Scientific Research

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NYT C02

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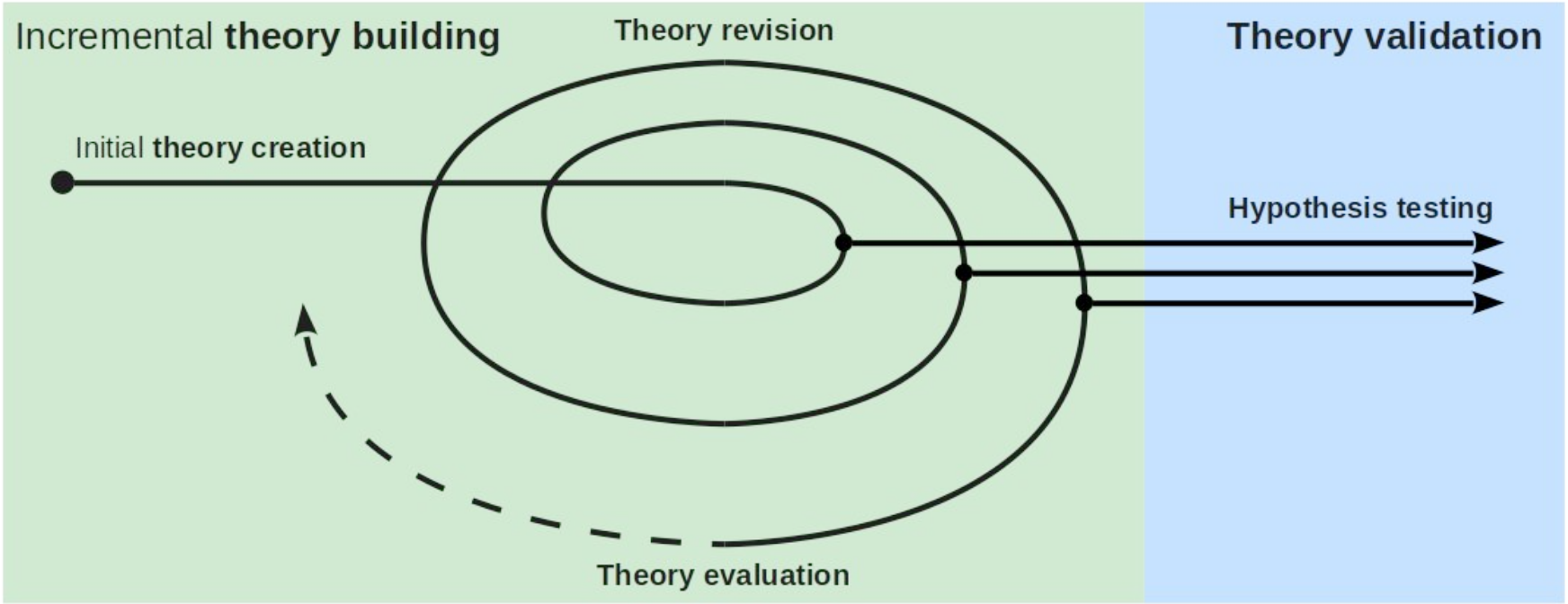
Agenda

1. Research questions
2. The research process
3. Research methodologies
4. Research methods and practices
5. Research quality criteria

Theory Building and Validation (Recap)



1. Research Questions

Research Question and Hypothesis

A **research question** is

- The question of interest to be answered by research

A **research hypothesis** is

- A research question that can only be answered with yes or no, true or false

Research questions should answerable and non-trivial

The can be big (a whole theory) or small (does this fit)

Example Research Questions

	People	Practices	Artifacts
Method of Analysis	How to measure communication effectiveness?	How to track bug fixes in software development?	How to measure effort spent on a piece code?
Method of Development	How to distribute roles in an agile development team?	How to perform code reviews?	How does agile development ensure high quality?
Evaluation of Instance	What skills of Linus Torvalds are key for the Linux kernel?	What are some new types of code refactorings?	How patchy is the Apache web server?
Generalization or Characterization	What does it take to be a good programmer?	What's common to all open source processes?	How does the the open source commit distribution look like?
Feasibility or Exploration	Do energy drinks help programmer productivity?	Is “Test First” a viable principle?	What could a power plant security hole do to safety?

