KTH, Division of Philosophy
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Theory and methodology of science, course description

Background

As of 2007 the Masters programmes at KTH are required to contain 5 points (7.5 ECTS) on the theory and methodology of science. According to a policy adopted by the faculty board, this should consist of 3 points (4.5 ECTS) in general theory and methodology and science, and 2 points (3 ECTS) that focus on methodological issues specifically relevant in the masters programme in question. The general part should be given in three versions. One of these has its focus on natural and technological sciences, another on social science, and the third on computation-based research.

A course with this structure is given by the Division of Philosophy at KTH since 2002 for both PhD students and undergraduates. Below we provide a detailed description of this course. The description includes some improvements that we have made in order for the course to suit the masters programmes. We are of course interested in any suggestions on how the course can be further improved and how it can be fitted into the different masters programmes.

The theory of science is often taught with emphasis on issues that have little relevance in day-to-day science. It is a major characteristic of this course that it focuses on those general theoretical and methodological issues that have a direct bearing on how we conduct research, such as: How do we identify and cope with sources of error in an experiment? What are the major pitfalls in modelling of empirical phenomena? What does it take to confirm or disconfirm an hypothesis?

Our course also differs from most other courses in the theory of science in paying more attention to the technological and applied sciences.

As mentioned above this 3 points course is required to be combined with 2 points on the more specific issues in the area of the masters programme in question. We are willing to take full or partial responsibility also for the 2 points course. Different options are possible for this course. One option is that the students write a short exam paper on some methodological

issue or problem that is of particular interest in their own field. We have good experiences of this from our previous teaching.

Overview of the 3 points course

The course consists of ten lectures and four seminars/exercises. The lectures and seminars are partly overlapping between the three variants of the course. The course requirements are a Active participation (1pt) and two written exams (1+1 point).

The course literature will consist of two books and an additional selection of articles. We will use Sven Ove Hansson's, *The art of scientific thinking* on all three variants of the course. (It has been written specifically for the needs of KTH students.) In the natural science version of the course we will also use Chalmer's *What is this thing called science* and in the other two versions Salmon et al. *Introduction to the philosophy of science.* The additional articles will be different for the three different versions of the course.

The lectures and seminars/exercises in the three versions of the course as follows. (Other combinations are also possible, for instance for programmes that have strong components of both empirical and computation-based research.) Details about the different lectures and exercises can be found in the Appendix.

The *natural science version* of the course contains the following lectures

Knowledge, subjectivity, intersubjectivity and objectivity
Hypothesis testing I
Hypothesis testing II
Observation and Experiment I
Observation and Experiment II
Models I
Measurement theory
From data to decision
Explanations, laws, and causes.
Research ethics

It contains the following seminars/exercises

The definition clinic
Models in hypothesis testing ("boxes")
Peer-review of a scientific text
Two great experiments

The *social science version* of the course contains the following lectures

Knowledge, subjectivity, intersubjectivity and objectivity
Hypothesis testing I
Hypothesis testing II
Observation and experiment I
Data and methods in the social sciences
Measurement theory

Models II
Laws and explanation in social science
From data to decision
Research ethics

It contains the following seminars/exercises

The definition clinic
Models in hypothesis testing (“boxes”)
Peer-review of a scientific text
Using social science for policy formulation.

The *version for computation-based research* contains the following lectures

Knowledge, subjectivity, intersubjectivity and objectivity
Hypothesis testing I
Hypothesis testing II
Models I
Models II
Simulations
Models III
Explanations, laws, and causes.
From data to decision
Research ethics

It contains the following seminars/exercises

The definition clinic
Pitfalls in computer experiments
Models in hypothesis testing (“boxes”)
Peer-review of a scientific text

Appendix: Contents of lectures and seminars

What follows is a brief description of the contents of the different lectures.

Lectures

Knowledge, subjectivity, intersubjectivity and objectivity

The lecture introduces key concepts such as knowledge, truth, belief, subjectivity, intersubjectivity and objectivity. These concepts are then tied to the practice of science (the peer-review system, etc.)

1. The concept of knowledge.
    a. Practical versus theoretical knowledge
    b. Scientific knowledge
2. Subjectivity, intersubjectivity, objectivity
    a. Belief versus truth
    b. "Good" reasons for belief - standards of evidence
    c. Common basis for belief - intersubjectivity
3. The peer-review system
4. The burden of proof
5. Small and big doubts

Hypothesis testing - The ”deterministic” case

This lecture introduces the basic concepts of hypothesis testing in a “deterministic” setting:

1. Hypotheses, theories and model
2. The hypothetico-deductive model
    a. "Observable" consequences
    b. Asymmetry between verification and falsification
3. Auxilliary hypotheses
4. *Ad hoc* hypotheses
5. The Duhem-Quine thesis
6. Popper:
    a. Falsifiability as a criterion for science
    b. Corroboration versus verification

Hypothesis testing - The ”indeterministic” case

An introduction to the basic methodological issues underlying statistical hypothesis testing.

1. Statistical hypotheses
2. Falsification and verification in statistical hypothesis testing
3. Null-hypothesis:
    a. Choosing a null-hypothesis
4. Gathering statistical data
5. Significance tests
    a. Significance levels
    b. "Rejecting" versus "Accepting" hypotheses?
6. Type I and Type II errors
7. Mass correlation
8. From correlation to causes

Observation and experiment I

Introduces basic theoretical and methodological issues on observation and measurement.

