

Lecture 2

Research method classification

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Research methods and their classification

A classification by Järvinen (2004) on possible research approaches

An example of empirical research in software testing

What is a research method?

Methodology is the systematic, theoretical analysis/study of the methods applied to a field of study

- The system of methods and principles used in a particular discipline

A research method/methodology is a structured process of conducting research. It may include

- Data collection principles
- Data analysis principles
- General epistemological principles (i.e. what is knowledge in research)
- Process description
- Analysis rules
- Validation rules and principles (how to evaluate the validity of results)

Research method classification

- **Problem: How to present typical research methods and approaches (in software engineering) to students**
- Some kind of holistic view is needed to understand them
- **Solution: Classify them to distinct classes where each class has clear features that can be contrasted with others**
- **There are many ways to classify research, for example**
- Basic research \leftrightarrow applied research
- Quantitative research \leftrightarrow qualitative research
- Positivistic research \leftrightarrow interpretive research
- **In addition, different fields of sciences make also a classification**

Some basic concepts for classification

- Positivism
- Interpretivism (or antipositivism)
- Quantitative
- Qualitative

Positivism

The meaning of positive with a philosophical sense of 'imposed on the mind by experience'

Historically positivism is a rejection of metaphysics as explanation

- Metaphysics = explaining the fundamental nature of being and the world
- In positivism the goal of knowledge is to describe the phenomena that we experience (not metaphysics)
- Science can explain only what we can observe and measure → emotions, thoughts, etc. can not be studied

Behaviorism

- B.F. Skinner (1920s): psychology must concentrate only on the positive and negative reinforcers of **behavior** in order to predict how people will behave
 - *everything else is irrelevant because it can't be measured*
 - *C.f. Pavlov's dogs*

Positivism (2)

Logical positivism/ logical empirism

Scientific knowledge is the only kind of factual knowledge and all traditional metaphysical doctrines are to be rejected as meaningless

Only statements verifiable either logically or empirically are cognitively meaningful

Carnap (1929): Der Logische Aufbau des Welt

Strict methods and procedures for sensory observations to verify the truth of scientific hypotheses of the physical universe.

Formal methods of mathematical logic construct a strictly scientific language that represents the structure of the world.

Interpretivism/antipositivism

- **The social realm may not be subject to the same methods of investigation as the natural world**
- Interaction between theory and data – the data can be reinterpreted in light of another theory
- Sociological research must concentrate on humans and their cultural values
→ a complete value-freedom or scientific objectivity is not possible when studying society
- An interpretive process in which an outside observer relates to indigenous people or sub-cultural group on their own terms rather than interpreting them in terms of his or her own concepts
 - *Observer = software engineering researchers*
 - *Indigenous people = software developers in a company*

Interpretivism/antipositivism (2)

- **Critique condensed**
- Positivism is restricted to observable phenomena
 - *it is impossible to study freedom, irrationality and various unpredictable actions typical to human behaviour.*
- Knowledge about humans can never be neutral
 - *It directly translates into power*
 - *Positivists attempt to draw an artificial line between observer and the subject*

Assumptions	Positivism	Interpretivism
Nature of reality	Objective, tangible, single	Socially constructed, multiple
Goal of research	Explanation, strong prediction	Understanding, weak prediction
Focus of interest	What is general, average and representative	What is specific, unique, and deviant
Knowledge generated	Laws Absolute (time, context, and value free)	Meanings Relative (time, context, culture, value bound)
Subject/Researcher relationship	Rigid separation	Interactive, cooperative, participative
Desired information	How many people think and do a specific thing, or have a specific problem	What some people think and do, what kind of problems they are confronted with, and how they deal with them

Quantitative research

Describe and measure the level of occurrence on the basis of numbers and calculations

- How many? How often?

