

## **Research Methodology**



### **Basic Information**

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### **Basic Information**

- Your Instructors
- Program of the Lessons
- Goal of the Course
- Material
- Modalities of Examination



**Your Instructor**  
Fausto Giunchiglia  
(<http://www.dit.unitn.it/~fausto>)

## **Program of the Lessons**



**Every Friday**

**From February, 25<sup>th</sup> until July, 1<sup>st</sup> 2005**  
from 10.30 a.m. to 12.45 p.m.

**Except 8th, 15th, 22th April**

## Goal of the Course



- ✍ teach fundamental notions and concepts underlying scientific and technological research
- ✍ overview of the various definitions of "Science"
- ✍ process of doing research, with a slight emphasis on the research done during a Doctorate Program
- ✍ topics of thinking, reading, speaking and writing

## Material



### Web Page of the Course:

[http://www.didatticaonline.unitn.it/sci\\_cls\\_inform.asp](http://www.didatticaonline.unitn.it/sci_cls_inform.asp)

## Material

### Suggested textbooks:

- ✍ Bruno Buchberger: "Thinking, Speaking, Writing"
- ✍ Martha Davis: "Scientific Papers and Presentations"
- ✍ James G. Paradis, Muriel L. Zimmerman:  
"The Mit Guide to Science and Engineering Communication"
- ✍ Robert V. Smith: "Graduate Research: A Guide for  
Students in the Sciences"
- ✍ Jeffrey A. Lee: "The Scientific Endeavor: A Primer on  
Scientific Principles and Practice"
- ✍ John L. Casti: "Paradigms Regained"

## Modalities of Examination

Writing a **short paper** and giving a **presentation** about a selected topic from the list of topics on the web page of the course.

### Grading

A maximum of 30 out of 30 computed as follows: 10 short paper, 15 presentation and 5 for questions during the others presentations.

# Introduction to Science and its methods

*Fausto Giunchiglia*

*Thanks to R.Brandtweiner*

*Literature:*

*Robert V. Smith. Graduate Research, 1998*


*Jeffrey A. Lee. The scientific endeavor, 2000*

## Index:

1. Science ... and Engineering
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3. Languages and Models
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6. Misconduct in Science



# 1. Science ... and Engineering



Ever since the dawn of civilization, people have not been content to see events as unconnected and inexplicable. They have craved an understanding of the underlying order in the world ... Humanity's deepest desire for knowledge is justification enough for our continuing quest.

Stephen Hawking

## Science, Research, Scholarship

- *Science*: acquisition of reliable but not infallible knowledge of the world, including explanation of the phenomena
- *Research*: process of discovery of knowledge
- *Scholarship*: creative organization, criticism and reinterpretation of facts and concepts

## Science

- Creative function
  - To create (the basis for) statements about objects, their relationship as well as explanation.
- Critical function
  - Discovery and revision of mistakes and errors
- Predictive function
  - To produce better / newer explanations and models

## Research

The process of producing new knowledge

- Basic research
  - About fundamental properties of objects, their relationship and their behavior
  - Theoretical Research
  - Experimental Research
- Applied research
  - Usefulness of objects and their behavior, may lead to improved technology
  - Provides quicker results
  - Question of normative issues?

## Areas of science

- Physical science
- Biological science
- Behavioral science (human behavior, individuals and groups)
- Earth science

*Humanities* such as literature, art: concerned with artistic phenomena and mostly qualitative study of human affairs

*Mathematics and logic*: „language“ as well as formal system descriptions, not necessarily based on real-world phenomena

*Belief fields* (religion, ethics): based on faith, what is wrong and right, not necessarily based on physical reality

*Engineering disciplines* to build artifacts based on scientific theories



## Science and Engineering

Science: explain the world

Engineering: affect the world

Science: build artifacts to “explain”

Engineering: build artifacts to “affect”

What is the difference from artificial and natural?

They are two faces of the same coin...

## ... Us ...

- Computer science
- Computer engineering
- Electrical engineering
- Artificial Intelligence
- ...



