www.DSinGIS.eu

Lesson 1: Science foundations

Research Methodologies and Scientific Communication

Author(s): Erika Blaschke

Co-funded by the Erasmus+ Programme of the European Union

Science foundations

Welcome

In this course we will address the topic scientific writing and communication. You most probably have already acquired some academic working experiences and skills in your undergraduate studies. You need such skills for many assignments or writing some essays.

To write such a scientific text you need to research literature, cite the sources you used and you have to express yourself in a logic and concise way.

In the first lesson we will focus on the **history** and **development of science** and how science has evolved in different research fields over time.

Science foundations

Content

- Definition of “Science”
- History of Science and development over time
- Most important philosophers in science (Galileo, Hume, Popper)
- Theory of Science

Science foundations

Definition of Science

Word „science“ originates from the Latin ‚scientia‘ (= knowledge)

In google scholar you can find many definitions, some examples show the following:

- science is defined as the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena.
- a process of constructing predictive conceptual models
- For many people the term science refers to the organized body of knowledge concerning the physical world, both animate and inanimate, but a proper definition would also have to include the attitudes and methods through which this body of knowledge is formed; thus, a science is both a particular kind of activity and also the results of that activity. (Pearson 2004)

Literature: https://onlinelibrary.wiley.com/doi/epdf/10.1002/tea.3660280107 (13.05.2020)
Pearson, SA. 2004. *The Columbia Electronic Encyclopedia*. Columbia University Press. Pearson Edu. Pub. Columbia, USA.

Science foundations

History of science – in a nutshell

The history of science is the **study** of the **development of science**, including both the natural and social sciences.

Science is a body of **empirical, theoretical** and **practical knowledge** about the natural world, produced by scientists who emphasize the observation,explanation, and prediction of real-world phenomena.

The English word ***scientist*** is relatively recent, first coined in the 19th century. Before that, investigators of nature called themselves „natural philosophers".

Observations of the natural world have been described since classical antiquity.

Scientific method has been employed since the Middle Ages.

Modern science began to develop in particular in the scientific revolution of 16th- and 17th-century Europe.

Science foundations

History of science – in a nutshell

From the 18 through the late 20 century, the history of science, especially of the physical and biological sciences, was often presented as a progressive accumulation of knowledge, in which true theories replaced false beliefs.

More recent historical interpretations, tend to portray the history of science in terms of competing paradigms or conceptual systems within a wider matrix of intellectual, cultural, economic and political trends.

However, these interpretations met with opposition because they also represent the history of science as an incoherent system that does not lead to actual scientific progress, but only to the illusion that it has taken place.

Science foundations

Journey through the history of science

Priest as a scientist in ancient Egypt and Mesopotamia

The history of science goes back thousands of years. At first, science and religion were closely related. Priests and wise men in Egypt, Mesopotamia or China did research thousands of years ago and used this knowledge. For example, they calculated the course of the celestial bodies and were thus able to determine the length of the year. This made it possible to set favorable times for sowing and harvesting.

Science foundations

Journey through the history of science

The Platonic Academy in Ancient Greece

Science has been closely linked to philosophy since ancient Greece. At that time, knowledge was first developed and taught in an institution.

The philosopher Plato founded the "Platonic Academy" in the olive grove of the Akademos.

The principles of logic on which scientific methods are based come from Greek philosophy. Much of what scholars like Archimedes, Pythagoras or Hippocrates have found is the basis of many sciences today.

Science foundations

Journey through the history of science

Foundation of the first universities in the Middle Ages

Due to the collapse of the Roman Empire and the migrations of people, much of this ancient knowledge was lost again until the Middle Ages.

In the following centuries, knowledge was preserved primarily through monasteries.

Books had to be copied by hand. Many were destroyed or locked away because it was knowledge that came from pre-Christian people.

At the same time, hardly any research was carried out - so little new knowledge was added.

