TECHNISCHE HOCHSCHULE
OSTWESTFALEN-LIPPE
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS

Scientific Methods and Writing

Prof. Dr. Dr. Dr. Carsten Röcker & Hitesh Dhiman, M.Sc.

Overview

- Organizational Information
- What is Science?
- How is it Done?
- Fields of Science
- Scientific Contributions
- Research Question and Approach

Overview

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Lecturers

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Study Material

- all slides will be made available on ILIAS after the lecture
- password: SMW_2022

Goals & Contents

- acquire basic knowledge about scientific methods and writing
- understand typical structures of scientific papers
- gain hands-on experience in
  - conduction a scientific study
  - drafting, organizing and revising a scientific paper

Curriculum (Master IT)

Course	1st Sem.	2nd Sem.	3rd Sem.	4th Sem.	CH	CR
1st Semester, Compulsory Courses						
- Advanced Topics in Algorithms	4				4	5 CR
- Discrete Signals and Systems	4				4	5 CR
- Probability and Statistics	4				4	5 CR
- Usability Engineering	4				4	5 CR
- Scientific Methods and Writing	4				4	5 CR
- Management Skills and Business Administration	4				4	5 CR
2nd Semester, Compulsory Courses						
- Innovation and Development Strategies		4			5	5 CR
2nd semester, Compulsory Elective Courses (4 out of 6) plus Lab Project 2						
- Communication for Distributed Systems		4			4	5 CR
- Embedded System Design		4			4	5 CR
- Industrial Software Engineering		4			4	5 CR
- Information Fusion		4			4	5 CR
- Intelligent Technical Systems		4			4	5 CR
- Network Security		4			4	5 CR
- Advanced Topics in Machine Learning		4			4	5 CR
- N.N.					4	5 CR
3rd Semester, Compulsory Courses						
- Research Project						30 CR
4th Semester						
- Master’s Thesis						30 CR
Total CH	**24**	**24**	**0**	**0**	**48**	
Total CR	**30 CR**	**30 CR**	**30 CR**	**30 CR**		**120 CR**

Official Dates

- Lecture: Thursdays, ~~08:00~~ - 09:35 => new start time: **08:15**
- Exercise (Group 1): Thursdays, 09:45 - 11:20
- Exercise (Group 2): Thursdays, 11:30 - 13:05

- **important:** schedule and lecture format will be adapted to current pandemic situation and requirements of a practical course
- see next slide for actual course program

Course Program

Week	Date	Topic
1	22.09.2022	Exam Week
2	29.09.2022	no lecture
3	06.10.2022	Introduction to Scientific Methods and Writing
4	13.10.2022	Study Design and Data Analysis & Presentation of Research Project
5	20.10.2022	Structuring Scientific Papers
6	27.10.2022	Preperation of Draft Paper (no lecture)
7	03.11.2022	Basic Writing Guidelines & Deadline for Draft
8	10.11.2022	1. Check-In: Individual Appointments for Feedback
9	17.11.2022	Writing (no Lecture)
10	24.11.2022	Writing & Data Collection (no lecture)
11	01.12.2022	Practical Introduction into Data Analysis & Data Collection
12	08.12.2022	Writing (no lecture)
13	15.12.2022	Writing (no lecture)
14	22.12.2022	2. Check-In: Individual Appointments upon Request
15	29.12.2023	Christmas Break
16	05.01.2023	Preparation of Presentation (no lecture)
17	12.01.2023	Presentations (online)
18	19.01.2023	Presentations (online) & Deadline for Final Paper
19	26.01.2023	Exam Week
20	02.02.2022	Exam Week

Exam

Requirements for Successful Completion

- on-time submission of <u>all</u> course assignments, not graded
- scientific paper (4 pages, IEEE format), graded
- oral presentation, graded

Job Offer

Part-Time Position as Research Assistant and Software Developer

- programming experience required
- previous work experience is a bonus
- flexible working hours
- if interested, please contact me (carsten.roecker@th-owl.de)

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Definition of „Science“

- from the Latin word *„scientia“*, meaning *„knowledge“*
- in early days, the term was used mainly for formal knowledge
  - mostly educated, upper-class individuals studied different aspects of nature
  - one early field of interest was astronomy
  - but: no defined processes how knowledge was gathered
- over time, the meaning changed
- today, science also refers to the *process of gathering knowledge*

Definition of „Science“

Science is an Ongoing Process

- science will never be finished
- discoveries lead to new questions
- many unanswered questions

„The more we know, the more we know we know nothing at all."