## 2. Tasks of Science

### Science



- Science is based on what is observable in the universe, for something being subject of scientific research it must be measurable. It is empirical in that it relies on observations and experience.
- Value judgements are not *scientifically* measurable
- Science: What is
- Belief fields: What should be

## Scientific statements

- Attempts to describe / explain real phenomena (force = mass x acceleration)
  - However, there is no absolute scientific truth
  - Some knowledge is less likely to be wrong than other knowledge (e.g., Americans vote to in an attempt to improve their economic situation)
  - Statements must be testable
  - reproducible (a paper is good if I can redo what is written in this paper)
- Scientific knowledge tempts to represent the most accurate view of the world

## Tasks of science

- *describe*: precondition for other tasks. Result is a model (systematic model - documentation of reality)
- *explain*: explanation of relationship between objects and their dependencies.
- *predict*: statements able to explain phenomena can also be used to predict. Applying a general theory plus specific boundary conditions one can predict future events.
- *construct (?)*: constructing artificats (such as in Computer Science), or giving economic (political) advice, or advice for companies (managment science as normative discipline) – (Science vs. Engineering)

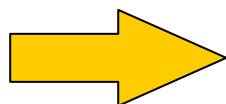


### 3. Languages and Models

#### Terms and languages



Not reality but only statements about reality are objects of science.



Languages are used to express theories.

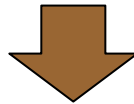
## Languages and terms

### Languages based on words:

Objects of reality → words

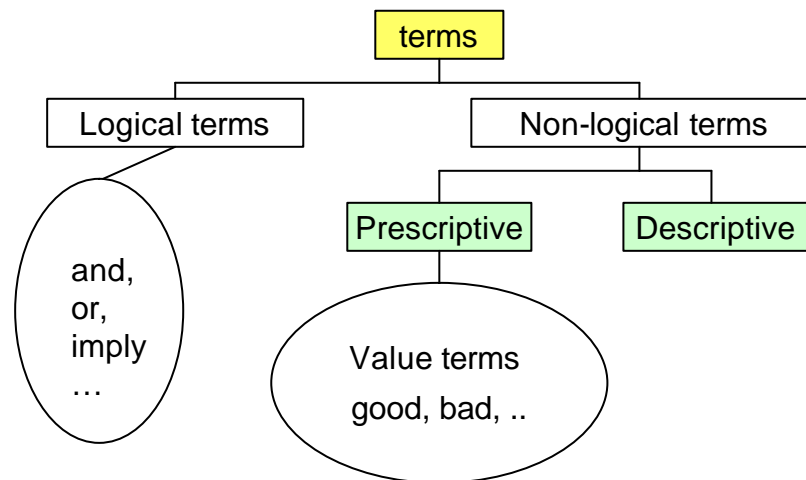
### Languages based on symbols:

Objects of reality → symbols



Languages consists of terms.

## Languages and terms



## Languages and terms



- every day language
  - expert language
  - symbol language
- } Languages based on words

## Languages and terms



**Languages based on symbols (mathematics, logic) are logically consistent, therefore also models based on them. And operations are sound.**

***But***

This does not imply that this logical system has to exist in reality.

➡ Question of relevance

## Models



Representation of real thing, models represent theories about real world in a simplified version. Real world might be too

- Big
- Small
- Dangerous
- Complex

Models are used to experiment  
Problem of verification, relevance to real world

## Models



- Ignore details , depending on objective
- Necessarily reality is not modeled „correctly“
- Using a computer a model can be easily adapted to specific conditions
- Property of (Omo)morphism

Examples:

Picture, statue, Lego construction, set theoretic models,  
Graph theoretic models, ...



