Empirical Methods: Experiments and Case Studies with Human Subjects

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Today's objective

- An introduction to empirical research methods.
- A brief introduction to case studies.
- A more in-depth introduction to the experimental process for running experiments with human subjects.

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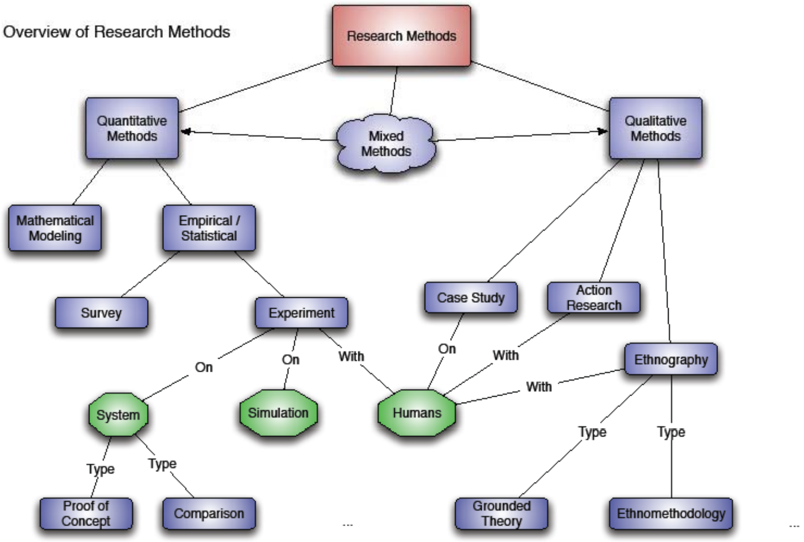
Overview of Research Methods



Quantitative methods

- Survey
- Experiment
  - Human subjects (main focus in the lecture)
  - Simulation
  - Real system (proof of concept, comparison)
- Case study
  - Often both qualitative and quantitative

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Why empirical methods?

Evaluation and validation of methods, techniques and tools mean focusing on applying empirical methods, including:

- Controlled experiments
- Case studies
- Surveys

In many cases we perform statistical analysis.

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Some noteworthy things

- Proposal by Barbara Kitchenham
  - Research-in-the-typical: case study
  - Research-in-the-large: survey
  - Research-in-the-small: experiment

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A comparison

- Survey
  - Sample from population
- Case study
  - Often in-depth study of an object, for example development project or an activity
- Experiment
  - Treatment to outcome
  - Cause and effect
  - Although, a sample is still used

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Process/method prototyping

To understand, evaluate and validate a product solution, a prototype may be built. We may do the same for processes/methods using empirical studies.

Especially, experiments using human subjects or simulation may be used for process evaluation.

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Empiricism meets engineering 1(3)

- ***Confirmation*** of more or less accepted hypotheses**.** *For example*: object-orientation is good for reuse.
- ***Evaluation*** of methods, models, languages and tools**.** *For example*, whether Java produces higher quality code than C++.
- ***Identification*** of relationships**.** *For example*: find a relationship between fault-prone components and design concepts.

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Empiricism meets engineering 2(3)

- ***Validation*** of models or measures. *For example*, to validate a specific cost estimation model.
- ***Understanding*** of methods, techniques and models. *For example*, to understand the relationship between inspections and test.

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Empiricism meets engineering 3(3)

- ***Guidance/control*** to help in management. *For example*, as input to planning of personnel to software inspections.
- ***Change/improve*** to support decision-making with respect to changes. *For example*, the result of a study can help us to decide whether or not to introduce a new development tool.

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Case Study

"Case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident"

Robert K. Yin, Case Study Research

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Case studies in software engineering

An example: software process improvement

- Involves complex activities
- success or failure depends on many interrelated factors
- cannot be fully studied in isolation
- needs empirical studies in real world settings.

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Different types of case studies

Some possible dimensions:

- Snapshot (situation now)
- Longitudinal (over time)
- Pre-post (before and after a change)
- Patchwork (combining related case studies)
- Comparative (cross-unit comparison)

The different types of case studies provide different types of evidence.

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Within a case study

A case study may often be conducted as a combination of other methods, for example:

- Archival analysis (documentation)
- Interviews
- Survey
- ...

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Experiment

- Experiments are carefully planned and fully controlled. An experiment should be replicable, i.e. somebody else should be able to repeat it.
  - This type of method will be used to exemplify empirical studies with human subjects.

