CT10A9512
Research Design and Methods
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Introduction

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About the course

- This course is about scientific research
- Most examples and applications are taken from software engineering, but most topics can be directly transferred and used to any other scientific field
- In the core is the method of science
  - How can we do research so that the results are valid for science?
    - This is an interesting question: what is science?
  - “How” means that we understand the method and the practice of science
  - Difficult problems in the philosophy of science are included here
    - These will be mostly just mentioned
  - “Practice of science” requires the ability to plan research and to produce valid results
    - The core objective of the course is to understand the essence of this

From the study guide

- Objectives
  - The student will be able to describe the essential concepts and methods in empirical research, especially in software engineering.
  - The student will understand the principles of scientific research and reporting and be able to prepare a research plan for a Master's thesis and doctoral studies.
- Content
  - Principles of science and scientific communities.
  - Epistemology and ontology in research.
  - The practical research process.
  - Designing empirical research, research questions and hypotheses.
  - Research methods including qualitative methods, experiments, quantitative methods, and design research.
  - Reporting scientific work.

Course web

- All communication, material, assignments, etc. through Moodle
  - https://moodle.lut.fi/course/view.php?id=19276

Some demographics of us first

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Mentimeter

The department of your degree program

Software engineering (any master, incl. Lahti)	Industrial Engineering and Management (any)	Computational engineering (any)	Electrical Engineering (any)	Other
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Mentimeter

I am

Master student	Doctoral student	Other (should not be possible)
	0	0

Doing the course

- Grading components:
  - Course work – max 38 points, min 16 required.
    - Research plan 20 points.
    - Seminar presentation 18 points.
- Learning diary (weekly task) – 6 x 3 = max 18 points.
- Moodle exam, evaluated separately, max 44 points.
  - The exam requires skills to apply learnings! ChatGPT will not be very useful.
  - THE EXAM IS DONE ONLY ONCE!
- The final grade comes from the sum of all, max 100 points.
- The exam includes also a reading package.
- An accepted course work is a mandatory requirement.

Lectures

- Lectures, 1. period, mostly on Thursdays (exceptions)
    1. Introduction
    2. Research methods
    3. Qualitative inquiry
    4. Quantitative approaches
    5. Design and action in research
    6. Experiments and case studies
    7. Experiences of research planning, discussion and guidance for the course work
- Course work presentations start in the second period
    - Separate Lahti and Lappeenranta sessions at campus, if possible. Also an online group.
    - Times are agreed later, first seminars tentatively in 6.-8.11.

Course work

- Plan research on a selected topic. Each topic may require a different approach on research. Your task is to
  - Select and design the research approach and methodology for the topic
  - Define the objectives of the research
  - Write a research plan
- You present the plan in a seminar. The purpose of the presentation is to discuss about research methods in practical research planning cases.
- The work is done in pairs (probably, let's see how many students we have)
- NO ACTUAL RESEARCH IS DONE!

Implementing and reporting the course work

1. Select your pair (in October)
2. Select your topic/research question from the list
   - Will be available later
3. Select a research approach and method for your study
   - The used method needs to be suitable to answer to the research question
   - The method needs to be one of those presented during the course
4. Write the research plan
   - Write a realistic plan – how this research could be implemented. You can ask for any resources – be aware of practicalities and risks
5. Present your plan in the seminar
6. Finalize the report before the DL (in December)

The deadlines are STRICT

- 1st deadline: group formation, registration and topic selection (October)
  - I will give the date when the number of students is known
  - The first survey on seminar locations very soon
- 2nd deadline: your presentation (schedule available at the end of October)
- 3rd deadline: plan submission (18.12.)

- No mercy. Read your emails or check Moodle regularly.

Weekly task: learning diary

- 2-3 questions to answer about each week’s lectures
- May include reading the articles in the reading package
- SHORT answers are required and valued
  - The answer lenght is restricted to 300 words
- The goal is to facilitate understanding of the core of each lecture

Reading package

- A set of articles about scientific methods
- Required for exam, but useful also for course work

- The final set of articles is initially available in Moodle (changes pending)

AI policy

- You must declare all your AI use, in all your answers, separately
- I will reduce your points, if I have any suspect on direct copying AI texts in your works and answers without declaration
- AI can be a good tool, but it does not replace your learning objectives
- It is up to you how learn
- Copying AI answers does not promote learning

AI declaration in your written works

- In your writings, you must
  - Name all AI systems that were used in the development of the contents of the plan, and for each
  - How and where they were used (illustrations, proofreading, getting ideas for text, to generate diagrams etc.) or
  - Clearly state that no AI assistance or tools were used.

