MÄLARDALEN UNIVERSITY SWEDEN

CDT413: Advanced Software Engineering
Software Engineering Research

Software Engineering Research

- What is software engineering research?
  - What is software engineering?
- Empirical research methods in software engineering
  - Experiments and surveys
  - Case studies
  - Validity and reliability

What Is Software Engineering?

1. The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software
2. The study of approaches as in 1

IEEE Standard Glossary of Software Engineering Terminology, IEEE std 610.12-1990, 1990.

What Is Software Engineering?

- Software engineering is an engineering discipline that is concerned with all aspects of software production.
  - Software engineers should adopt a systematic and organised approach to their work and use appropriate tools and techniques depending on the problem to be solved, the development constraints and the resources available.

Ian Sommerville, *Software Engineering*, 8th edition, 2006

What Is Software Engineering Research?

- Engineering research – study methods, tools, etc. that can be used to solve practical problems
  - May include invention of new methods, tools, etc. or improvement of existing ones
  - But invention is neither necessary nor sufficient
- As opposed to basic research – study phenomena and try to find “the truth”

What Is Software Engineering Research?

- What kinds of questions are "interesting"?
- What kinds of results help to answer these questions, and what research methods can produce these results?
- What kinds of evidence can demonstrate the validity of a result, and how to distinguish good results from bad ones?

Types of Research Questions

- Method or means of development
- Method for analysis
- Design, evaluation, or analysis of a particular instance
- Generalization or characterization
- Feasibility

Types of Research Questions

- Method or means of development
  - How can we do/create (or automate doing) X?
  - What is a better way to do/create X?
- Method for analysis
  - How can I evaluate the quality/correctness of X?
  - How do I choose between X and Y?
- Design, evaluation, or analysis of a particular instance
  - What is a (better) design or implementation for application X?
  - What is property X of artifact/method Y?
  - How does X compare to Y?
  - What is the current state of X / practice of Y?

Types of Research Questions

- Generalization or characterization
  - Given X, what will Y (necessarily) be?
  - What, exactly, do we mean by X?
  - What are the important characteristics of X?
  - What is a good formal/empirical model for X?
  - What are the varieties of X, how are they related?
- Feasibility Does X even exist, and if so what is it like?
  - Is it possible to accomplish X at all?

Types of Research Results

- Procedure or technique
- Qualitative or descriptive model
- Empirical model
- Analytic model
- Notation or tool
- Specific solution
- Answer or judgment
- Report

Types of Research Results

- Procedure or technique
  - New or better way to do some task, such as design, implementation, measurement, evaluation, selection from alternatives,
  - Techniques for implementation, representation, management, and analysis, but not advice or guidelines
- Qualitative or descriptive model
  - Structure or taxonomy for a problem area; architectural style, framework, or design pattern; non-formal domain analysis
  - Well-grounded checklists, well-argued informal generalizations, guidance for integrating other results,
- Empirical model
  - Empirical predictive model based on observed data
- Analytic model
  - Structural model precise enough to support formal analysis or automatic manipulation

Types of Research Results

- Notation or tool
  - Formal language to support technique or model (should have a calculus, semantics, or other basis for computing or inference)
  - Implemented tool that embodies a technique
- Specific solution
  - Solution to application problem that shows use of software engineering principles – may be design, rather than implementation
  - Careful analysis of a system or its development
  - Running system that embodies a result; it may be the carrier of the result, or its implementation may illustrate a principle that can be applied elsewhere
- Answer or judgment
  - Result of a specific analysis, evaluation, or comparison
- Report
  - Interesting observations, rules of thumb

Validation Techniques

- Analysis
- Experience
- Example
- Persuasion
- Evaluation
- Blatant assertion

Validation Techniques

- Analysis - I have analyzed my result and find it satisfactory through
  - … rigorous derivation and proof
  - … data on controlled use
  - … experiment
- Experience – My result has been used on real examples by someone other than me, and the evidence of its correctness / usefulness / effectiveness is
  - … narrative
  - … data, usually statistical, on practice
  - … comparison of this with similar results in actual use
- Example – Here's an example of how it works on
  - … a toy example, perhaps motivated by reality
  - …a system that I have been developing

Validation Techniques

- Persuasion – I thought hard about this, and I believe
  - … if you do it the following way, …
  - … a system constructed like this would …
  - … this model seems reasonable
  - If the original question was about feasibility, a working system, even without analysis, can be persuasive
- Evaluation – Given the stated criteria, my result
  - … adequately describes the phenomena of interest
  - … accounts for the phenomena of interest
  - … is able to predict … because …, or … gives results that fit real data …
  - Feasibility studies, pilot projects
- Blatant assertion – No serious attempt to evaluate result