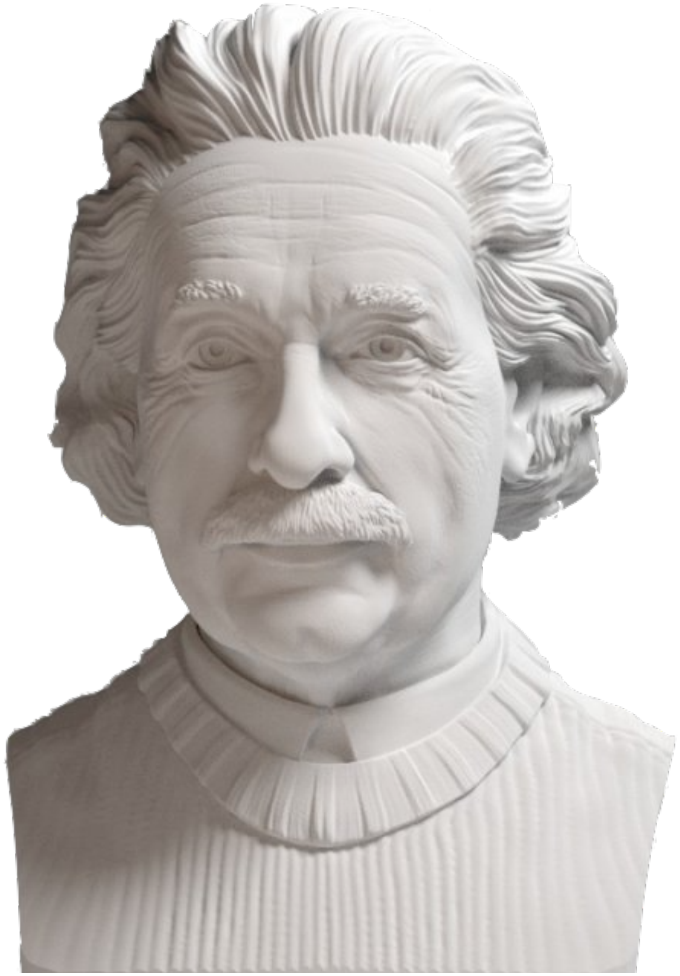
Aristotle

No Absolute Certainty

- potential of change always exists,
  if new evidence is found
- but: only very rare cases, where existing knowledge had to be revised, e.g., theory of relativity
- in most cases, gradual changes lead to improvement of theory

„The important thing is never to stop questioning.“

Albert Einstein



What is NOT Science?

- science is limited to answering questions about the physical world
- questions related to supernatural forces, values and ethics can not be answered
- reason: hypotheses can not be disproved