## **4. The Philosophy of Science**



### **4.1 Scientific Methods**



## Scientific Methods

- Play central role, the way how scientific knowledge is gained.
- “methodos” means way
- methodology is the discipline of scientific procedures

## 4.2 Syllogism

## Syllogism

- As classical approach to science (Greeks, Aristotle)
- If argument is sound, then the conclusion is trustworthy
- Works well in mathematics and logic
- But what appears correct in mind and what exists in reality?
- B. Russell: Aristotle could have avoided his mistake of thinking women have fewer teeth just asking his wife to open her mouth

## 4.3 Empiricism

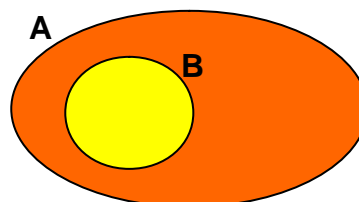
## Empiricism

- As a result of the renaissance
- Reason alone is not sufficient
- Ideas must be tested, to make observations, measurements and experiments are important
- Two approaches:
  - Induction
  - Deduction

## Induction

Induce from parts to the total

***„If one observes a huge number of A’s – under varying conditions – and all these A’s have the same feature B, then all A’s have the feature B.***



## Induction

Data collection - Measurement



Analysis



Generalization - Theory

## Deduction

Theory



Data collection



Analysis

## Theory



A set of statements, systematically ordered,  
reflecting a well defined part of the real world.

Theories should be

- *Rational*, logically consistent
- *Relevant*
- *Extensible*, able to explain more than before

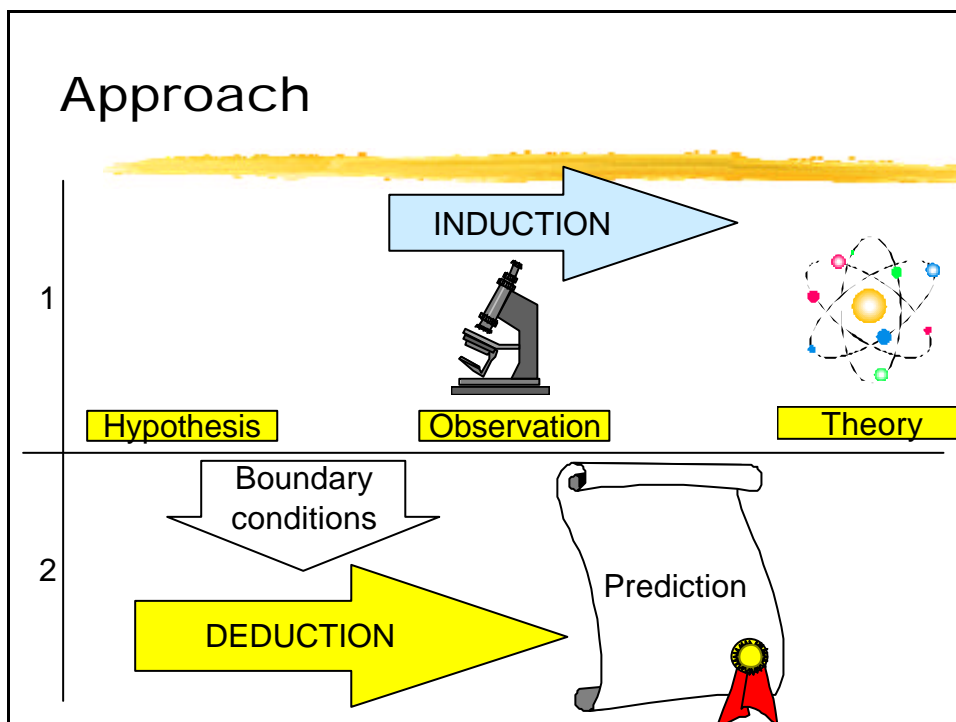


## 4.4 Positivism

## Positivism

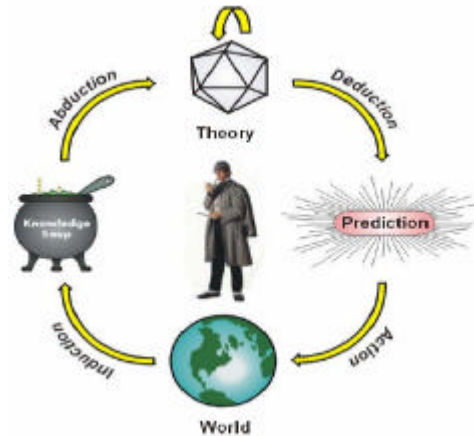
- Best known scientific method
- Hypothesis (? theory): a possible explanation (possibly coming from past observations)
- Test Hypothesis to find out if they are likely to be correct (laboratory)
- Test and refine

