

Methods of science

Why *Justify* One's Method Choice?

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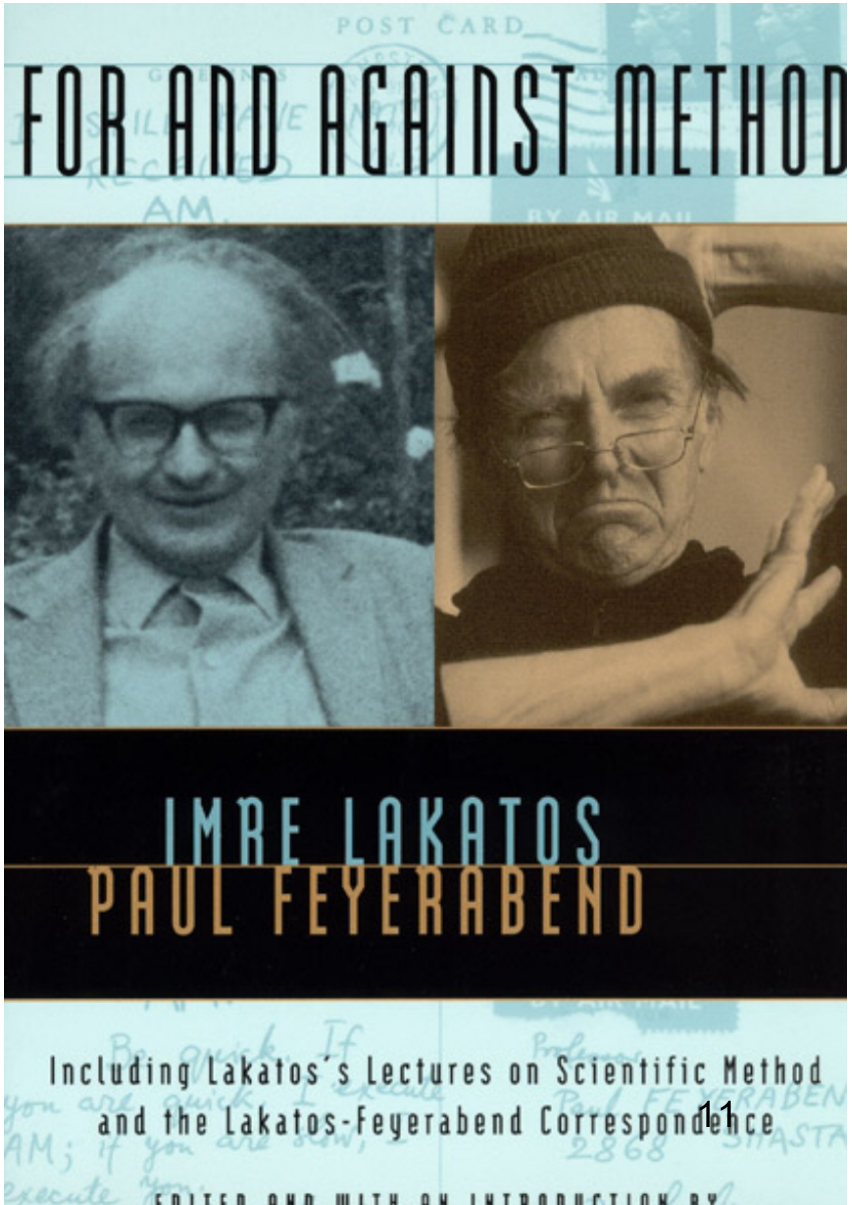

Why *Justify* One's Method Choice?