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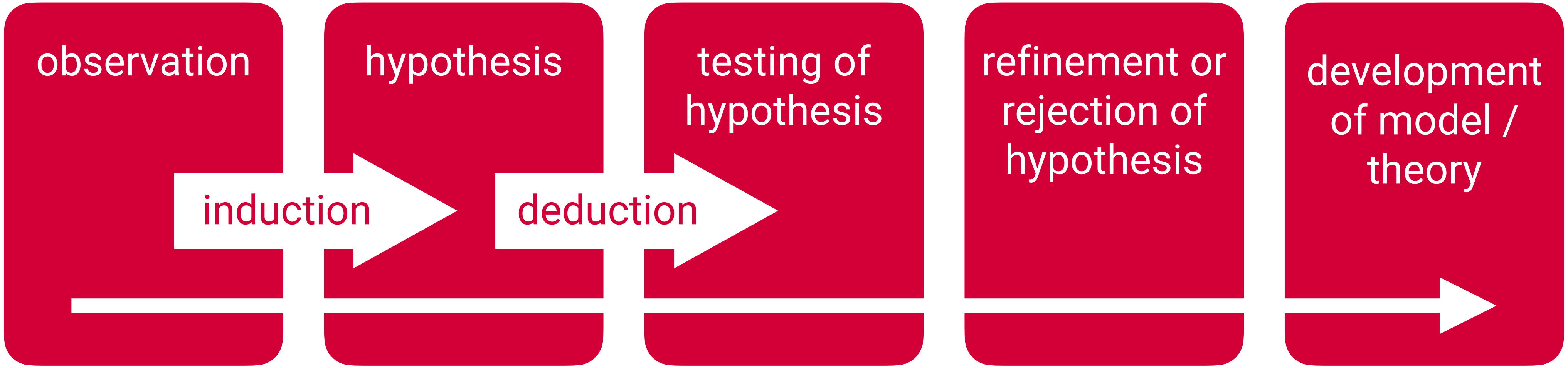
Scientific Method

- goal: explain a (natural) event in a reproducible way
- defined process



Formulation of a Hypothesis

- hypothesis = „goal-directed scientific claim“
- a hypothesis must be
  - testable
    - properties must be „measurable“
      - e.g., „cars with powerful engines are faster than cars with less powerful engines“
      - both engine power and speed are measurable
    - also possible for non-physical properties
      - e.g., opinions of people could be „measured“ by polls

Formulation of a Hypothesis

- hypothesis = „goal-directed scientific claim“
- a hypothesis must be
  - testable
  - generalizable
    - must be formulated so that is true for all entities of a group or domain
      - e.g. not for one specific car but for all cars

Formulation of a Hypothesis

- hypothesis = „goal-directed scientific claim“
- a hypothesis must be
  - testable
  - generalizable
  - formulated as a conditional clause
    - the expected result must be bound to a certain condition
      - e.g. the more powerful the engine, the higher the maximum possible speed

Formulation of a Hypothesis

- hypothesis = „goal-directed scientific claim“
- a hypothesis must be
  - testable
  - generalizable
  - formulated as a conditional clause
  - falsifiable
    - it must be possible to prove that a hypothesis is not correct