1. Observation and the senses
2. Direct and indirect observations
3. Different types of observation in science:
    a. Experiment
    b. Controlled observation
    c. Uncontrolled observation
    d. Reports on observations by others"
4. The observer's influence on the observations
5. Brief introduction on measurements and measurement errors
6. The epistemic status of observation
    a. Empiricism/logical positivism
    b. The theory dependence of observations
    c. Example: behaviourism

Observation and experiment II

Introduces and discusses the basic concepts relevant for the construction and evaluation of experiments

1. Three kinds of experiment
    a. Testing an hypothesis
    b. Measuring a variable
    c. Explorative experiements
2. Four aspects of experiments:
    a. Realise
    b. Separate
    c. Control
    d. Observe
3. Documenting experiments

Measurement theory

Introduces the basics of measurement theory:

1. Scales (ordinal, interval, quotient, etc.)
2. Isomorphisms
3. Measurement and underlying theory
4. Meaningfulness: transformations and applicable operations.
5. Formal results: representation and uniqueness.

From data to decision

This lecture introduces the problem of applying scientific results to practical problems. We use the risk assessment process as an example, and focus on its key role in conveying scientific knowledge to decision-makers. Some questions that will be addressed are:

1. What does it mean that an assessment is scientific or science-based
2. How is scientific data used for risk assessment purposes?
3. How is scientific uncertainty handled in risk assessment?
4. What is the role of expert judgment in cases of scientific uncertainty, and what are the pitfalls?
5. Why do risk assessors sometimes come to different conclusions?

Explanations, laws and causes

Raises questions concerning the nature of explanations and their relationship to natural laws and causality

1. The Deductive Nomological (DN) model of explanation.
2. Problems with DN
3. What are Laws of Nature?
4. Non-subsumptive explanations.
5. Causes as primitives
6. Capacities and nomological modalities.

Laws and explanations in social science

Raises the problems of formulating laws and explanations in the social sciences

1. Different types of explanations: causal, covering-law, functional, teleological
2. Explanation and understanding
1. Reasons and causes
2. Laws in social science
3. Positivism. Comte and Mill. Nomologicalism vs. historicism. Behaviourism

Data and methods in the social sciences

Provides an overview of different methodologies that are used in the social sciences, and discusses their advantages and disadvantages.

1. Differences between qualitative and quantitative methods
2. Observations and interviews (Questionnaires, structured and semi-structured intervies etc)
3. The theory dependence of observations in social science
4. Interpretation
5. Source evaluation: Criteria and Applications. Primary and secondary sources.
6. Case study methodology
7. Strengths and weaknesses of qualitative methods: hidden variables, gatekeepers
8. General/specific knowledge in social science

Models I

Introduces basic concepts of model-based research and the relationship between models and laws.

1. Theoretical vs. empirical/phenomenological models
2. Models and theories
    a. Syntactic views
    b. Semantic views
3. Models as mediators.

Models II

Raises basic issues on the role of models in research and how models are evaluated

1. Models and representation.
2. Models and stories
3. How to evaluate models
4. Good model building practices

Models III

This lecture discusses the methodological issues involved in applying models in the technological sciences

1. Model and datasets
    a. Adjusting models to fit the data
    b. Model "competitions"
2. The role of models in applied science.

Simulations

Discusses the basic concepts relating to simulation and the epistemological role of simulations:

1. Experiment vs. Theory
2. Uses of simulation
3. Model validation:
    a. Assessment of realism
    b. Operational success

Research ethics

The lecture introduces and defines the concepts of ethics and morality. Ethical problems related to the practice of science, as well as possible ways of solving them are discussed.

1. The concepts of ethics and morality
2. What is an ethical problem?
3. What are the main responsibilities of the scientist and what are the potential ethical problems in science?
    a. responsibilities of conducting reasearch in a methodologically sound way (potential problems: 'bad' science, fraud)
    b. responsibilities towards research subjects
    c. responsibilities towards other scientists (publication ethics, credit, etc.)
    d. responsibilities towards the public/society (consequences of research results, informing the public, etc)
4. How to deal with ethical problems
5. Moral deliberation
6. Ethical theories and their relevance

Seminars and Exercises

Definition clinic

An exercise in the problems of defining technical terms. Some background on definitions is given. Different adequacy criteria for definitions are discussed and applied. The students are divided into small groups that are given the task to define various concepts. These definitions are handed over the other groups, that evaluate and criticize them.

Hypothesis testing ("the boxes")

An exercise designed to give training in hypothesis testing in direct relation to a "mini-experiment". Students are given three identical boxes and are given the task to determine the content of the boxes without opening them. Various operations can be performed on the boxes to help determine the contents (some of the operations are "destructive" i.e. change the internal structure of the box.)

Peer-review of a scientific text

The students are assigned the role of referees for a scientific journal. They are given an actual scientific report or article and are to produce a referee report on the report or article.

Two great experiments

A text seminar. We study the background, experimental setup, results and interpretations of two classic experiments in the natural sciences.

Using social science for policy formulation

A text seminar/case study. A topic in the social sciences is followed from theorizing and empirical studies, to policy formulation in the political arena.

Pitfalls in computer experiments

A text seminar. We discuss a text describing methodological problems in computer experiments.