Collection of numerical data

Deductive relationship between theory and research

- Such as in natural science (the scientific method)

Objectivist conception of social reality (and a positivistic view)

- Strict methods of observation
- Analysis with formal mathematics

Typical methods, tools and techniques of research

- Closed-ended questionnaires
- Experiments
- Correlation analysis (relationship between two random variables)
- Regression analysis (relationship among many variables, independent → dependent)

Qualitative research

Interpretive, aim at depth of understanding

Qualitative research attempts to interpret words, perceptions, feelings rather than analyze numbers

- Experiments, interviews, case studies, focus groups, questionnaires with open-ended questions
- Rich observational data

Abstraction and generalization as important principles

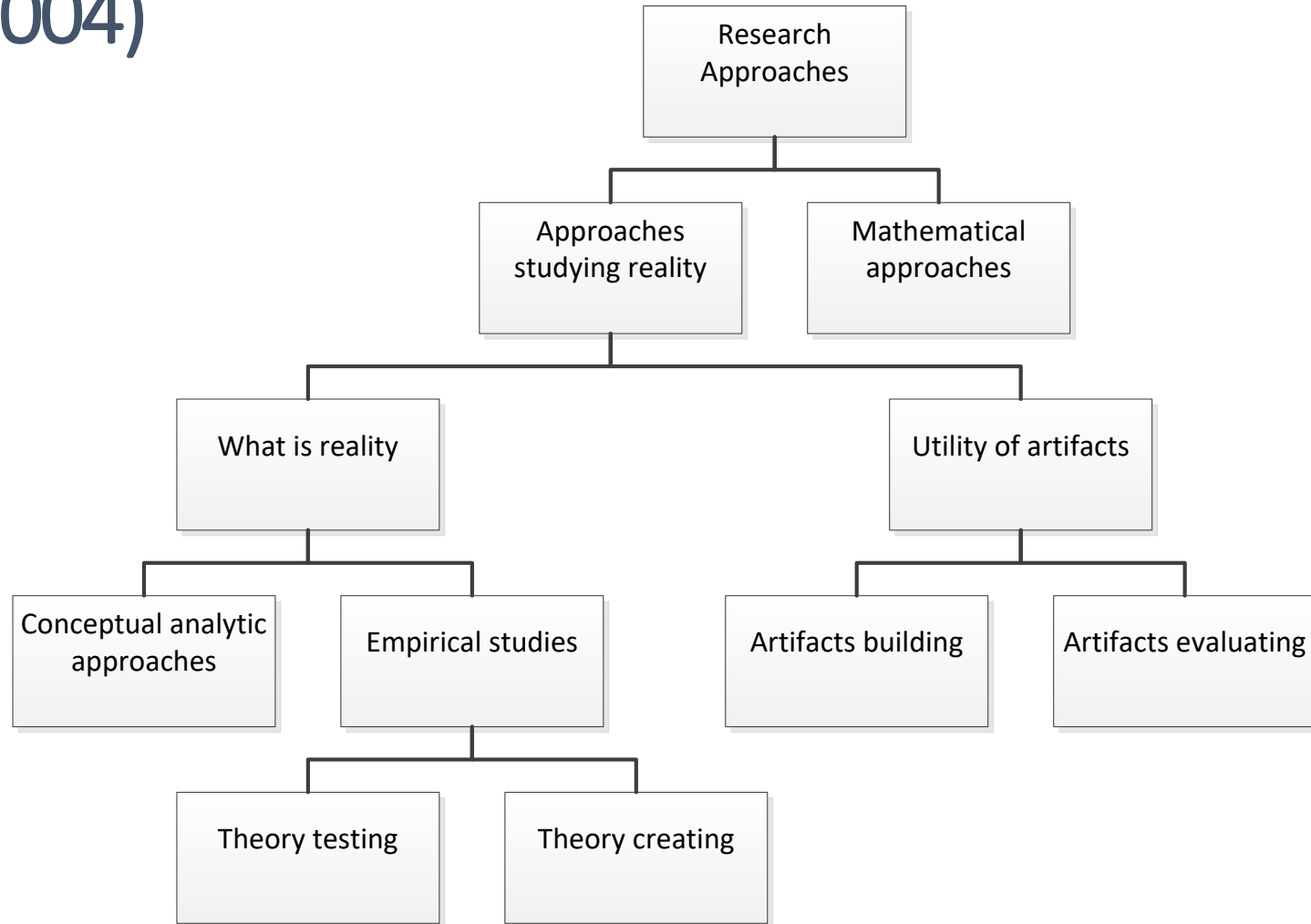
- Theoretical abstraction and generalization of single observations (do not confuse with statistical generalization)
- Produces theories and hypotheses – not confirmed and verified facts