Science foundations

Journey through the history of science

Foundation of the first universities in the Middle Ages

Due to the collapse of the Roman Empire much of this ancient knowledge was lost.

In the following centuries, knowledge was preserved primarily through monasteries.

With the creation of the first universities in the Middle Ages in Italy, France and England in the late 11th and 12th centuries, places of teaching of knowledge emerged.

Science foundations

Journey through the history of science

The Renaissance - Detachment of Science from the Catholic Faith

The Renaissance is known as the "**hour of birth of modern science**":

- letterpress printing was invented.
- Voyages of discovery brought a new picture of the world.
- Most important, however, was the slow detachment of science from (Catholic) beliefs.

Scientists like Galileo Galilei, Nikolaus Kopernikus and Johannes Kepler paved the way. They refuted the existing worldview that saw the earth (and man) at the center of everything.

Science foundations

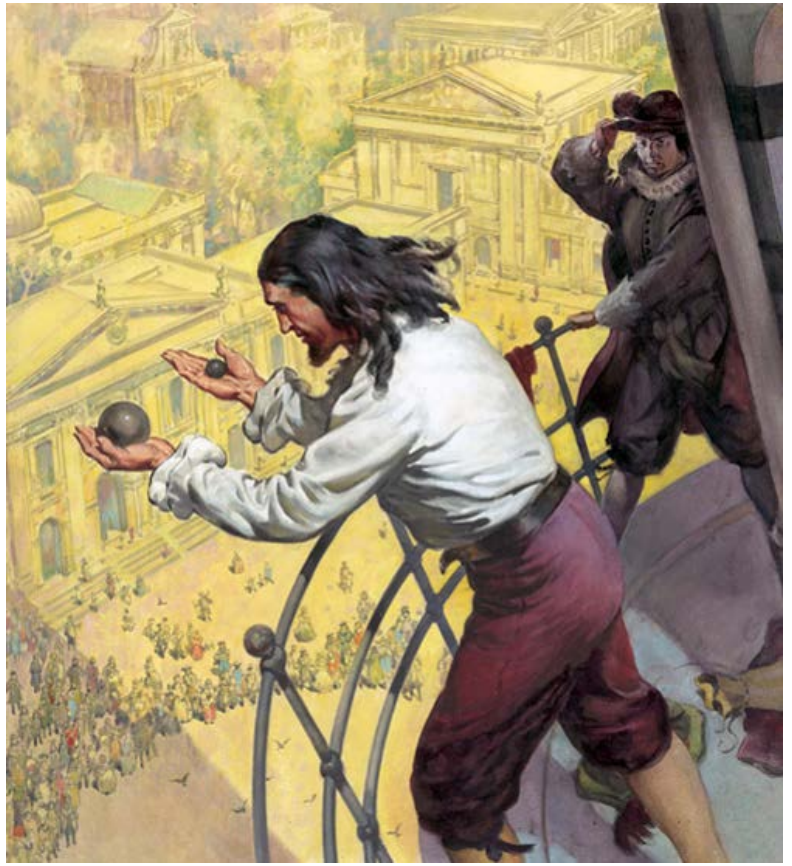
Important scientists over time

- Galileo Galilei
- Francis Bacon
- David Hume
- Karl Popper

Science foundations

Galileo Galilei

- 1564 – 1642
- Italian astronomer, physicist and engineer
- Called „father of observational astronomy“
- Studied speed, velocity, gravity and free fall
- His famous experiment on the speed of falling objects symbolizes a paradigm shift in the history of science.