Software Engineering Research

Question	Result/method	Validation
Feasibility	Qualitative model	Persuasion
Characterization	Technique	Implementation
Method/means	System	Evaluation
Generalization	Empirical model	Analysis
Selection	Analytic model	Experience

A Common Plan

Question	Result/method	Validation
Feasibility	Qualitative model	Persuasion
Characterization	Technique	Implementation
Can X be done better? →	Build a Y →	Measure Y and compare to X
Generalization	Empirical model	Analysis
Selection	Analytic model	Experience

A Common, But Bad, Plan

Question	Result/method	Validation
Feasibility	Qualitative model	Look it works!
Characterization	Devise a technique	Implementation
Can X be done better?	System	Evaluation
Generalization	Empirical model	Analysis
Selection	Analytic model	Experience

Two Other Good Plans

Question	Result/method	Validation
Can X be done at all?	Qualitative model	Look it works!
Characterization	Technique	Implementation
Method/means	Build Y that does X	Evaluation
Is X always true of Y?	Empirical model	Check proof
Selection	Formally model Y and prove X	Experience

Empirical Research Methods

- Definitions and motivation
- Different types of methods
  - Experiments and surveys
  - Case studies
- Validity and reliability of empirical studies
- Measurements

Empirical Research Methods

- Based on observations
  - As opposed to methods relying only on analysis, e.g. in mathematics or theoretical computer science
- Two main categories of observations
  - Quantitative – based on "measurement"
  - Qualitative – explanations without measurement

Empirical Research Methods

- Controlled experiments
- Surveys
- Case studies

Controlled Experiments

- Researchers control independent variable(s) and observe dependant variables(s)
- Useful for studying isolated activities in controlled environments
  - E.g. comparing the use of two programming languages using students as subjects
- Research "in-the-small"

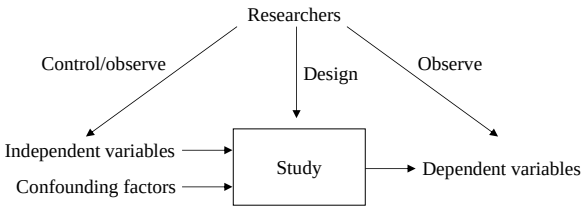
Surveys

- Researchers observe a phenomena in a representative subset of some population
  - E.g. collecting data about a number of projects in different organization through questionnaires and/or interviews
- Research "in-the-large"

Case Studies

- Researchers observe a phenomena in a “real-life context”
  - E.g. collecting data about an ongoing project
  - Possible methods for data collection include interviews, project participation, documents, artifacts (software), …
- Research “in-the-typical”

Empirical Research Methods



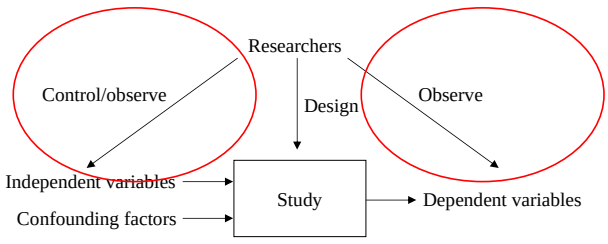
Validity of Empirical Studies

- Construct validity
- Internal validity
- External validity
- Conclusion validity

Construct Validity

- Establishing correct operational measures for the concepts being studied
- Indirect measures are often used
  - E.g. reported working hours as a measure of effort

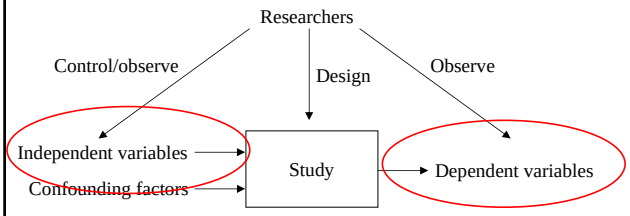
Construct Validity



Internal Validity

- Establishing a causal relationship, whereby certain conditions are shown to lead to other conditions
- As distinguished from spurious relationships

Internal Validity



External Validity

- Establishing the domain to which a studies findings can be generalized
- Can an experiment using students as subjects be generalized to software professionals?
- Can a case study of one project be generalized to other projects in
  - The same/other organization
  - The same/other application domains
  - The same/other countries

Reliability (Conclusion Validity)

- Demonstrating that the operations of a study can be repeated with the same results

Empirical Research Methods

- "Hard" science
  - Controlled experiments – high level of control, repeatable
  - Surveys – sampling, statistically valid
- "Soft" science
  - Case studies – needs careful documentation, multiple-case studies can strengthen results