Characteristic	Quantitative research	Qualitative research
Type of data	Phenomena are described numerically	Phenomena are described in a narrative fashion
Analysis	Descriptive and inferential statistics	Identification of major schemes
Scope of inquiry	Specific questions or hypotheses	Broad, thematic concerns
Primary advantage	Large sample, statistical validity, accurately reflects the population	Rich, in-depth, narrative description of sample
Primary disadvantage	Superficial understanding of participants' thoughts and feelings	Small sample, not generalizable to the population at large

Research method classification by Järvinen (2004)

- Järvinen: "On Research Methods", 2004
- A classification of research methods from the viewpoint of information technology and systems
- Includes also engineering and design research
- Does not really name the different methods, but provide a classification on which individual research methods and approaches can be put.

Järvinen: On research methods (2004)

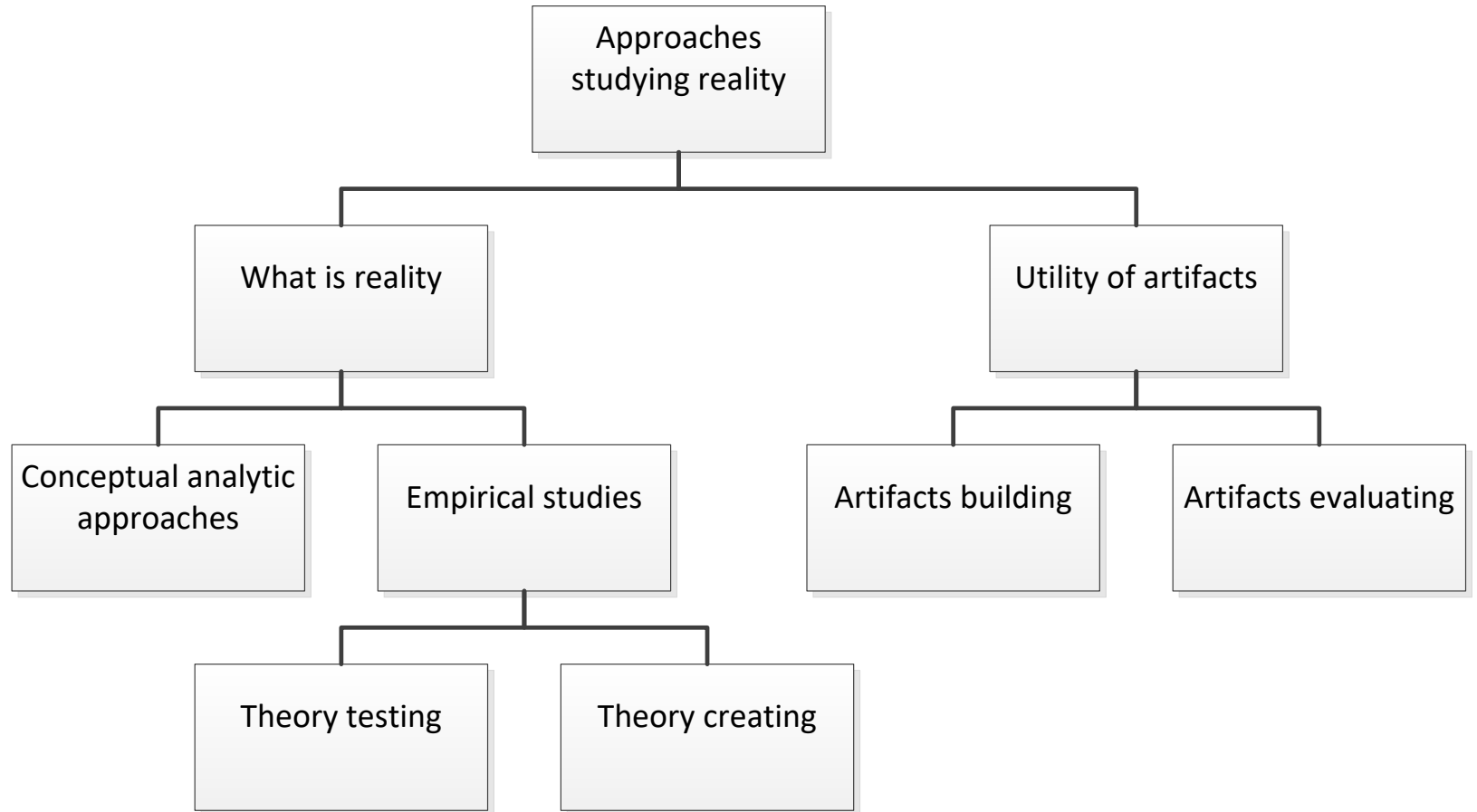


Mathematical approaches

Proving of mathematical theorems

Used in computational research, but not very relevant in software engineering

Approaches studying reality



Conceptual-analytic approaches

- Analysis of assumptions behind theoretical constructs
- Identification of theories, models, and frameworks in earlier research
- Literature studies
- Includes logical reasoning
- Does not require original observations of "reality"
- Possible to use in software engineering
- Problem: what parts of the results are based on opinions and intuition instead of scientific inquiry?

Theory testing approach

- Laboratory experiment, controlled experiment
- Survey – collect and analyze statistical data from a population
- Field study, field test
- Mostly quantitative research
- The theory is taken from literature or developed/refined
- The study tests if the theory is "true"
- Problem: how to select and develop the theory? Where does it come from?

Theory creating approach

A multitude of approaches

- Case studies
- Ethnography
- Grounded theory
- Discourse analysis
- Etc.

Mostly qualitative research

Observation of the practices, "reality" → theoretical conclusions

Various methods of data collection

- Interviews, direct observations, collecting archive material, ...

Inductive theory creation → observations are refined and classified into theories

Problem: is it possible to generalize the theories to other contexts?

Building new artifact as research approach

A particular construct, method, or model is applied and an artifact is produced

The utility aspects of the artifact are considered

The output is reported and the usefulness of the artifact is discussed

A very common approach in engineering

Design research – the science of the artificial

- Or: studying the design process itself

Problem: we have the artifact, so what? How to evaluate it? What is its scientific value?