Testing

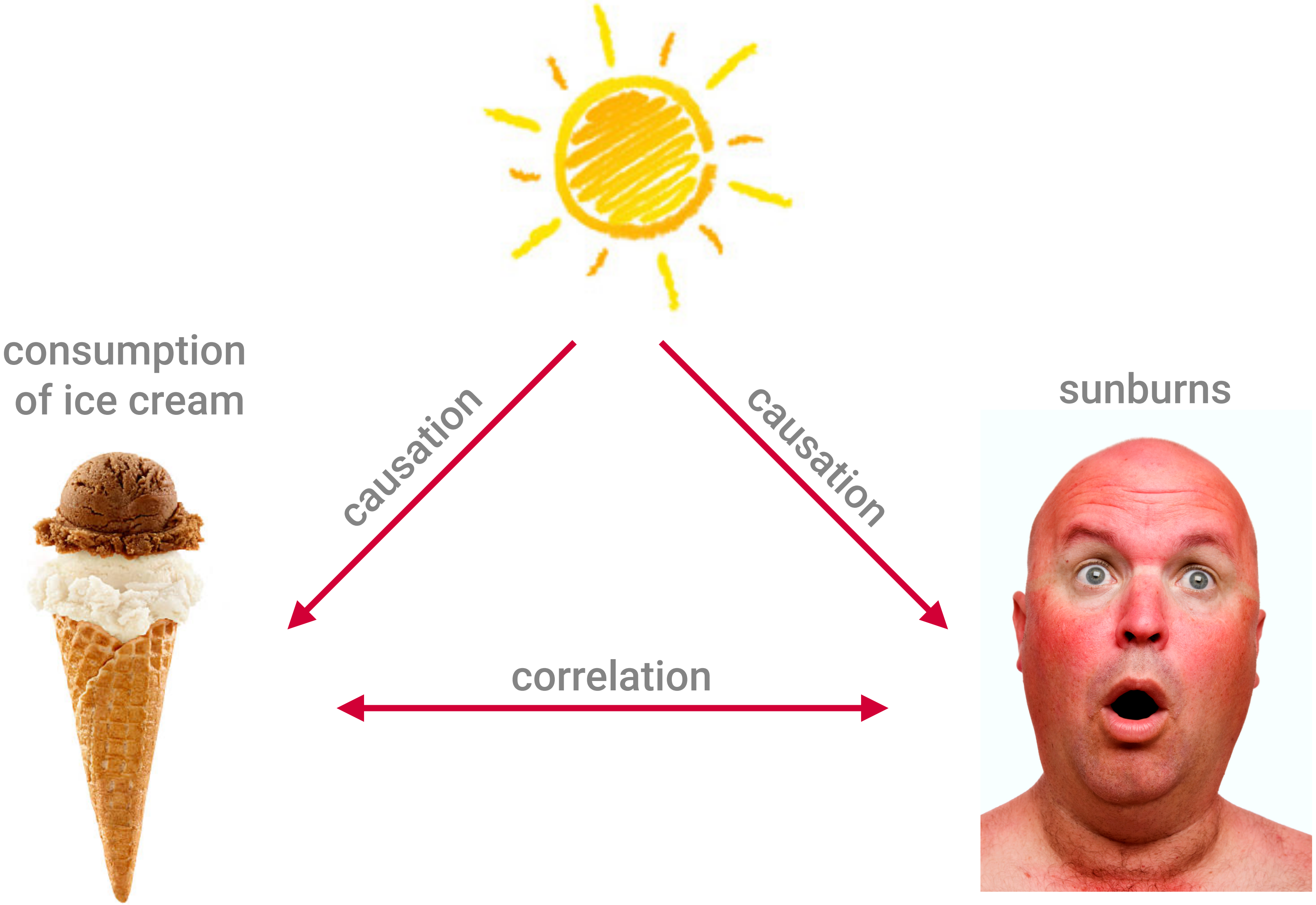
- test of hypothesis by predicting the results of new observations
- problem: hypothesis can not be proven true
  - not possible to be sure that we have looked at all cases
    - be careful if you see the label „scientifically proven“ => not possible
  - but: it can be proven that a hypothesis is false (falsification)
    - one case in which a hypothesis is not true is sufficient to reject it
    - e.g. if we find one car, what is slower with a powerful engine than with a less powerful engine we have to reject our initial hypothesis
- hence: if a hypothesis withstands a test to falsify it, there is a certain probability that the hypothesis is true/correct

Testing

Observation vs. Experimentation

- different ways of testing a hypothesis (depending on discipline)
- **observation**
  - of natural phenomena, e.g., astronomy
- **experimentation**
  - simulation of events under controlled conditions, e.g., physics or chemistry
- experimentation necessary to confirm causal relationships
  - in contrast to a correlation

Testing



consumption
of ice cream
causation
causation
sunburns
correlation

Testing

Correlation vs. Causality

- caution: correlation and causality can seem similar
- but: they are not necessarily
  - **causation** => action A causes outcome B
  - **correlation** => relationship between action A and action B

    (does not necessarily imply that one action caused the other event to happen)
- correlation and causation are often confused as humans want to find patterns (even if the do not exist)

Refinement or Rejection

- if the hypothesis proves wrong, it is either modified or discarded
- sometimes it takes years or decades to falsify a model
- example: solar system
  - early belief: earth is the center of the universe and the sun is orbiting around it
  - model was accepted for a long time
  - today, we know better

Scientific Quality Control

- **objectivity** is most important criteria of scientific work
- outcome must not be influence by feelings and/or interests
- different types of biases
  - sampling bias
  - measuring bias

Scientific Quality Control

Sampling Bias

- sample is not representative for the intended population

Scientific Quality Control

Measuring Bias

- different types:
  - observer bias
    - people „see what they want to see“
    - e.g., a „severe pain“ in a medical study
  - expectation bias
    - certain outcomes are expected
    - e.g., perceived well-being after taking a new drug (placebo effect)
- conclusion: experiments must be designed carefully