Hilbert's 23 Problems [1]

Problem	Brief explanation	Status	Year Solved
1st	The continuum hypothesis (that is, there is no set whose cardinality is strictly between that of the integers and that of the real numbers)	Proven to be impossible to prove or disprove within the Zermelo–Fraenkel set theory with or without the Axiom of Choice (provided the Zermelo–Fraenkel set theory with or without the Axiom of Choice is consistent, i.e., contains no two theorems such that one is a negation of the other). There is no consensus on whether this is a solution to the problem.	1963
2nd	Prove that the axioms of arithmetic are consistent.	There is no consensus on whether results of Gödel and Gentzen give a solution to the problem as stated by Hilbert. Gödel's second incompleteness theorem, proved in 1931, shows that no proof of its consistency can be carried out within arithmetic itself. Gentzen proved in 1936 that the consistency of arithmetic follows from the well-foundedness of the ordinal ε_0.	1936?
3rd	Given any two polyhedra of equal volume, is it always possible to cut the first into finitely many polyhedral pieces which can be reassembled to yield the second?	Resolved. Result: no, proved using Dehn invariants.	1900
4th	Construct all metrics where lines are geodesics.	Too vague to be stated resolved or not.[n 1]	–
5th	Are continuous groups automatically differential groups?	Resolved by Andrew Gleason, depending on how the original statement is interpreted. If, however, it is understood as an equivalent of the Hilbert–Smith conjecture, it is still unsolved.	1953?

[1] See https://en.wikipedia.org/wiki/Hilbert%27s_problems

Related Work

Related work is

- All existing scientific work related to your research question

Related means

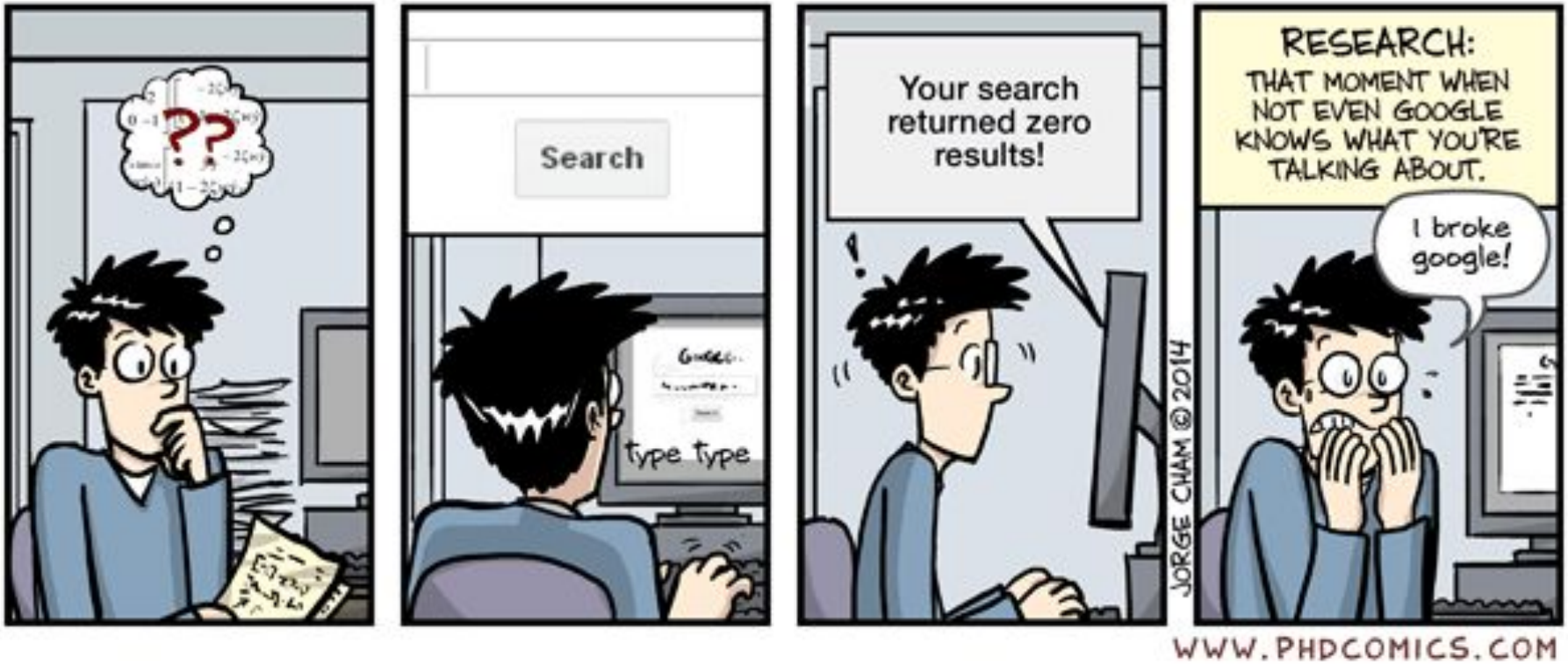
- Someone else worked on the same or similar research question
- The work takes an alternative or contradicting starting point
- Your proposed work requires and builds on this (related) work