- **Self-reflect** – ensure that you think your choice is the best
- **Plan** – convince your future selves that they should implement your choice
- **Coordinate** – motivate others to join in on your approach
- **Persuade** – give others reasons to trust your results
- **Be accountable** – document your motivations for making this choice

Practical Matters: The Structure of TaMoS

The Structure of TaMoS

- Different course codes – different structure and requirements

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- Credit requirements:
  - Prepare for and attend seminars
  - Pass exam
  - (Fulfil project requirements)

The Structure of TaMoS

- Different course codes – different structure and requirements
- Credit requirements – seminars, exam, (project)
- Additional offers:
  - Introduction lecture
  - 10 Video lectures (with ca. 5 chapters each) – bonus points for quiz answers
  - 2 Flipped classrooms – bonus points for participation
  - Script covering all video lectures & additional reading material

The Structure of TaMoS

- Different course codes – different structure and requirements
- Credit requirements – seminars, exam, (project)
- Additional offers – campus/video lectures, bonus points
- Bonus points
  - Max 5 points
  - Counts towards part 1 of the exam (max 15 points)
  - Good for this term's exam and re-exam

The Structure of TaMoS

- Different course codes – different structure and requirements
- Credit requirements – semi
- Additional offers – campus/
- Bonus points
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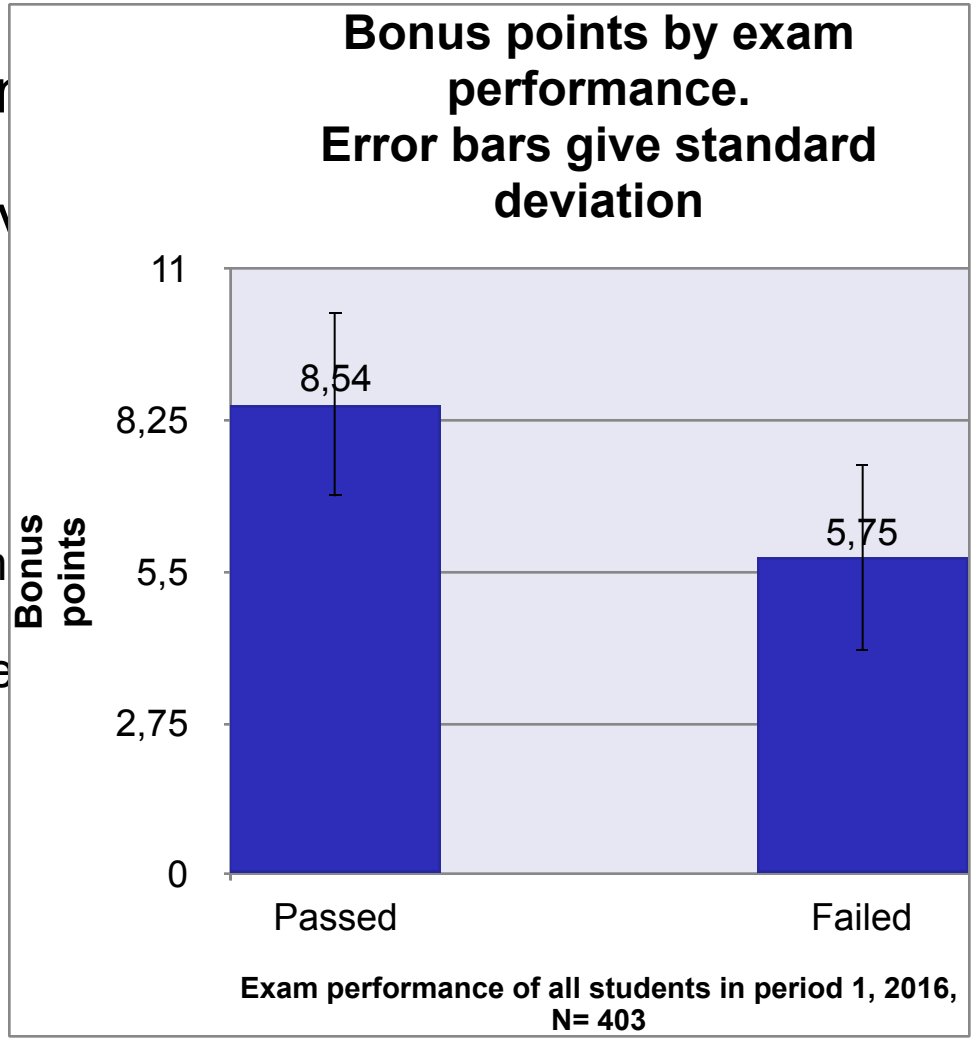