Evaluating the artifact

The built artifact is evaluated according to designed criteria

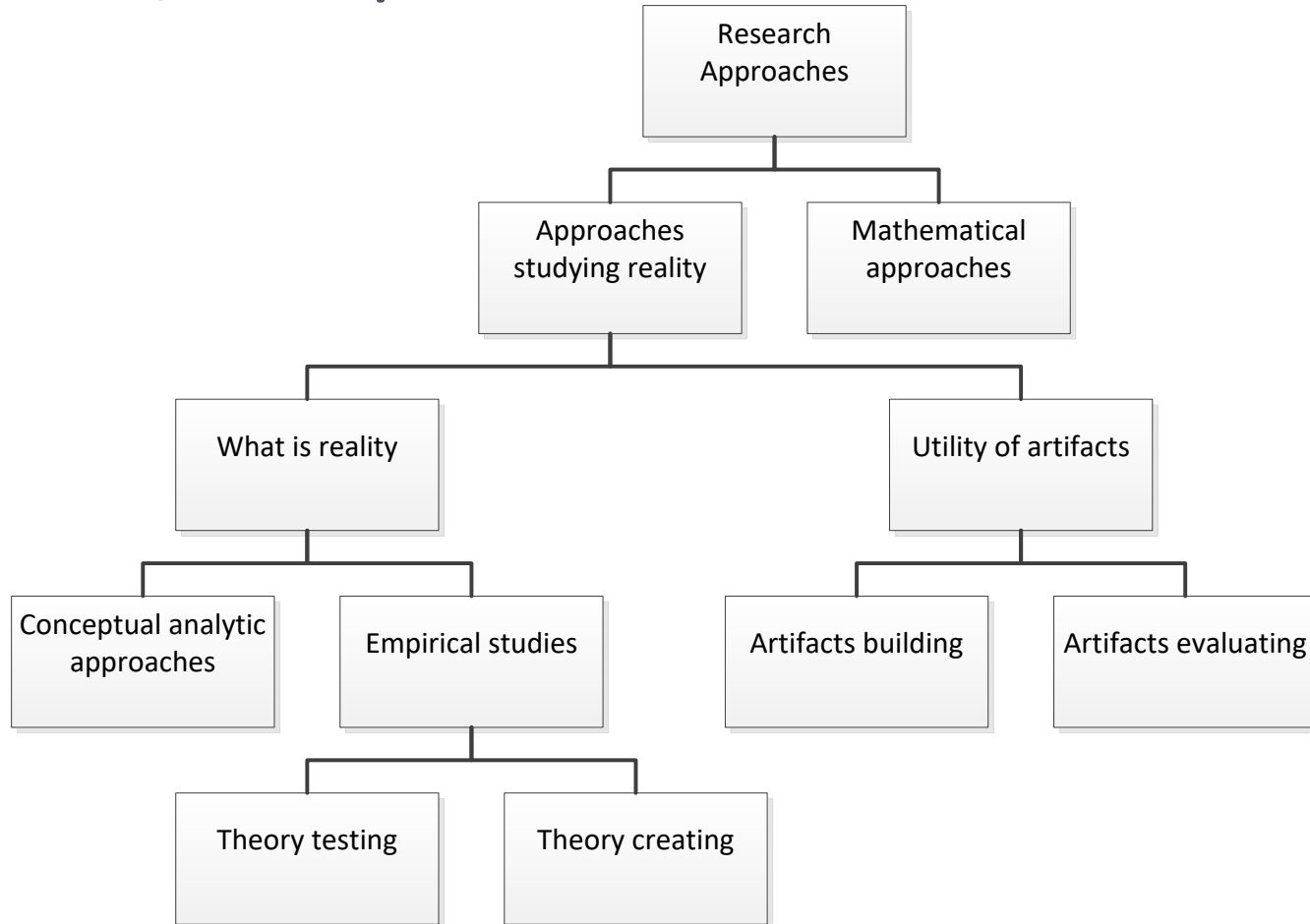
Measurements/observations are performed

Can be a controlled experiment, but in real-life that is seldom possible

Action research:

- Diagnose the problem
- Design an intervention or an artifact to solve the problem
- Do the intervention or take the artifact into use
- Evaluate the intervention
- Learn from the evaluation

RE: Research approaches (Järvinen, 2004)



Example: ESEM 2010

Test Case Selection and Prioritization: Risk-Based or Design-Based?

Jussi Kasurinen, Ossi Taipale, Kari Smolander

Content

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Introduction to the research area

- How are test cases selected in the industry?

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Using grounded theory as the research method

- Data collection and analysis

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Observations on test case selection

- A set of hypotheses
- Two stereotypical approaches

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Conclusions

Introduction: testing and test case selection

Testing is an expensive process

- One estimate: 50% of total development costs (Kit, 1995)

Full-coverage testing is in practice impossible

- Exponential growth in size and complexity

“Let go – deliver now and correct later” causes too much expenses in the long run

→ a strategy or method for test case selection is needed in any real-world development effort

Research question

How real-world software organizations select their approach to test case selection?

- Observation of the practices
- Identifying how organizations select their test cases
- Analyzing and explaining why they apply this type of approach

Belongs to a series of empirical studies of testing practice (2004-), e.g.