1st Lecture: What is science?
What is software engineering as science?

- Science and scientific research
- Scientific community
- Some important terms of science
- What kind of research is software engineering?

What is science and scientific research?

- Narrow meaning of science
  - The intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment
  - Produces testable explanations and predictions about the universe.
- Broad meaning of science
  - A systematically organized body of knowledge on a particular subject
  - Reliable and teachable knowledge about a topic

- What does scientific research mean in software engineering?
  - Is software engineering a study of physical and natural world?
    - Make examples of for and against.

Background to previous: Software engineering

- IEEE 610.2 Standard Glossary of Computer Applications Terminology
  - The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software
- Two views on software engineering
  - Software as a technical artifact
    - The structural qualities of software
    - The qualities of software development tools
  - Software development as an industrial activity
    - Development processes
    - How human organizations work when developing software
    - Practical usability and applicability of tools and development principles

Let’s have some interaction

- First, a discussion in Zoom random breakout rooms
  - List at least two examples of research topics when software engineering IS and IS NOT a natural science, i.e. a study of physical and natural world (vs. study of humans and the social)
  - Write down these
- Second, write these examples to an interactive poll at Menti
  - Instructions will follow

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Software engineering is a natural science. It studies t
of humans) and uses the scientific method. Give an e
topic.

All responses to your question will be shown here

Each response can be up to 200 characters long

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Software engineering is NOT a natural science. It stu
and interprets them. Give examples.

All responses to your question will be shown here

Each response can be up to 200 characters long

How science works?

- Intersubjective pattern recognition or intersubjective verifiability
  - Concepts that can be accurately communicated between individuals
  - Basis of empirical and scientific investigation
- Scientific method
  - Explanation of events of nature in a reproducible way
  - Hypothesis = proposed explanation of a phenomenon
  - Hypothesis is tested by experimentation or observation
  - If a hypothesis survives, it can be adopted into a scientific theory
  - Theory = logically reasoned, self-consistent model or framework for describing the behavior of natural phenomena
- The scientific method is the basis of natural sciences, but not necessarily of others (we will discuss this later)

Formal sciences

- Mathematics is very essential to other sciences, especially the natural ones
- Statistical methods are very important to most sciences
- Computation and computational sciences enable the advancement of many other sciences
- Is mathematics a science? Are pure computational sciences really sciences?
  - They do not study natural world
  - No experimentation or observation are required

- A difference between formal sciences and empirical sciences, such as natural and social sciences.

Applied research vs. basic research

- Systematic inquiry involving the practical application of science
- Driven by utility and solves practical problems using theories, knowledge, methods and techniques of science

- Basic research is driven by curiosity
  - Searches knowledge
  - Have led to unexpected and unimaginable technological advancements