The Structure of TaMoS

- All information on CANVAS – make sure you have access
  - Schedule
  - Videos
  - Quizz questions
  - Script
  - Old exams
  - Teacher contact
  - For registration purposes only: fatemeh.tayebi@abe.kth.se

BREAK

Different Ways of Justifying Method Choice

1. *The* scientific method: "I choose the method that is the scientific one – in contrast to non- or pseudoscientific ones"

2. Conventions: "I choose the methods my teachers / my peers choose"

3. Epistemic Tools: "I choose the method that tends to best satisfy my epistemic goals"

Different Ways of Justifying Method Choice

1. The scientific method: “I choose the method that is the scientific one“

Problem 1: Diversity of science

- Different goals
- Different methods
- Different standards

Different Ways of Justifying Method Choice

1. The scientific method: “I choose the method that is the scientific one“

Problem 2: Lack of an accurate demarcation

- E.g. Popper’s falsifiability criterion

Different Ways of Justifying Method Choice

2. Conventions: "I choose the methods my teachers / my peers choose"

Some problems:

How to correct mistaken theories or methods that are dominant in your field?

How to collaborate with other disciplines that have different conventions?

Different Ways of Justifying Method Choice

3. Epistemic Tools: “I choose the method that tends to best satisfy my epistemic goals”

- Take scientists' actual epistemic goals
- Conceptual analysis: what properties important for which goals
- Instrumental rationality: choose methods that best satisfy these properties!
- Which methods are best instruments? Conceptual + empirical question

Different Ways of Justifying Method Choice

3. Epistemic Tools: "I choose the method that tends to best satisfy my epistemic goals"

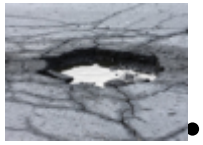
- Reasons: considerations that justify choosing a method (over others) for a given goal

Method A	
pro	*con*
…	…

Method B	
pro	*con*
…	…

- Choose the method that has the stronger supporting or the weaker contradicting reasons

Epistemic Tools Justification - Illustration



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Should you do this by…

- laboratory experiment, or field experiment, or…?

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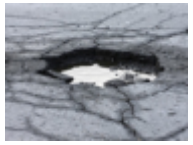

Your task is to investigate wear of a new road cover.
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- laboratory experiment, or field experiment, or…?

Goal: *explain* why the new cover wears differently than the previous one in Sweden

Analysis: explanation requires identifying the difference-making causes

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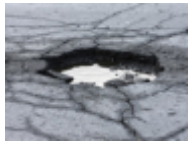

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Good tool to identify causes	Good tool to identify causes	Less good tool to identify causes

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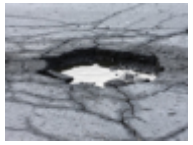

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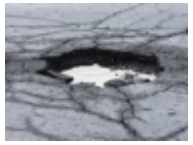

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Comparison:

Lab experiment	Field experiment	Observational study
Good tool to identify causes	Good tool to identify causes	Less good tool to identify causes
Good background variable control	Less good background variable control	Less good background variable control
Difficult to generate actual background conditions	Set in actual background conditions	Set in actual background conditions

What are the Goals of Science?

Predicting X	Explaining X	Designing X

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Predicting X	Explaining X	Designing X
Knowing that at time t, X will occur	Knowing the cause(s) that produced X	Knowing that artifact X will satisfy functions F

Scientific Knowledge

Classical Definition of Theoretical Knowledge

Knowledge is true, justified belief

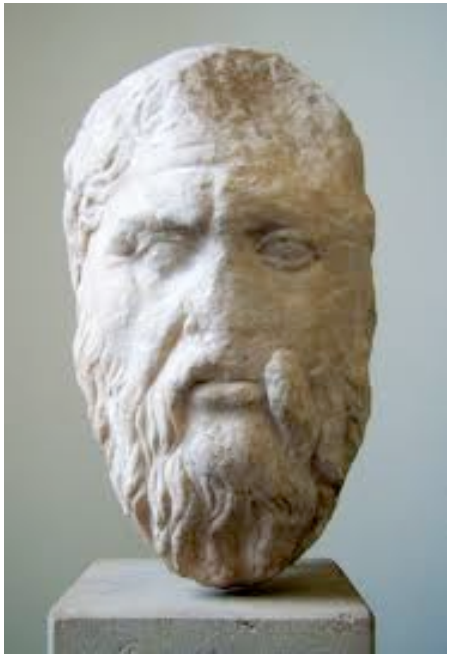
X knows that P only if

i. X believes that P.