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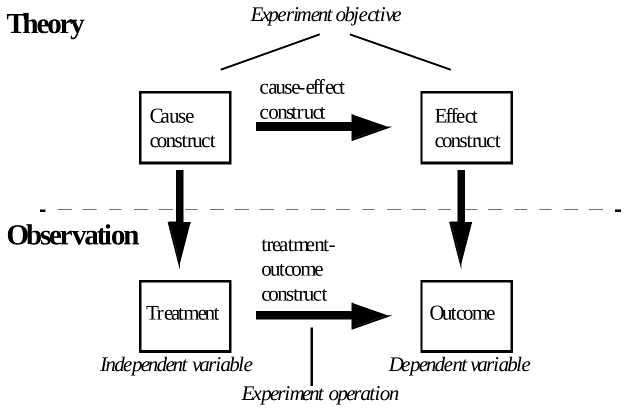
Experiment principle



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Independent and dependent

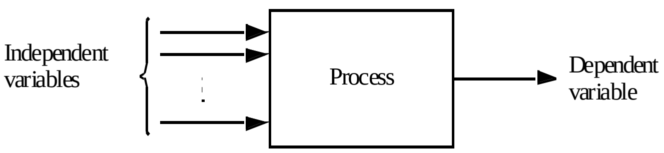

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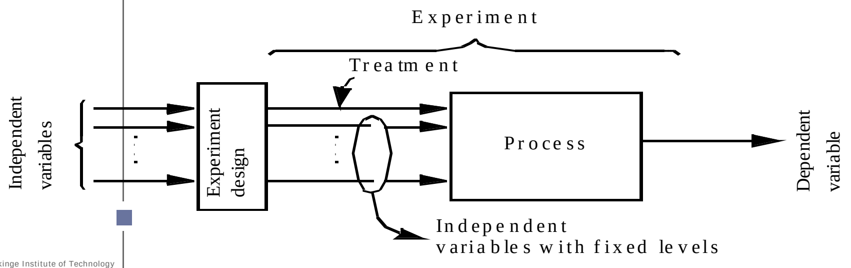
Illustration of experiment



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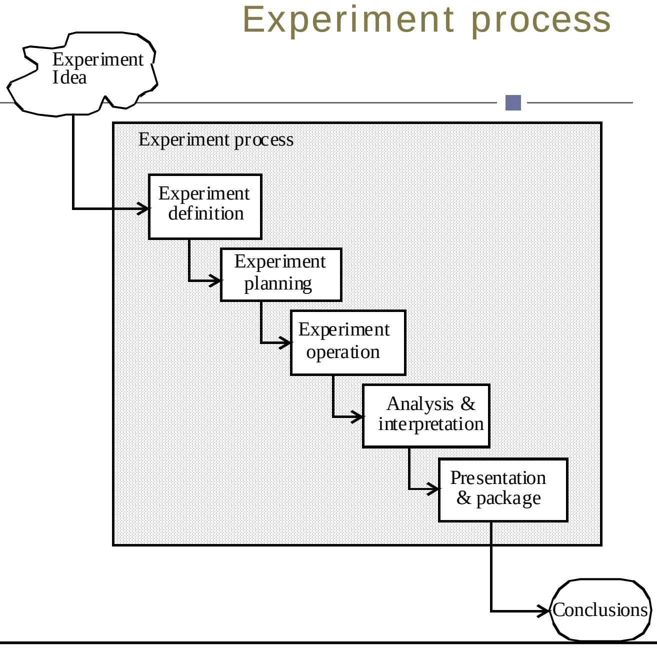
Experiment process



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Experiment definition

- The goal template is:

  Analyse *<Object(s) of study>*

  for the purpose of *<Purpose>*

  with respect to their *<Quality focus>*

  from the point of view of the *<Perspective>*

  in the context of *<Context>*.

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An example definition

Analyse *the PBR and checklist techniques*

for the purpose of *evaluation*

with respect to *effectiveness and efficiency*

from the point of view of *the researcher*

in the context of *students reading requirements documents*.

PBR – Perspective-based reading

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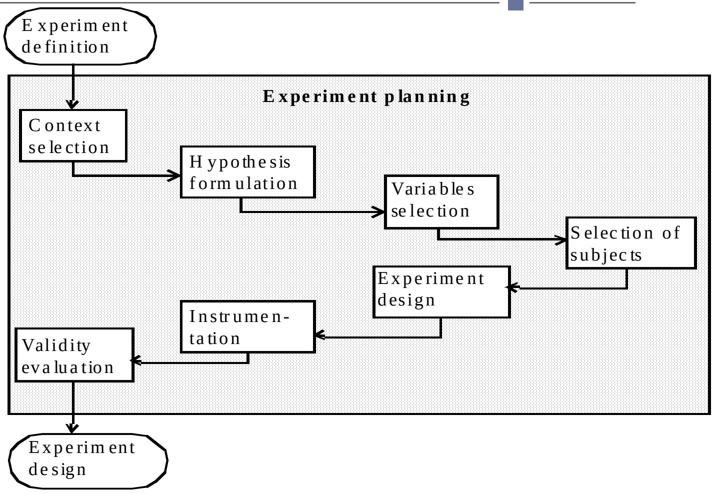
Experiment planning



Planning phase overview

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Steps in planning 1(4)

- Context:
  - Off-line vs. On-line
  - Students vs. Professionals
  - Toy vs. Real problems
- Hypothesis formulation:
  - Null hypothesis (no real underlying trend or pattern) and alternative hypothesis. The objective is to reject the null hypothesis with as high significance as possible.