Searching for and identifying

- **Related work is likely to change your research question**

A literature review is a common form of searching for related work

One Stopping Criterion [1]



[1] See https://phdcomics.com

Research Result

A **scientific research result** is

- Any piece of information resulting from scientific research
- Where scientific research is work following proper methods

The **answer** to a research question is

- A scientific result that answers a corresponding research question

A scientific result should be

- verifiable,
- reproducible, and
- independent of the researcher

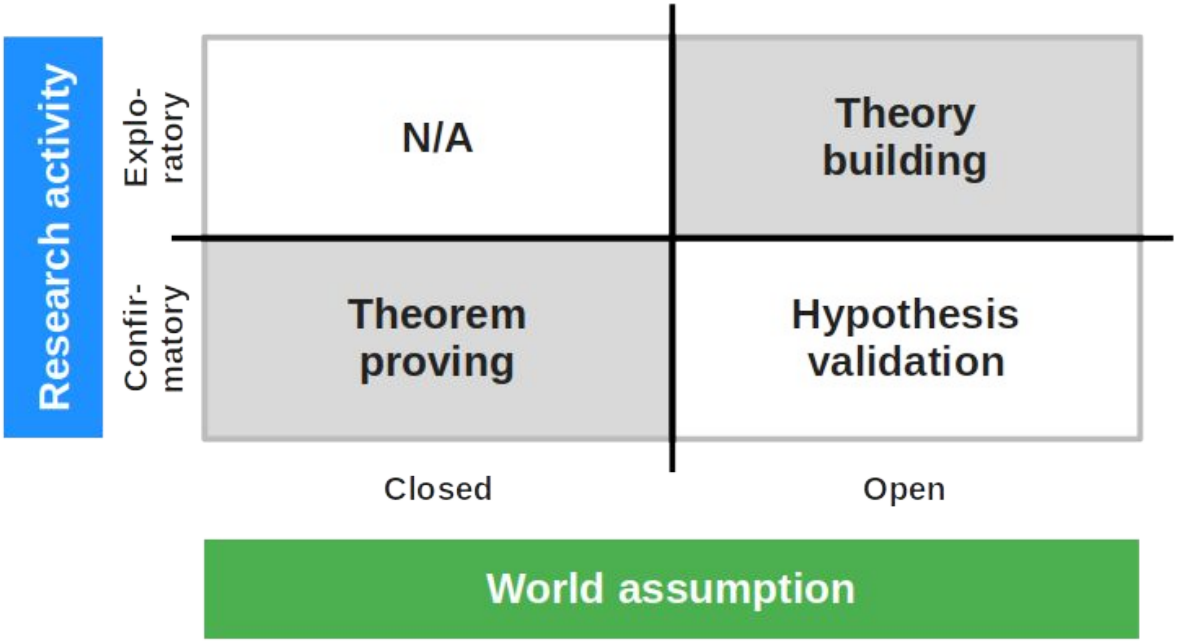
Contribution

A **contribution** is

- Scientific term for a publishable / published research result

To be found in the contributions section of a research paper

Open vs. Closed World Assumption



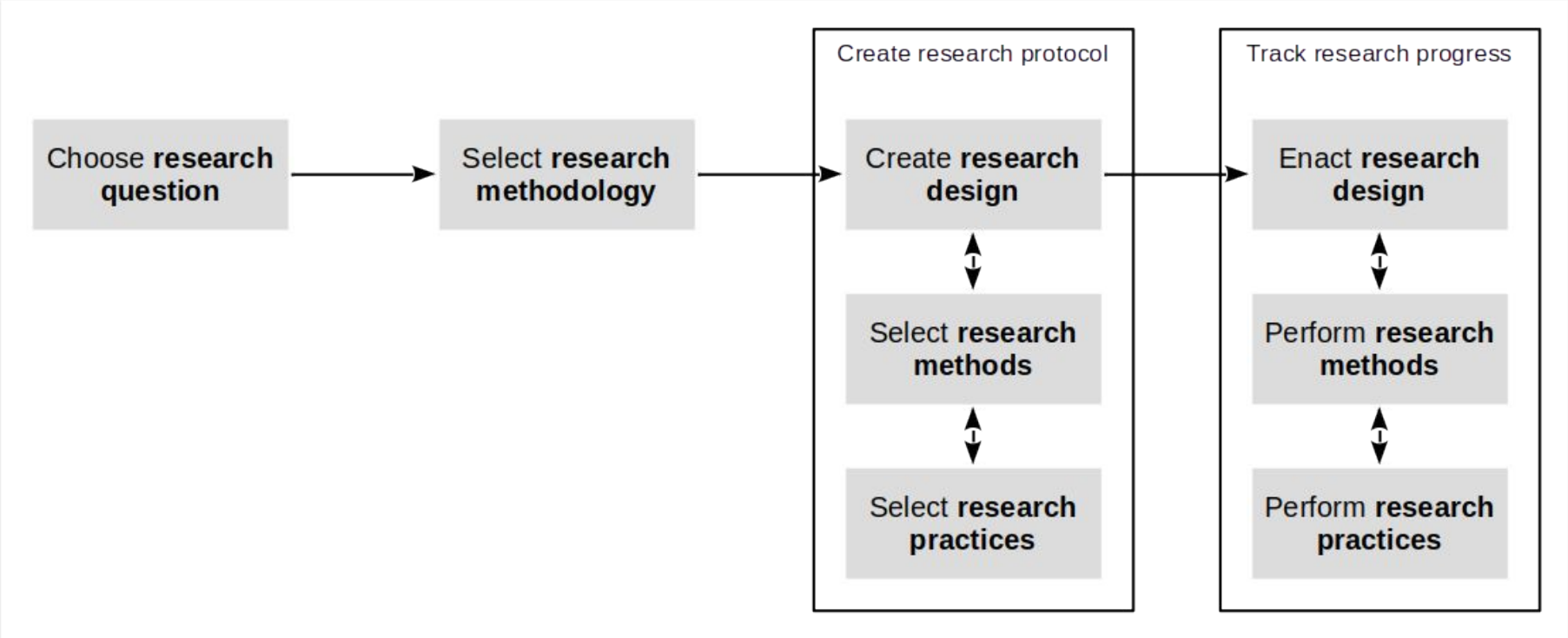
Is This So? Why / Why Not?

“In theory, practice and theory are the same. In practice, they are not.” [1]

[1] Attributed to Albert Einstein

2. The Research Process

How to Perform Research (Simplified / Idealized)



Research Methodology vs. Design vs. Method vs. Practice

A **research methodology** is

- A start-to-finish framework for how to perform theory building

A **research design** is

- A process description of how to answer a research question

A **research method** is

- A method of how to answer a type of research question

A **research practice** is

- A way of doing something with a defined outcome

Research Projects

A **research project**

- Is a project that contributes to scientific progress
- Typically answers a (large or small) question
- As a project has a start and an end date

Research projects can be built from parts

- A principal investigator may define a whole project
- Graduate researchers may work on subprojects
- Thesis students may work on one question