ii. X is justified in believing that P.

iii. P is true.

(Not sufficient! Look up *Gettier problems*)



Plato (427-347 BC)

Knowledge is **Belief**

Belief is the state of mind in which a person thinks something to be the case

- tied to an individual
- action guiding
- comes in degrees:

  “I fully believe that”, “I tend to believe you”, “This is hard to believe”

Belief Comes in Degrees

Distinguish *degrees* of confidence in scientific claims

Belief Comes in Degrees

X believes P to a degree less than certainty

≠

P is false

Knowledge is **True** Belief

- If your prediction is false, you did not know what would happen
- If your causal claim is false, you did not give an explanation
- If your artifact does not satisfy the functional requirements, your design is not valid

Knowledge is ***True*** Belief

Unfortunately, we cannot directly and with certainty observe what is true and what is false…

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That inference is fallible, even when it is justified

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That inference is fallible, even when it is justified

P is true ≠ X believes P is true

P is true ≠ X's belief in P is justified

Knowledge is ***True***, Justified Belief

If a belief is justified, it does *not* necessarily follow that this belief is true

Example:

Astronomy before the telescope

Best available sensory experience did not suffice to justify rejection of Geocentric model

Knowledge is ***Justified*** True Belief

Justification

- The *proof* or *evidence* or other *reason* that can be put forward in defense of the claim.

Knowledge is ***Justified*** Belief

Justification

- The *proof* or *evidence* or other *reason* that can be put forward in defense of the claim.
- Unjustified but true belief is *not* knowledge – e.g. guessing the correct number of a lottery draw

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"I believe that *it rained today at 8 am at KTH*, because…

… I saw the raindrops fall

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"I believe that *it rained today at 8 am at KTH*, because…

… I saw the raindrops fall
… I felt my hair getting wet
… I heard the rain hitting the ground
… I registered a dark-grey cloud in the sky

} Direct observation – fallible but reliable

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… an instrument installed on the main building detected rain

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By what method of observation/detection? Is it reliable? Is it better than other available methods?

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- Justification of claim in science often proceeds through justification of method that provides evidence or allows conclusion from evidence to claim
- Claims can be *more or less* justified.

Justification as a Social Enterprise

In science, individuals are requested to give reasons for their beliefs

- *Discussion with other scientists*

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- *Discussion with other scientists*
- *Evaluation through other scientists*

Justification as a Social Enterprise

Reproducibility as a scientific virtue

- Other people should be able to assess the justification and come to the same conclusion on the same grounds
- for instance, reproduce an experiment and get the same result

Justification as a Social Enterprise

The peer review process in scientific journals

- Research papers are submitted to specialized scientific journals.
- Experts (1-5, often anonymous) read the research paper before recommending *accept, reject* or *revise.*
- The experts typically do not redo the experiment or study.
- They base their recommendations on how well the authors ***justify*** their claims (and whether the justification is original).

Justification as a Social Enterprise

The scientific ethos:

- Few (if any) claims can be *conclusively* proven.
- Justify your claims; respond to reasonable challenges to your claims.

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This was not always so…

Learning Results

- Distinguish methodology from methods
- Be able to discuss the presented arguments against scientificness and conventional justifications
- Explain the epistemically tool approach to method choice justification
- Discuss the major goals of science and relate to the concept o knowledge
- Explain the classical definition of knowledge
- Describe the concept of belief and the uncertainty of scientific knowledge
- Explain the concept of justification of scientific knowledge: reproducibility, peer review