Scientific Quality Control

Additional Measures

- repeated tests by independent experimenters
- peer review process (review before publication)

Scientific Theories and Models

- when a hypothesis was sufficiently tested, I can become the basis of a **scientific theory** or **scientific model**
- a theory has a much *broader scope* than a hypothesis and helps us to
  - describe (what is happening?)
  - explain (why is something happening)
  - predict (what will happen?)
- often multiple hypotheses are combined to formulate a theory
- the process follows the same scientific principles as for hypotheses

Scientific Theories and Models

Model vs. Theory

- very similar terms
- often used synonymously (even by scientists)
  - e.g. „Big Bang Theory“, „Big Bang Model“
- both create abstractions from concrete observations
- but: differences in the scope and degree of specificity

Scientific Theories and Models

Theory

- usually describes a higher-level principle
- theories help to understand

Model

- describes concrete applications of higher-level principles (i.e. theory)
- model help to intervene (social sciences) or do something

Scientific Theories and Models

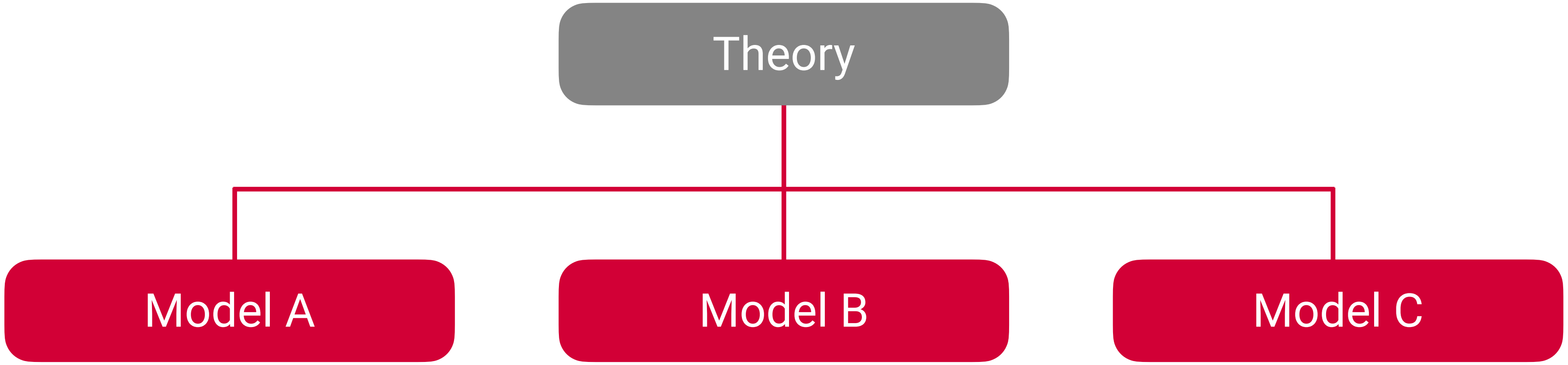
Examples (by Kevin de Laplante)

Theory	Model
theory of gravity	model of a gravitating two-body systems (describing the interrelation of two planets)
evolutionary theory	model of the evolution of the horse
machine learning theory	model of facial recognition