## Approach



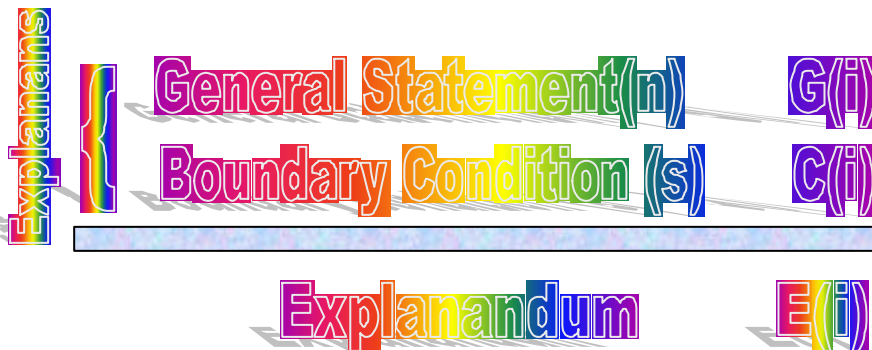
## Testimonial from student ? 1 [Pavel Shvaiko]

### The challenge of knowledge soup by John Sowa



<http://www.jfsowa.com/talks/challenge.pdf>

## Scientific explanation (deduction)



## Scientific explanation

(example of deduction)

$G_1$ : If in a group A the social isolation is higher than in a group B, then also the suicide rate is higher in A.

$C_1$ : In Baltimore the social isolation is higher than in New York.

$E_1$ : In Baltimore the suicide rate is higher than in New York

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## Good hypothesis

Hypothesis 1: Either the sun shines or it does not shine.

bad Hypothese

Hypothesis 2: When metal heats up, it expands.

good Hypothese



## Hypothesis

How to come to hypothesis:

- Analogy
- Induction
- Deduction
- Intuition

It is not important how to generate one, but only that it is falsifiable.

- Hypothesis (e.g., there is a relationship between A and B)
- and Null Hypthesis (there is no relationship)
- Type I error: reject hypothesis that is true (false negative)
- Type II error: accept hypothesis that is wrong (false positive)

## 4.5 Popper: Principle of Falsification

## Verification – falsification

**Positivism:** if a hypothesis is empirically confirmed, then it is verified.

**Difficulty:** but even after verifying 10.000 observations, it is possible that the 10.001. one produces a contradiction

Thus, hypothesis can only be falsified, and they have to be falsifiable.

**Falsification:** is the only guaranteed approach

**Verification:** can never be guaranteed

## Principle of falsification

make an hypothesis and try to show that is not correct

Build new theory which extends old theory by explaining also new hypothesis (not explained in old theory)

**Note 1:** both positivism and principle of falsification test hypothesis by experiments

**Note 2:** a law is an hypothesis that most scientists are confident it will pass any conceivable test

Based on **Sir Karl Raimund Popper** with his work „*Die Logik der Forschung*“, in the 30s in Vienna.



## 4.6 Beyond positivism and Falsification

### Beyond positivism and Falsification



- **Post positivism:** emphasizes the importance of unobservable parts, not directly verifiable by experiments
- **Relativism:** importance of social factor, science defined by group, not towards objective truth. It solves problems even if it does not explain the world
- **Realism:** real world separate from our perception, science allows to get closer.



## 4.7 Kuhn: scientific paradigms

### Paradigm




**A paradigm is**

- a (temporarily) accepted basis of a discipline
- Generally accepted schema for selecting and solving problems
- Basic assumptions and also explanations

Thomas Kuhn: „*Die Struktur der wissenschaftlichen Revolution*“, 1962

## Changes of paradigm



Within a paradigm: if there are contradictions between specific theories, based on a paradigm, and the reality, so not the paradigm is questioned but the theory and measurement methods etc.

But paradigms change: from Ptolemy to Copernicus.

Paradigm change = change of scientific view of the world

Paradigm change = scientific revolution