Scientific community

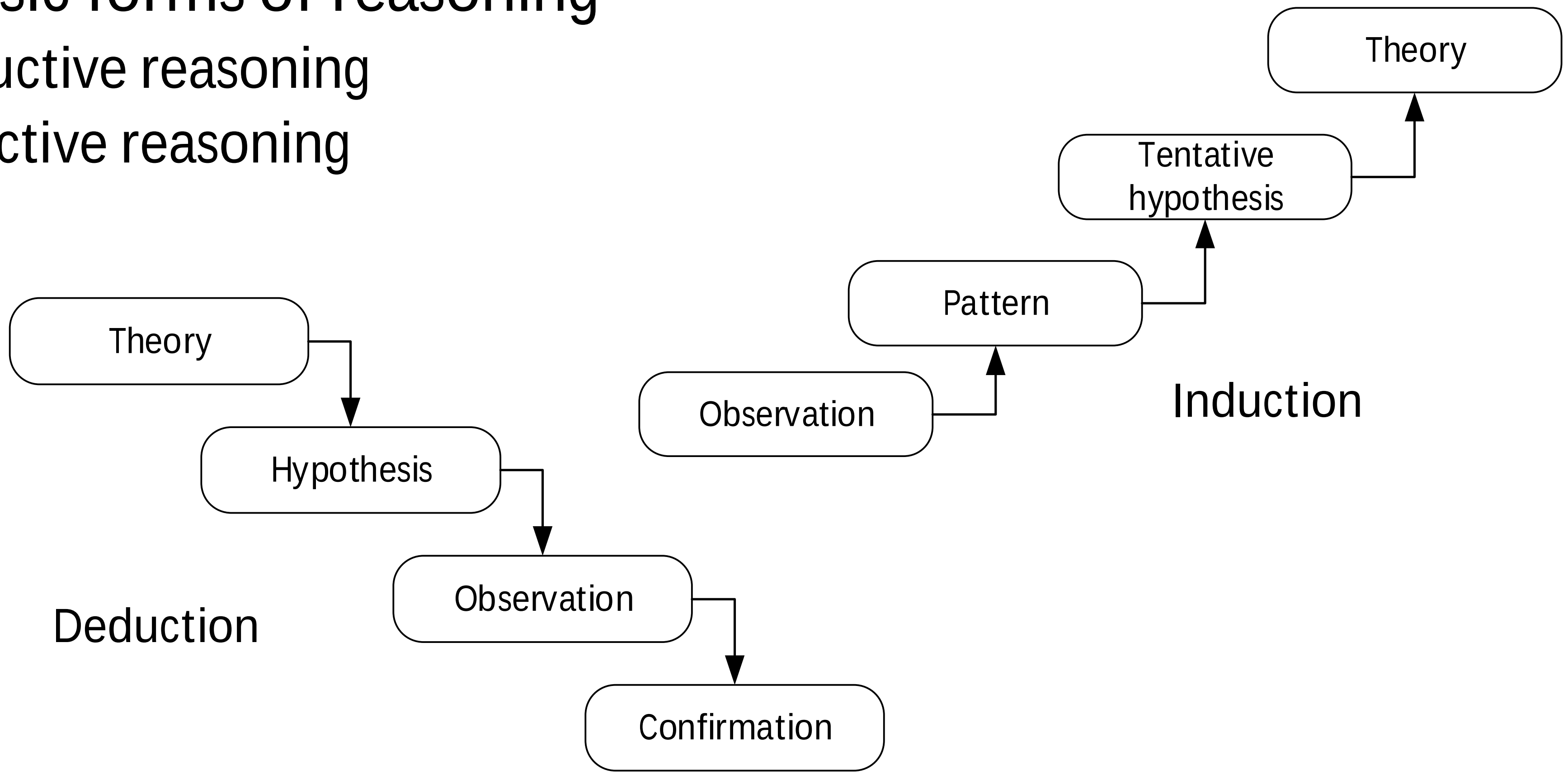
- The group of all interacting scientists
- Many sub-communities in many levels on particular fields
- Also: interdisciplinary communities
- Who decides what research is valid and of high quality?
  - Answer: the scientific community
  - There is a hierarchy, but also independency and peer review
- Peer review
  - Most research writings are selected for publication by peer review
  - Typically 2-4 competent reviewers evaluate the manuscript
- Important results provoke intensive discussion and counter-publications
- In some fields (but not in all!) the results must be repeated by independent researchers before they are generally accepted

Some important scientific terms

- Deduction and induction
- The problem of induction
- Falsifiability
- Accumulation of knowledge and scientific revolutions
- Theory
- Validity

Deduction and induction

- Two basic forms of reasoning
  - Deductive reasoning
  - Inductive reasoning



Deduction and induction (2)

Deductive reasoning

All Frenchmen like red wine

Pierre is a Frenchman

➔ Therefore, Pierre likes red wine

Inductive reasoning

The first five eggs in the box were rotten

All the eggs have the same best-before date stamped on them

➔ Therefore, the sixth egg will be rotten too

(Okasha, 2002)

The problem of induction

- The famous example
  - “All swans are white”
    - This was confirmed true by observing individual swans = induction
    - Until a black swan species was found from Southern Australia
- Induction cannot prove something 100% true
  - This problem applies to most research!
    - “Genetically modified maize is safe for humans”
      - Tested with a large number of humans and none of them suffered any problems
    - Most statistical research use a sample of a population
      - Sometimes it is possible to use the whole population
    - All qualitative research (more later) is based on induction
- Karl Popper’s (1934) solution: all scientific theories must be falsifiable
  - A single experiment or observation can falsify a theory

Falsifiability

- Karl Popper (1934), “Logik der Forschung”
- Also: refutability
- Empirical theories are characterized by falsifiability
  - It must be possible to prove a scientific theory false

- An asymmetry between verifiability and falsifiability
  - One contradictory observation is enough to falsify a universal statement (“all swans are white”)
  - How many observations are needed to verify a universal statement?