- Testing process problems and enhancement strategies
- Testing resources
- Test automation in practice
- Testing outsourcing

Research process: background

Testing is a complex phenomenon in practice

- A human, organizational activity with different approaches even in similar organizations
- No existing theory-base that could adequately explain this complex, human, organizational activity
- → a decision to approach the subject qualitatively by observing the practice
- Grounded theory as the research method
 - *Observing and describing real-life testing practice within its social and organizational context*
- Organizational unit as the unit of observation and analysis
 - *A part of an organization that deploys one process or has a coherent process context – operates within a set of business goals and policies*

Research process: data collection

- Three data collection rounds
 - 12 focus organizations (theme-based interviews, Rounds 1 & 2)
 - A survey in 31 organizations (Round 2 – not reported here)

Round type	Number of interviews	Interviewee role	Description	Themes
1) Semi-structured	12 focus OU interviews	Designer or Programmer	The interviewee was responsible for or had influence on software design.	Design and development methods, Testing strategy and methods, Agile methods, Standards, Outsourcing, Perceived quality
2) Structured with Semi-structured	31 OUs, including 12 focus OUs	Project or Testing manager	The interviewee was responsible for the software project or testing phase of the software product.	Test processes and tools, Customer participation, Quality and Customer, Software Quality, Testing methods and resources
3) Semi-structured	12 focus OU interviews	Tester or Programmer	The interviewee was a dedicated tester or was responsible for testing the software product.	Testing methods, Testing strategy and resources, Agile methods, Standards, Outsourcing, Test automation and services, Test tools, Perceived quality, Customer in testing

Data collection: focus organizations

OU	Business	Company size / Operation
Case A	MES producer and electronics manufacturer	Small / National
Case B	Logistics software developer	Large / National
Case C	ICT consultant	Small / National
Case D	Internet service developer and consultant	Small / National
Case E	Naval software system developer	Medium / International
Case F	Safety and logistics system developer	Medium / National
Case G	Financial software developer	Large / National
Case H	ICT developer and consultant	Large / International
Case I	Financial software developer	Large / International
Case J	SME business and agriculture ICT service provider	Small / National
Case K	MES producer and logistics service systems provider	Medium / International
Case L	Modeling software developer	Large / International
19 survey-only cases	Varies; from software consultancies to software product developers and hardware manufacturers.	Varies

Research process: analysis

Grounded theory process was followed:

- Open coding
 - *Search for pertinent items and phenomena in the data: codes and categories*
 - *Use of "seed categories" derived from the research question*
 - *Open coding produced 166 codes grouped into 12 categories*
- Axial coding
 - *Identification of causal conditions or any kinds of connections between the categories*
 - *Collecting chains of evidence from the data*
- Selective coding
 - *Selection of the core category and relating it to other categories*
 - *"applied test case selection approach" in relation to other categories that explain it*

Test case selection: developed categories

Category	Description
Applied selection approach	The method the organization is currently using to select which test cases are included in the test plan.
Software type	The type of software the OU is developing.
Test designers	The personnel responsible for designing and selecting the test cases.
Development approach	The method the organization is currently using to develop software.
Testing resources	An approximation on how large an amount of testing resources the organization currently has access to, in comparison to the optimal, ie. perfect amount of resources.
Customer influence	The type and method of customers to influence the organization's software test process.
Selection problem	The most common process hindrance the test case selection method causes to the organization.
Explorative testing	Does the organization apply non-predefined test cases in their test plan?

