

Scientific (and engineering) method - a mini-primer

KIV/OSN-E 2022+

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The Core

1. Idea / Hypothesis

→ **method** →

2. Proof

=>

either: wow, new product / knowledge (“confirmation”)

or: hmm, did not work (“falsification”)

or: meh, been there before (“prior art”)

Why “method”

- Avoid re-inventing the wheel
 - Enable reproducibility (of results)
 - Allow creativity and diligence to cooperate
 - Give no place to belief, but a lot of space for doubt
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- Common to both Engineering and Science

Engineering

- construction of new “things” (designs)
- problem not clear / fully defined, no one correct solution, contradicting requirements/constraints, incomplete information, time to market
- good enough
- knowledge & craft, creativity, robust analysis, timing and management

General **method**

- concept > plan > design > development > launch
- sold and accepted | forgotten

Result = working product

Science

- creating new knowledge (explaining “how the world works”)
- defining the problem is part of the work, no known “solution”, potentially unknown assumptions/constraints, information incomplete by definition
- provably correct
- thinking outside the box, deep knowledge, rigorous eval., doubt and humility

General **method**

- observation > hypothesis > experiment > analysis > conclusion
- supported | refuted

Result = published knowledge

“Hypothesis” phase details

Science

- Hypothesis => Research question
- Observation
- Review of Related Work (“State of the Art”)
- Formulation
 - research questions
 - hypotheses
 - assumptions
- Prediction

Engineering

- Idea => Specification
- Knowledge of the State of Practice
- Market research / insight
- Requirements
 - specification
 - risk analysis
 - assumptions
- Prototype, model

“Proof” phase details

Science

- Experiment / Formal proof
- Analysis, evaluation and interpretation
- Publication (incl. peer review)
- Independent verification

Engineering

- PoC / construction
- Testing (verification and validation)
- Putting into operation
- Evaluation

https://en.wikipedia.org/wiki/Scientific_method

Klaas-Jan Stol and Brian Fitzgerald. 2018. The ABC of Software Engineering Research. ACM Transactions on Software Engineering Methodology, 27, 3, Article 11 (September 2018). <https://doi.org/10.1145/3241743>

Specialized Methods in Science

- **Qualitative vs Quantitative Research**
 - words – questionnaires, coding
 - numbers – measurements and surveys, statistics
- **Primary vs Secondary**
 - experiments, measurements, surveys, prototype implementations, models
 - literature reviews, meta analyses

Analyzing Related Work / State of the Art

Due diligence before design, experiments or formal proofs

- Sometimes called “prior art” (patents)
- Helps get well versed in the domain
- Prevents blind alleys
- Provides inspiration, shows open issues, unexplored topics

(Separate topic with more details.)

Role of Publishing

Science

- Way to disseminate knowledge (to researchers, practitioners, public)
- Way to perform independent verification (dispute, maybe disprove)

=>

Conferences, journals, artefact repositories – peer reviewed

Engineering

- Way to make the product known, get customer feedback
- Way to help build company ecosystem

=>

Sales and marketing materials, press releases, white papers, industrial conferences

Both

- Protect IPR, show you are on the cutting edge

=> Registered designs and utility models, Patents, technical research papers

Summary: Same - Different

- creativity, innovative thinking
 - open ended
 - rigor, process and team
 - do your research
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- “product” is a means x the goal
 - “write-up” is the goal x a means
 - “the best” solution x “good enough”

“What is your contribution?”

“Don’t re-invent the wheel.”

“When you work on a hard engineering problem, you are bound to find an interesting research topic.”

Engineering Method

Phase 1 Idea



- Identify problem

Step 1 Ask A Question

Phase 2 Concept



- Existing solutions
- Requirements
- Constraints

Step 2 Do Background Research

Phase 3 Planning



- Define objectives
- Plan program and schedule

Step 3 Construct A Hypothesis

Phase 4 Design



- Drawings
- Schematics
- Models
- Algorithms
- Proof of concept

Step 4 Test Hypothesis

Phase 5 Development



- Prototypes
- Experiments
- Validation and verification

Step 5 Analyze Data & Draw Conclusion

Phase 6 Launch



- Results

Step 6 Communicate

Scientific Method