Accumulation of knowledge

- Ideal: science constructs a coherent and consistent theory on which knowledge is accumulated over time. The knowledge and theory approaches perfection over time.
- Two problems
  - Scientific revolutions
  - It is not always possible to fully agree on a coherent and consistent theory (e.g. in human sciences)
    - The observation and results require interpretation of human action
- Thomas Kuhn: “The Structure of Scientific Revolutions” (1962)
  - “Normal science” accumulates knowledge (normal = dominant paradigm)
  - Anomalies cause a crisis and a scientific revolution, where the accumulated knowledge is not necessarily valid any more
  - A paradigm shift and a new paradigm follows
    - For example from Ptolemaic to Copernican cosmology
    - From aether theory to electromagnetic radiation

What is theory?

- Theory is abstract and generalized thinking
  - Can be normative/prescriptive or not
  - Can be a body of knowledge
  - A well-substantiated explanation of some part of the world, based on facts
- In contrast with “practice” (praxis – doing)
- Different fields require different kind of theories
  - Theories of physics
    - A mathematical framework that is capable of producing predictions of physical systems
  - Theories of society
    - Often conceptual generalizations of empirical observations

Gregor (2006): A Taxonomy of Theory Types

Table 2. A Taxonomy of Theory Types in Information Systems Research

Theory Type	Distinguishing Attributes
I. Analysis	Says what is. The theory does not extend beyond analysis and description. No causal relationships among phenomena are specified and no predictions are made.
II. Explanation	Says what is, how, why, when, and where. The theory provides explanations but does not aim to predict with any precision. There are no testable propositions.
III. Prediction	Says what is and what will be. The theory provides predictions and has testable propositions but does not have well-developed justificatory causal explanations.
IV. Explanation and prediction (EP)	Says what is, how, why, when, where, and what will be. Provides predictions and has both testable propositions and causal explanations.
V. Design and action	Says how to do something. The theory gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact.

Validity of scientific reasoning

- How to evaluate the validity of a proposition, inference or conclusion in research?
- An extremely difficult philosophical question that includes
  - Epistemology – theory of knowledge
  - Ontology – theory of reality

- Each field and research methodology may have differences in the criteria for validity
- Perhaps we can discuss this later.

Positivistic method

- The method of natural sciences
  - The purpose of science is explanation, finding general laws and causal connections
  - Science is value-free and based on objective, measurable facts
  - The researcher is an independent observer
  - Studies and measurements can be repeated any time and by anyone with the same results
  - Research results increase the amount of scientific knowledge
  - The accumulated scientific method forms an internally harmonious system (no conflicts)

  - (Btw. is any of above true? Always/sometimes)

Is positivistic method the criterion of science?

- In natural sciences only the research that fulfils the criteria in the previous slide is acceptable
  - The method of natural sciences is the typical view of scientific method
- The method of human sciences
  - The positivistic method does not work in social sciences where the understanding and interpretation of human activity is in the center
    - How to measure unambigously attitudes, social norms, beliefs, perceptions, fears, motives, etc.?
    - The researchers cannot be completely neutral, independent, and value-free
    - The presence of a researcher may have an effect on the studied activity
    - It is often not possible to repeat the study with unchanged conditions
- Is software engineering a natural science?

Software engineering

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Software development as human activity

- Software is a technical artifact (although there is much human knowledge encoded in it) but <u>software development</u> is a human activity
  - How to study human activities?
  - How to measure and evaluate human activities?

- It is (relatively) easy to measure qualities and properties of software, but more difficult to measure and evaluate software development

Software development as human activity

- What affects on human activities?
  - Genetics
  - Attitudes
  - Social norms
  - Perceived behavioral control, experiences on difficulties and rewards
  - Faith, beliefs, religion, philosophy
  - Instincts, fear, habits
  - Etc.
- How to measure these unambiguously in software development?
  - Is it possible?

An example

- Agile manifesto (2001)
- This is not about software technology
- This is about human activity/ behaviour

Does software engineering study humans?

- An example: a researcher wishes to study how agile methods can be taken into use in a very large software organization

- Software engineering research must often evaluate the actions of individuals and human organizations
  - It may be essential to understand the motives, values, expectations and objectives of individuals and organizations
  - ➔ Software engineering must take also humans as the research subjects

Questions?
Comments?

Lectures

- Lectures mostly on Thursdays (exceptions are always possible)
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