Test case selection: observations in focus organizations

Case	Applied selection method	Software type	Test designers	Development approach	Testing resources	Customer influence	Test case selection problem	Explorative testing
A	Risk-based with changes first	Software module for hardware	Programmers	Plan-driven supported by agile	Low	Approves product	Important test cases are discarded	Yes, programmers do it.
B	Risk-based	Software product	Designers	Agile	Moderate	Participates in testing	Agile products seem to be difficult to test.	No, only defined cases are tested.
C	Risk-based with changes first	Software product	Programmers with clients	Agile	Moderate	Participates in testing	Some test cases are not implemented.	Yes, programmers do it.
D	Risk-based	Software service	Programmers	Plan-driven supported by agile	Low	Approves testing plan	Some test cases are not implemented	Yes
E	Risk-based	Software module for hardware	Programmers	Agile supported by plan-driven	High	Approves product	Important test cases are discarded	Yes, some phases apply.
F	Risk-based with conformance	Software module for hardware	Designers	Plan-driven	Moderate	Approves product	Some test cases are not implemented	Yes
G	Design-based with conformance	Software service	Test manager with testers	Plan-driven	High	Approves testing plan	Validating functionalities is difficult.	No, only defined cases are tested.
H	Design-based	Software service	Designers with clients	Plan-driven	High	Approves testing plan	Amount of policies affect test effectiveness.	No, not enough time.
I	Design-based	Software service	Test manager with testers	Plan-driven	High	Approves design	Too large reliance on test manager experience	No
J	Risk-based, changes first	Software product	Project manager	Plan-driven supported by agile	High	Participates in testing	Important test cases are discarded	Yes
K	Design-based	Software module for hardware	Project manager, clients	Plan-driven supported by agile	Moderate	Participates in test design	Some test cases are not implemented	Yes, in some projects.
L	Design-based	Software product	Project manager with designers	Plan-driven	High	Approves product	Test management in large projects	Yes, several phases apply.

Test case selection: a set of hypotheses

Cross-case comparison as an explanatory tool

- For example, in several cases, design-based approach appeared to exist together with plan-driven product development

We were able to classify the selection method to either risk-based or design-based (with variations)

- Risk-based selection
 - *"What causes the largest expenses when broken?"*
- Design-based:
 - *"Which are the main functionalities the software is supposed to do?"*
- How to describe and explain the difference between these methods?
- What is their effect on testing practice and management?

As the result, four hypotheses were derived

Test case selection: four hypotheses

Hypothesis 1: Risk-based selection is applied when the software design is not fixed at the design phase

- Risk-based selection was preferred when
 - *The organization used agile methods*
 - *A customer had a direct influence on the later parts of the process*
- Design-based selection co-occurred with
 - *Plan-driven methods*
 - *Indirect customer influence*

Hypothesis 2: The design-based approach is favored in organizations with ample resources and it requires more management

- Organizations using the design-based approach had more testing resources (73%) than the others (49%)
- The process difficulty differed:
 - *Risk-based: test coverage – including all critical cases*
 - *Design-based: managing and planning the testing process*

Test case selection: four hypotheses

Hypothesis 3: The use of test automation is not affected by the case design or case selection approach

- We identified no pattern of the feasibility of automation in relation to test case selection

Hypothesis 4: Exploratory testing may be seen by policy-makers as an unproductive task because of its ad hoc nature

- In exploratory testing testers do non-predefined activities as a part of standard process
- Risk-based selection co-existed with high level of exploratory testing
- Design-based selection and large organizations were less related to exploratory testing
- Exploratory testing is difficult to document and therefore causes additional requirements for management and policies

Test case selection: two stereotypical approaches

Category	Risk-based selection	Design-based selection
Test designers	Developers: programmers and testers	Managers: test and project managers
Development approach	Leans towards agile methods	Leans towards plan-driven methods
Testing resources	Limited	Sufficient
Explorative testing	Applied commonly	Applied rarely
Effect of policies in decisions on testing.	Small; most decisions done in project level.	Large; most decisions are based on company policies or customer requirements.
Customer influence	In the testing process	In the design process
Limitations of the model	Test case coverage may become limited.	Test process may become laborous to manage
Design concept	“What should be tested to ensure smallest losses if the product is faulty?”	“What should be tested to ensure that the product does what it is intended to do?”