(Almost) All Research is Iterative

The scientific process is

- Iterative and incremental in how it builds out theory

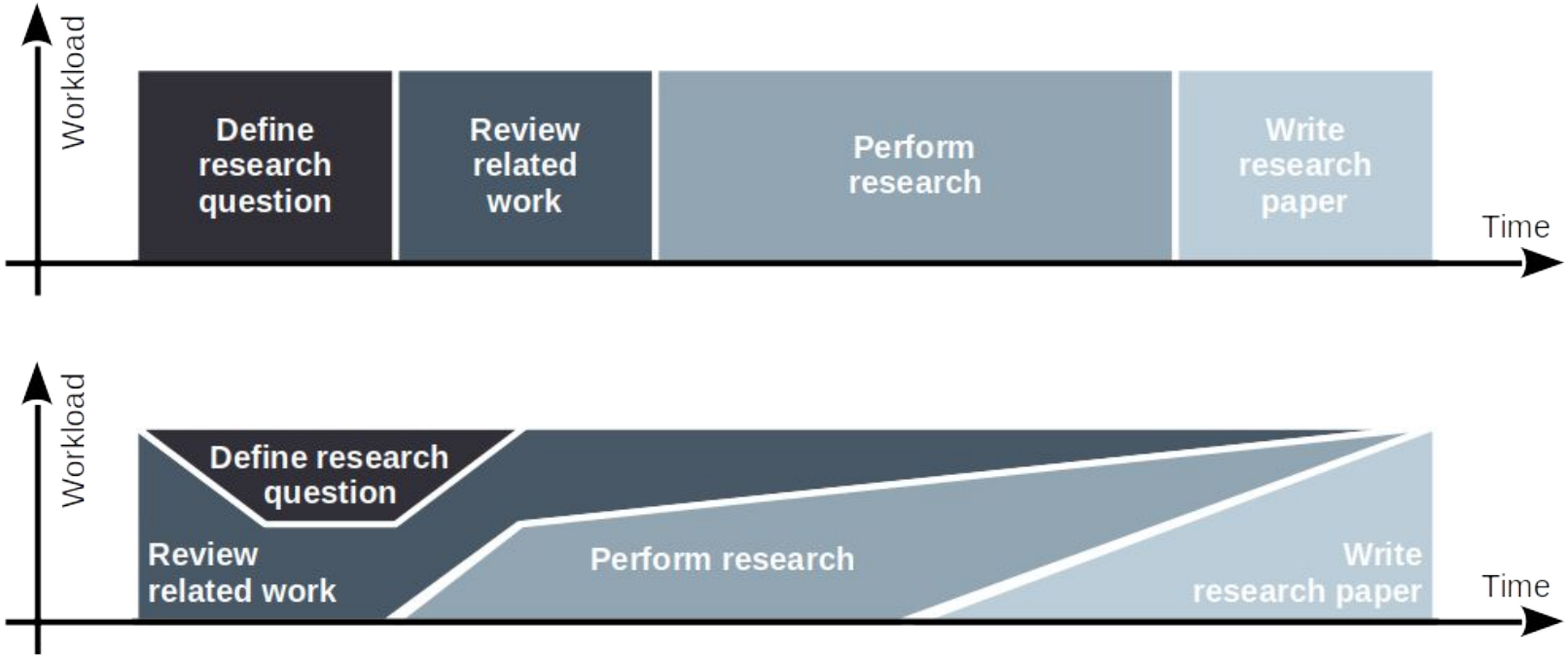
Its results presentation should

- Follow a linear logical structure usually corresponding to the research design

Beginners mistake: Presenting your process steps

- But: You should be discussing the process separately

How Time is Spent in Research



Research Protocol and Process Tracking

Document your research design and proposed process before you start

- Register this so-called research protocol with independent resource

Track data, process, and progress of actual work in lab book

- Discuss plan vs. execution in discussion and limitations section

3. Research Methodologies

Research Methodology

A **research methodology** is a

- Start-to-finish framework for theory building
- Constraint system for research designs
- Pattern for research designs

Example Research Methodology

The **qualitative survey** [1] according to Jansen (2010)