Scientific Theories and Models

Parent-Child Relationship

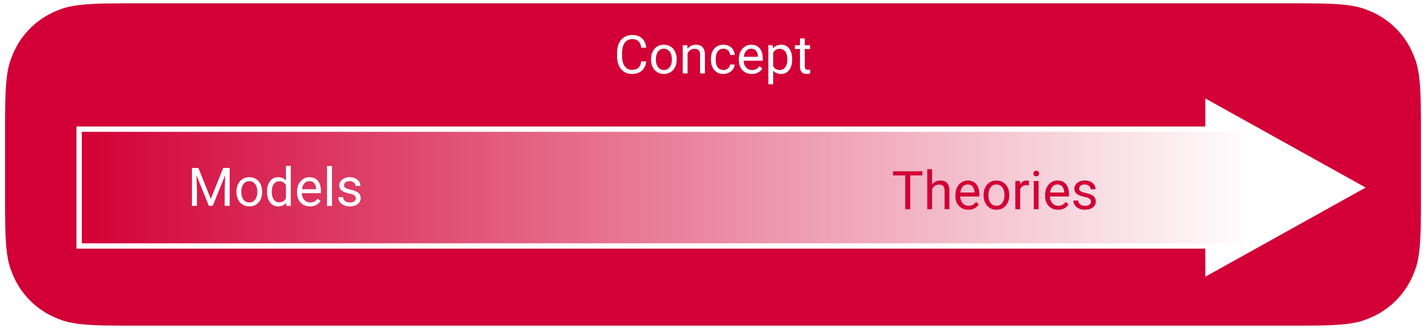
- models inherit characteristics from the „parent" theory
- but also add specific aspects not part of the theory



Scientific Theories and Models

Difference with regard to the amount of proof that exists

- Models
  - are generally qualitative
  - often not „proven“
- Theories
  - are more tested than models
  - usually numerous study necessary to prove a theory



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Fields of Science

- Natural Science
- Social Science
- Formal Science
- Applied Science

Natural Sciences

- study of natural phenomena based on empirical evidence
- sub-divided into
  - **life science** (or biological science)
    - the study of living organisms
    - biology, genetics, botany, zoology, neuroscience etc.
  - **physical science**
    - the study of the physical world
    - physics, chemistry, earth science, astronomy etc.

Social Sciences

- study of individuals and societies
  - economics, political science, public health, psychology, sociology, history etc.
- often not a single cause, but a combination of different factors, which are explored
  - e.g. psychology: combination of genetics, upbringing and education contribute to an observed behavior
  - important to understand the interactions among these factors in order to improve predictions

Empirical Sciences

- natural and social sciences are empirical sciences
- knowledge is based on empirical observations

Formal Sciences

- study of formal systems
- e.g., mathematics, logic, theoretical computer science etc.
- no empirical evidence required (cf. empirical sciences)
- solely based deductive reasoning

Applied Sciences

- disciplines that apply scientific knowledge for practical purposes
- engineering, medicine, applied computer science
- sometimes not considered as „science“

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Scientific Contributions

- extension of the body of (scientific) knowledge
- alternatively: contribution of new scientific knowledge
- different scientific field have different types of scientific contributions

Scientific Contributions

- **Example:** Research Contributions in Human-Computer Interaction (Wobbrock and Kientz, 2016)
  - Empirical Research Contributions
  - Artifact Contributions
  - Methodological Contributions
  - Theoretical Contributions
  - Dataset Contributions
  - Survey Contributions
  - Opinion Contributions

Jacob O. Wobbrock, University of Washington
Julie A. Kientz, University of Washington

Research Contributions in Human-Computer Interaction

Insights

- Knowledge generated by HCI research can be categorized into certain contribution types.
- Each contribution type has key characteristics that imply how it is judged.
- The contribution types used for submissions to the CHI conference have evolved over time to distill types of knowledge from other concerns.

IMAGE BY VARINTHRON MEKKAMON

All scholarly fields strive to contribute new knowledge. In the field of human-computer interaction (HCI), this new knowledge increasingly comes in rich forms like videos and demos, but the archival research paper remains the most widely used and accepted capture and delivery mechanism for research knowledge. The knowledge contribution made by a research paper—or more precisely, made by the work a research paper describes—is any research paper's central feature. For example, a theoretical physics paper may contribute a new mathematical model for the behavior of light near black holes. A civil engineering paper may contribute a new method for stress-testing bridges. A social anthropology paper may contribute an account of people's reactions to teen pregnancies in rural religious communities. Whatever the field of inquiry, whatever the phenomenon of interest, every research paper strives to make a research contribution by offering new knowledge. In an effort to distinguish this kind of knowledge from everyday know-how, some scholars even capitalize the term: Knowledge.