Source: UNIGIS materials

Science foundations

Francis Bacon

- 1561 – 1626
- English philosopher
- Outlined a new system of logic to improve upon the old philosophical process of syllogism.
- His method relied on experimental *histories* to eliminate alternative theories (empirical evidence)

Source: wikipedia (13.5.020)

Science foundations

David Hume

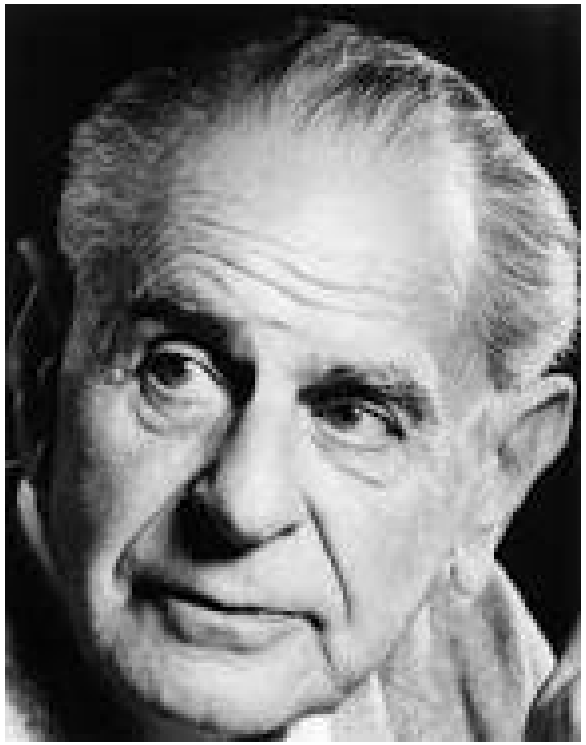
- 1711-1776
- cottish philosopher
- criticized inductive reasoning, i.e. drawing general conclusions from repeated observations (inductive reasoning).

Source: wikipedia (13.5.020)

Science foundations

Karl Popper

- 1902 – 1994
- Austrian-british philosopher
- expanded on Hume‘s theory and put forward the notion of empirical falsification.



Source: wikipedia (13.5.020)

Science foundations

Some science principles –
different kinds of research

Science foundations

A four-phase model in science

- Description
- Prediction
- Explanation
- Control

Science foundations

Description

Whatever their domain of interest, scientists must distinguish and describe the basic phenomena (entities and events) within that domain. This is essentially the intellectual act of classification (categorization) common to all sentient creatures, but scientists often carry it out especially systematically.

Science foundations

Prediction

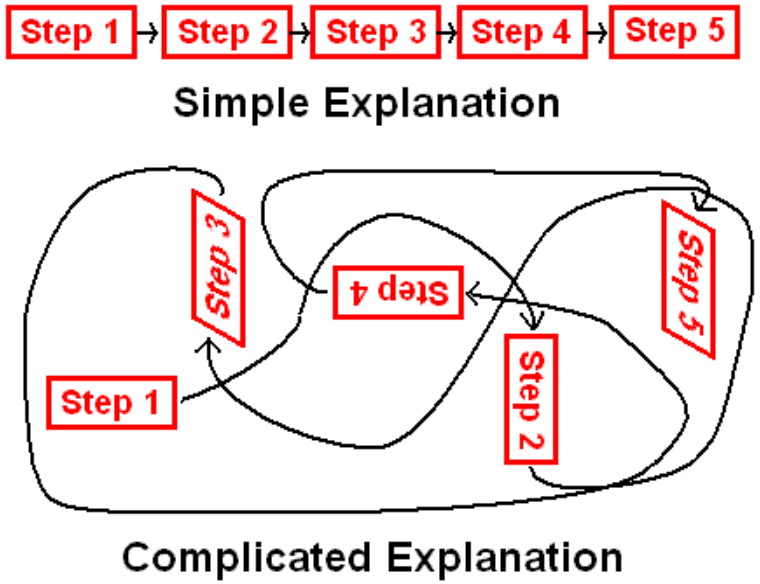
Given that they know something of the content of their domain, scientists want to be able to predict phenomena about which they cannot learn simply by direct observation. These predictions are often about the future, but can also concern facts about phenomena from the present or the past that are as yet unknown.