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Steps in planning 2(4)

- Variables:
  - Independent (input)
  - Dependent (output)
- Subjects
  - Sampling strategy, sampling from population
- Design principles
  - Randomization
  - Blocking (e.g. on experience)
  - Balancing (same number of subjects in groups)

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Steps in planning 3(4)

- Design types

A large number of standard designs exist, and we should select an appropriate design type depending on treatments and number of subjects and of course the objective (hypothesis) of the experiment.

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Steps in planning 4(4)

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- Instrumentation
  - Objects
  - Guidelines
  - Measurement instruments
- Validity evaluation
  - Conclusion validity: treatment to outcome (observation), ability to draw correct conclusions
  - Internal validity: treatment causes outcome, threat to causal relationship
  - Construct validity: relationship between theory and observation
  - External validity: generalization

Experiment operation

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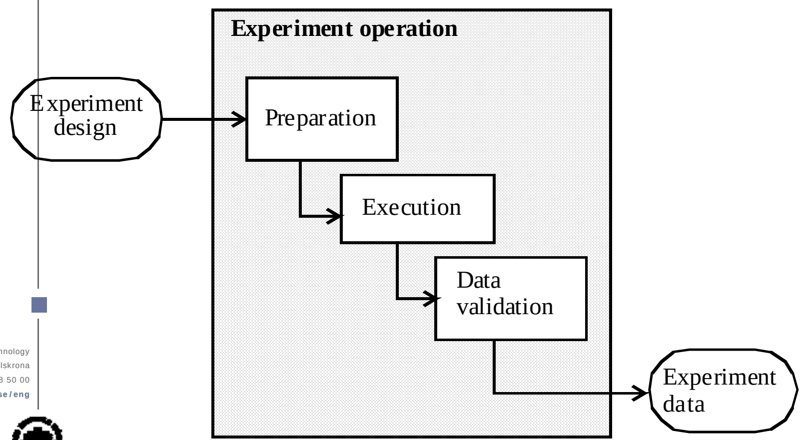

Steps in operation

- Preparation
  - Commit participants
  - Instrumentation (availability)
- Execution
  - Data collection
  - Experimental environment
- Data validation (general check)

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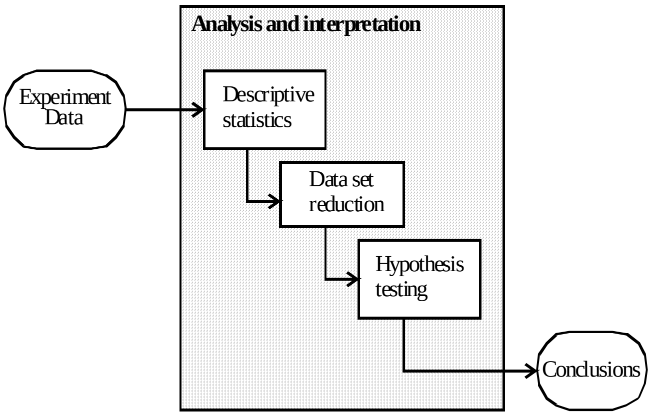
Analysis and interpretation



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Steps in analysis 1(2)

- Descriptive statistics
  - Scale types (nominal, ordinal, interval and ratio)
  - Measures of central tendency, dispersion and dependency
  - Graphical visualization
- Data set reduction
  - Outliers

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Steps in analysis 2(2)

- Hypothesis testing
  - Parametric tests (assumes a specific distribution, usually a normal distribution)
  - Non-parametric tests (no assumption on distributions)

The different types of tests are related to the standard design types. The intention is to be able to reject the null hypothesis with a statistical significance.

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Interpretation

The statistical analysis forms the basis for interpretation.

The interpretation is the foundation for decision-making based on engineering principles.

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Packaging

Report outline:

- Introduction
- Problem statement
- Experiment planning
- Experiment operation
- Data analysis
- Interpretation of results
- Discussion and conclusions
- Appendix

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Additional concerns

- Triangulation
- Replication
- Lab packages
- Meta-analysis

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Simplistic example: experiment

- Problem: We want to evaluate reading techniques for inspections.
- We have two competing methods. State a null hypothesis, for example method A and method B show no difference in defect detection for requirements specifications.
- Let people inspect a requirements specification with a known number of defects.
- Use a statistical method to evaluate the hypothesis. Could the null hypothesis be rejected?
- Determine which method is the best.
- Decide whether or not to start using the method.

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Some conclusions

- There is a lack of validated results in the field,
- Empirical studies is needed in software engineering to evaluate and validate development process activities,
- Empirical studies mean that the human dimension in software development can be included in the analysis.

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Some sources of information

- ISERN: International Software Engineering Research Network (www.iese.fhg.de/ISERN/)
- BESQ: Large research project together with industry at BTH (www.bth.se/besq)
- ESEM: International Symposium on Empirical Software Engineering and Measurement (www.esem-conferences.org). This year in Kaiserslautern, Germany and in USA in 2009.

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