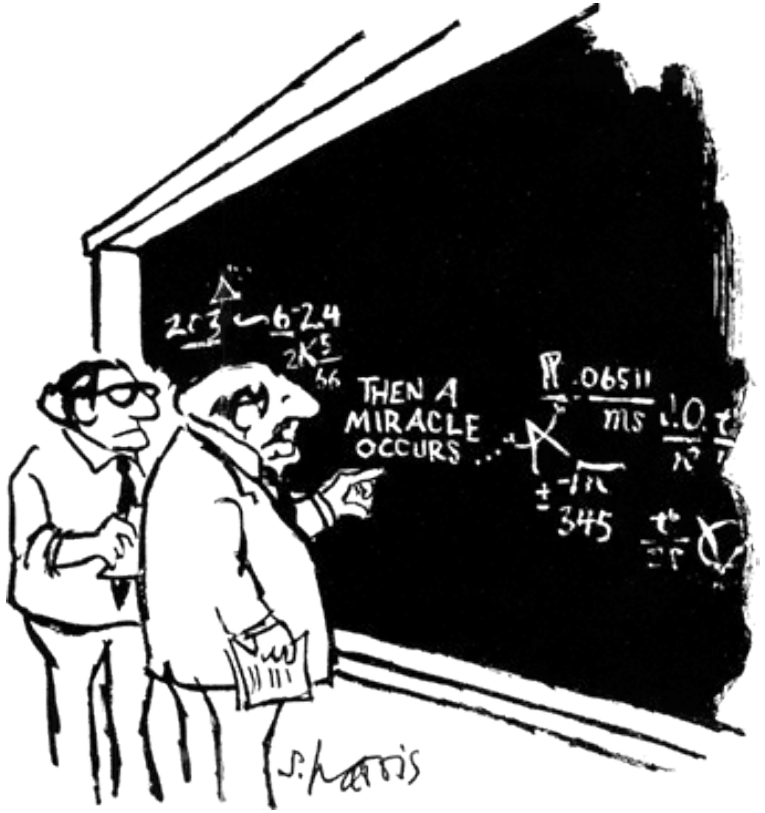
1. Write research protocol [3]
2. Build sampling model [2]
3. Sample for theory building [2]
4. Perform interviews [2]
5. Analyze transcriptions [2]
6. Determine saturation [3]
7. Iterate or conclude

[1] A.k.a. interview study (when restricted to interviews)
[2] A research method
[3] A research practice

(Main Categories of) Research Methodologies

- Literature survey
- Qualitative survey
- Action research
- Case study research
- Design science research
- Grounded theory
- Ethnographies

“I think you should be more explicit in step 2” [1]



[1] See http://www.sciencecartoonsplus.com/

Research Design

A **research design** is

- A structured plan to answer a research question
- Created by applying a research methodology

Example Research Design Inner Source Challenges

Research question

- What are challenges of intra-company collaboration in software development?

Possible research design

1. Refine research question through literature survey [K04]
2. Perform qualitative survey (research methodology)
    a. Model units of analysis (companies, employees) of interest
    b. Identify units of analysis using sampling model
    c. Contact and interview experts
    d. Analyze interviews using thematic analysis [BC12]
    e. Determine saturation and iterate if not satisfied

The Marshmallow Experiment [1]

[1] See https://www.youtube.com/watch?v=Yo4WF3cSd9Q

4. Research Methods and Practices

Research Method

A **research method** is

- A prescriptive procedure to answer a research question
- Which collects and analyses one set of data

Research method **vs. research methodology**

- A methodology provides a framework while a method provides a prescription
- It ain’t a methodology if it ain’t theory building

Example Research Methods

- Thematic analysis according to Braun & Clarke (2010)
- Controlled experiments according to Wohlin et al. (2012)
- Biometric measurements according to Fagerholm & Fritz (2020)

Research Practice

A **research practice** is a

- An established procedure that when employed provides a defined result

Research practice vs. **research method**

- A research practice may not have a name or formal definition
- A research practice may be a prototype of a method

Example Research Practices

Example practices **with a name**

- Forward snowballing (an article search strategy)
- Polar sampling (a purposive sampling strategy)
- Peer debriefing (a quality assurance practice)

Example practices **without a name**

- How to write a research protocol
- How to report on a Student’s t-test results
- How to codify a theory using best practices handbooks

Research Methods (Expanded)

A **research method** is

- A prescriptive procedure
  - For collecting and analyzing one type of data
  - To answer a research question

An **established** research method has been validated, i.e.