The most powerful tools for prediction available to scientists are inferences (both extrapolations and interpolations) from patterns of observations; these inferences take advantage of mathematical precision while exploiting the logical principle that observed regularities will probably hold in other situations not yet observed.

Science foundations

Explanation

Once scientists can describe and then predict, they want to explain why some described and predicted pattern exists. This requires the explication of causal relations among entities and events.



Science foundations

Control

Being able to describe, predict, and explain phenomena within their domain of interest, scientists typically want to apply this knowledge in order to control the phenomena - to bring about desired changes in the phenomena.

Science foundations

Basic versus Applied research

Basic research	Applied research
focuses on understanding reality for its own sake; it is primarily an expression of human curiosity and the desire for intellectual mastery. In terms of the goals of science, basic research is very concerned with description, prediction, and explanation, but less with control.	focuses on control, in addition to the first three goals, for the purpose of making some object or procedure that will help meet specific practical needs or solve specific problems.

Science foundations

Basic research

- Basic research expands our knowledge and leads to innovation.
- Basic research seeks answers to fundamental questions and provides broad insights to many different scientific fields.
- **“It's important for humanity to understand the world in which we live”**

- Examples of basic research
  - A study looking at how caffeine consumption impacts the brain
  - A study looking at how the living environment impacts the depression rate

Science foundations

Applied research

- Findings of applied research can be applied to resolve issues
- Purpose of applied studies is closely associated with the solution of specific problems
- research objectives are set by clients or sponsors as a solution to specific problems they are facing
- Research validity represents an important point to be addressed in all types of studies. Nevertheless, applied studies are usually more concerned with external validity
- Examples of applied research
  - Development of strategies to introduce change in Starbucks global supply-chain management with the view on cost reduction
  - An investigation into the ways of improving employee motivation in Motel One, Salzburg, Austria.

Science foundations

Science and ....Engineering

Science is the understanding and continuous exploration of the natural world. In short, it is a study of "As Is".

Technology is applying the outcome of scientific principles to innovate and improve the man-made things in the world. The output of Technology is a new or better process of doing.

Engineering is applying the outcome of technology to design, develop, and manufacture the end product. Engineering provides feedback to technology to innovate or improve better ways of doing. Inputs from technological innovation allow science to explore other natural phenomenon.

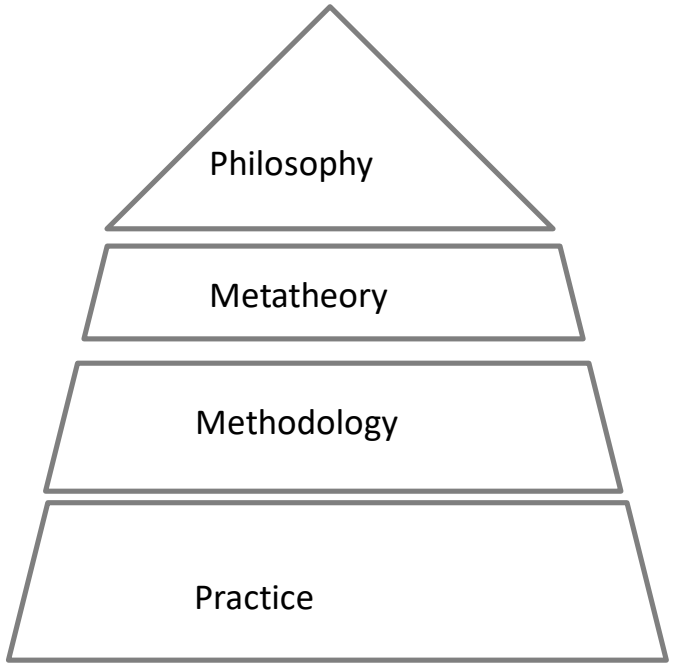
Science foundations

Engineering

The branch of science and technology concerned with the design, building, and use of engines, machines, and structures.