In the whole of human inquiry, there are, of course, countless specific research contributions to be made. But

Wobbrock, J. O., Kientz, J. A. (2016). Research Contributions in Human-Computer Interaction. In: Interactions, Vol. 23, No. 3, Association for Computing Machinery, New York, NY, USA, pp. 38 - 44.

Empirical Research Contributions

- backbone of science
- provide new knowledge based on observation and data collection (qualitative or quantitative)
- typical instruments in HCI research: experiments, field observations, interviews, log files, sensors etc.
- contributions evaluated mainly on the importance of their findings and on the soundness of their methods

Artifact Contributions

- artifacts: systems, architectures, tools, toolkits, techniques, mockups
- new knowledge represented by artifact
- evaluation of contributions depends on the type of artifact
  - *new systems, architectures, tools, and toolkits:* holistic assessment based on what they make possible and how they do so
  - *new input and interaction techniques:* mostly evaluated based on improvement of their human performance and/or comfort

Methodological Contributions

- provide new knowledge on how we carry out (scientific) work
- improvements might refer to the analysis, conceptualization, implementation, evaluation
- contributions are evaluated based on the utility, reproducibility, reliability, and validity of the new method

Theoretical Contributions

- provide new or improved concepts, definitions, models, principles, or frameworks
- methodological contributions inform *how* we do things
- theoretical contributions inform *what* we do, *why* we do it, and *what we expect* from it
- can be descriptive and/or predictive
- evaluated based on their novelty, soundness, and power to describe, predict, and explain

Dataset Contributions

- provide a new and useful corpus of data
- enable benchmark tests of new algorithms, systems, or methods
- evaluated based on the usefulness and representativeness of the corpus

Survey Contributions

- review and synthesize work done on a research topic
- goal: identification of trends and gaps
- not just listing of prior work
- evaluated based completeness, depth, maturity, and organization

Opinion Contributions

- also called essays or arguments
- do not just inform, but try to *persuade* the reader
- goal: stimulate reflection, discussion, and debate
- draw upon previous contribution types to make their case
- evaluated based on the strength of their argument

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Why you need a research question

- *research question* = primary questions your research aims to answer
- sometimes also called „research problem“
- defines goal
- sets boundaries and helps to focus
    - what is part of your research and what is not?

Characteristics of a research question
(The Writing Center, 2018)

- **clear:** it provides enough specifics that one's audience can easily understand its purpose without needing additional explanation
- **focused:** it is narrow enough that it can be answered thoroughly in the space the writing task allows
- **concise:** it is expressed in the fewest possible words
- **complex:** it is not answerable with a simple "yes" or "no," but rather requires synthesis and analysis of ideas and sources prior to composition of an answer
- **arguable:** its potential answers are open to debate rather than accepted facts

The Writing Center (2018). How to Write a Research Question. George Mason University, available online: https://writingcenter.gmu.edu/guides/how-to-write-a-research-question

Developing a research question
(The Writing Center, 2018)

Steps to developing a research question:

- choose a general topic you are interested in
  - e.g., artificial intelligence
- conduct preliminary research on your topic
  - get an overview over state-of-the-art research and issues currently being discussed
- consider your audience
  - envision the types of research questions your audience might be interested in

The Writing Center (2018). How to Write a Research Question. George Mason University, available online: https://writingcenter.gmu.edu/guides/how-to-write-a-research-question

Developing a research question
(The Writing Center, 2018)

- write down questions
  - begin with “how” and “why” questions about your general topic
  - e.g., „How can AI support learning in higher education institutes?“
- evaluate your question
  - use the criteria presented above
- choose a question and begin your research

The Writing Center (2018). How to Write a Research Question. George Mason University, available online: https://writingcenter.gmu.edu/guides/how-to-write-a-research-question

Typical Mistakes

- unclear or ambiguous questions (e.g. better, easier)
- combination of multiple aspects into one questions
- (non-scientific) questions whose answers could be looked up

How to answer the question

The Paper Pentagon (Rienecker and Stray Jørgensen, 2013)

Rienecker, L., Stray Jørgensen, P. (2013). The good paper. A handbook for writing papers in higher education. Samfundslitteratur, Frederiksberg.

Summary

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Questions