- It has been shown to deliver what it promises
- Methods should have their own quality assurance criteria

Two Categories of Research Methods

A **qualitative research method** is a

- Research method that
  - Collects and analyses qualitative data
  - Creates theoretical insights

A **quantitative research method** is a

- Research method that
  - Collects and analyses quantitative data
  - Lets researchers draw descriptive or statistical conclusions

Qualitative vs. Quantitative Data (Expanded)

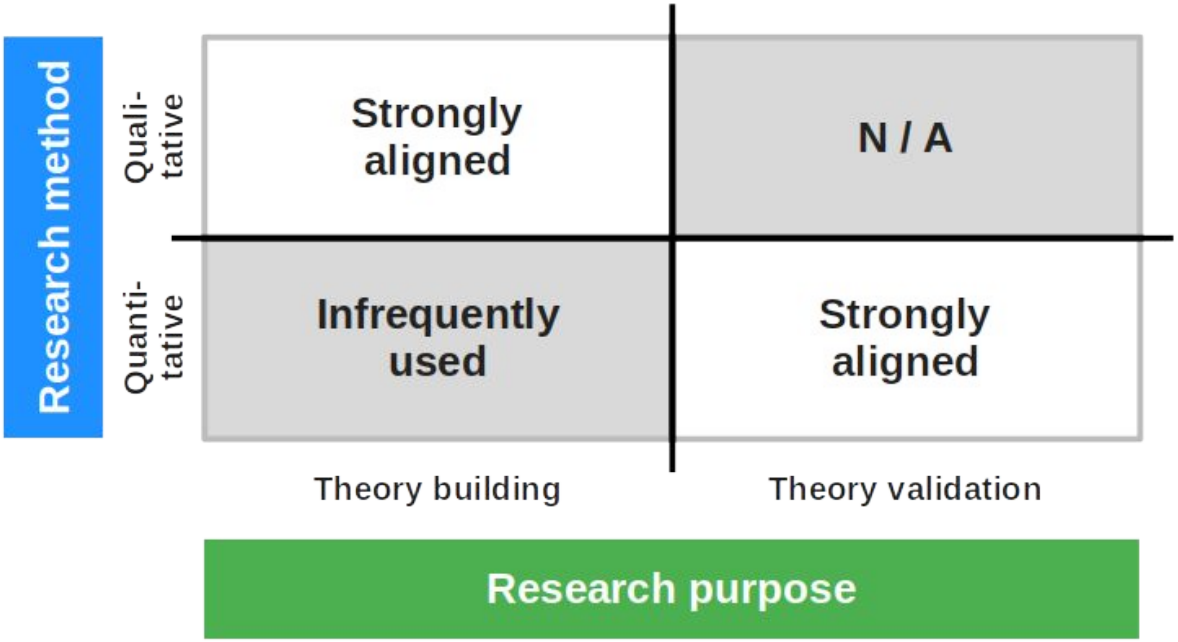
Qualitative data is data that

- Usually is not numeric
- Requires interpretation
- Is used in theory building
- Denies statistical generalizations

Quantitative data is data that

- Usually is numeric (various scales)
- Has objective (formal) definition
- Is used for theory validation
- Serves statistical generalization

Qualitative / Quantitative vs. Theory Building / Validation



“Soft” vs. “Hard”

Qualitative research

- Deals with qualitative data
- Feedback takes time
- Feedback is not binary

Quantitative research

- Deals with quantitative data
- Feedback is fast
- Feedback is precise / binary

Should You Invent Your Own Methods?

Never invent your own methods

- Rather use established research methods

There will always be exceptions, but think hard if your situation is one

5. Research Quality Criteria

Quality Criteria for Research Methods [GL82]

Intuition	Qualitative research	Quantitative research
Truth value	Credibility	Internal validity
Applicability	Transferability	External validity
Consistency	Dependability	Reliability
Neutrality	Confirmability	Objectivity

Truth Value

Truth value (intuition)

Credibility (naturalism)

- The degree of confidence in the truth of the research findings

Internal validity (rationalism)

- The degree of confidence in a cause and effect relationship

Applicability

Applicability (intuition)

Transferability (naturalism)

- The degree to which results can be transferred to another context

External validity (rationalism)

- The degree to which results can be generalized beyond the study

Consistency

Consistency (intuition)

Dependability (naturalism)

- The degree to which research results are stable over time

Reliability (rationalism)

- The degree to which results can be recreated under the same conditions

Neutrality

Neutrality (intuition)

Confirmability (naturalism)

- The degree to which the research results can be confirmed by other researchers

Objectivity (rationalism)

- The degree to which the research results can be repeated by other researchers

Summary

1. Research questions
2. The research process
3. Research methodologies
4. Research methods and practices
5. Research quality criteria

Thank you! Any questions?

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