Science foundations

Theory of Science - Scientific pyramid



Science foundations

Theory of Science - Scientific pyramid

- Science building as a hierarchical system
- Practitioners: majority; no development of new methods
- Methodologists: new scientific methods for improvement of practice;
- Meta-theorist: questioning the logical systems
- Theories behind theories
  -> Origin of theory (inductive, deductive)
  -> Inclusion of the researcher's personality

Science foundations

Theory of Science - Scientific pyramid

- Philosophists:
  - abstract problems of a general nature for all sciences;
  - Meaningfulness of scientific activities
- CONCLUSION: Problem solving will be developed on all of these stages: solutions for ...
  - PRACTICAL problems at the 1st level
  - METHODICAL problems at the level of methodologists
  - THEORETICAL problems at the level of meta theory
  - GENERAL problems for the whole science through the philosopher

Science foundations

Theory of Science

- Positivism
- Phenomenologica-hermeneutical approach (‘hermeneutics’)
- Critical rationalism
- Action-theoretical approach

Science foundations

Theory of Science

Positivism

- objective reality exists outside of subjective consciousness
- objective knowledge of reality through methods of exact science
- all allegations must be traceable to verifiable facts
- Principle of verification -> every statement that is confirmed by an observation is true -> criterion for truth is experience
- -> Goal: Establishment of general laws or theories

Science foundations

Theory of Science

Hermeneutics

- Phenomenology: Classification of the objects of the scientific field
- Hermeneutics: scientific method of understanding
- Objective world does not exist
- objective knowledge, detached from the knowing subject, is not possible
- the world is created through the subjective interpretation> development of the meaning of social action
- Meaningful interpretation of social action > Causal explanation of action and effects

Theory of Science

Critical rationalism

- there are no absolute truths
- Theories hold until they are disproved
- Principle of falsification: Hypotheses can fail
- Reason is the source of knowledge
- Principle of progress: hypothesis -> repeated reformulation -> provisionally confirmed -> further repeated confirmation -> proven statement -> further verification -> generally applicable hypothesis
- Theories at the beginning and at the end on empirical research

Theory of Science

Action theoretical approach

- no principle of causality,
- "Systematic continuation of life practice"
- Action follows a logic of situation
- Consideration of alternative actions
- Intentionality (purposefulness)

Science foundations

Literature

Agassi, J. (1963). Towards an historiography of science.
Bhaskar, R. (2013). *A realist theory of science*. Routledge.
Buckley, A. (2015). A Short History of Natural Science. Adelaide, eBooks@Adelaide.
Caldwell, B. (2010). *Beyond positivism*. Routledge.
Casini, L., Illari, P. M., Russo, F., & Williamson, J. (2011). Models for prediction, explanation and control: Recursive Bayesian networks. *THEORIA. Revista de Teoría, Historia y Fundamentos de la Ciencia*, *26*(1), 5-33.
Chesterman, A. (1998). Description, explanation, prediction: A response to Gideon Toury and Theo Hermans. *Current issues in language & society*, *5*(1-2), 91-98.
Godfrey-Smith, P. (2009). *Theory and reality: An introduction to the philosophy of science*. University of Chicago Press.
Kafle, N. P. (2011). Hermeneutic phenomenological research method simplified. *Bodhi: An interdisciplinary journal*, *5*(1), 181-200.
Lakatos, I. (1971). History of science and its rational reconstructions. In *PSA 1970* (pp. 91-136). Springer, Dordrecht.
Laudan, L. (1996). Beyond positivism and relativism: Theory, method, and evidence.
O'hear, A., & Oohear, A. (1980). *Karl Popper*. London: Routledge & Kegan Paul.
Plager, K. (1994). Hermeneutic phenomenology. *Interpretive phenomenology: Embodiment, caring, and ethics in health and illness*, 65-83.
Sintonen, M. (1990). Basic and Applied Sciences-Can the Distinction (Still) Be Drawn?. *Science & Technology Studies*.