Conclusions

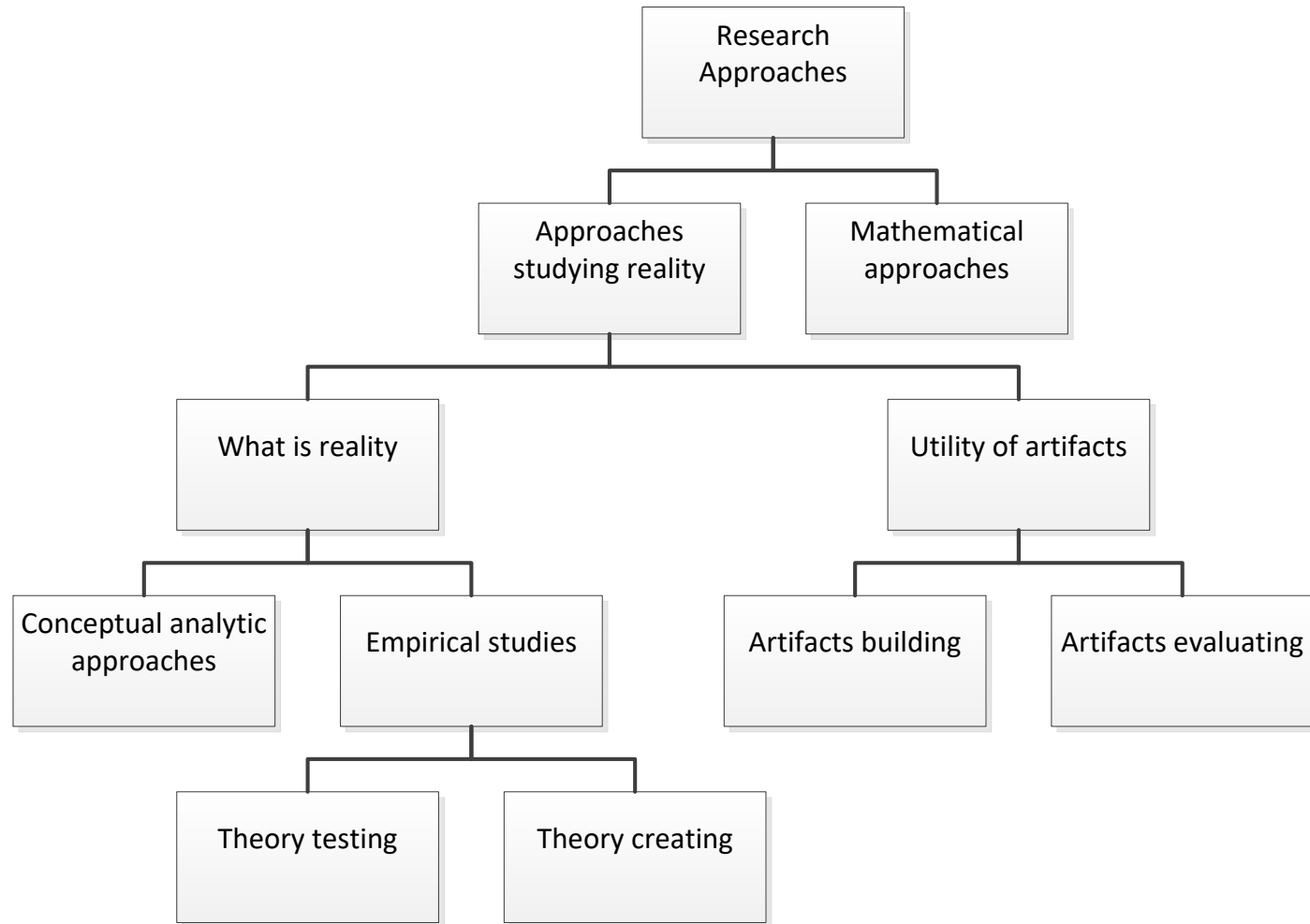
Two main approaches to test case selection were identified: risk-based and design-based

Risk-based co-occurred with limited testing resources and higher flexibility requirements

Design-based co-occurred with more sufficient resources and plan-driven processes

Awareness of this distinction between the approaches helps software organizations to understand and enhance their testing practices

What was the research approach?



Thank you!

Questions? Comments?