

# Empirical Studies of Software Engineering: A Roadmap

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June 8, 2000

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## Roadmap

- Where we are
- Where we should be
- Some suggestions to get there

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## Current State

- Implementation Oriented
  - Fenton: poor statistical designs, don't scale
  - Basili: differences in projects make comparisons difficult
  - Johnson: practitioners resist measurement
- Need to be requirements oriented
  - Think hard about what experiments really are
  - How they can be most effectively used
- Core problem: conceptualizing and organizing a body of work as scientific basis

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## Software Development

- Little hard evidence to inform decisions
  - correlations suggestive but not sufficient in all cases
  - many times don't know exception cases
- Do not know fundamental mechanisms
  - software tools
  - methods and techniques
- Empirical studies are the key
  - show mechanism
  - eliminate alternative explanations

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## Strengths

- Empirical validation is standard in some fields
- Quality of empirical studies (ES) rising
- Funding agencies recognizing value of ES
- Many currently interested
- ES tutorials, panels, SOTAs, papers, etc.
- Key consciousness raising papers (Tichy et al., Zelkowitz)
- Several key organizations: SEL, ISERN

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## Systemic Problems

- Research ideas often not empirically validated
  - should retroactively validate, proactively direct
- Search for perfect study - focus on credibility
- Study the obvious
  - OK, but need deeper insight
- Lots of data
  - not enough - should answer important questions
- Lack hypotheses
- Lack conclusions from data

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## Challenges

- Improve state of research and practice
- Create better studies
- Draw more credible conclusions

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## Create Better Empirical Studies

- Establish principles that are
  - causal: correlated, temporally ordered, testable theory
  - actionable: causal agent effectively controllable
  - general: widely applicable
- Answer important questions
- Family of focused studies - illuminate related aspects
- Cost effective
- Reproduced and extended by others

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## Credible Interpretations

- Degree of confidence we have in conclusions
  - eliminate alternative explanations
  - need a compelling logic in the discussion
- Validity is critical: construct, internal, external
- Hypothesis is critical - ask important questions
- Resolution appropriate to the intent of the study
- Make data public

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## The Way Forward

- In empirical study design, maximize
  - accuracy of interpretation
  - relevance
  - impact
- Subject to
  - resource constraints
  - risk

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## Structure of an Empirical Study

- Research context
  - problem definition
  - research review
- Hypothesis
  - abstract - about the world
  - concrete - about the design
- Experimental design
  - variables: independent and dependent
  - plan to systematically manipulate variables
  - control operational context

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## Structure of an Empirical Study

- Threats to validity: construct, internal, external
- Data analysis and presentation
  - quantitative: hypothesis testing, power analysis
  - qualitative
- Results and conclusions
  - limits, influences
  - explain how answered question
  - practical significance
  - sufficient information for repairability

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## Concrete Steps

- Designing Studies
  - ask significant questions
    - Knight-Leveson, N-version programming
  - family of studies
    - Schneideman et al, on value of flow charts
  - build partnerships
    - takes time; multi-person effort; interdisciplinary; industry
  - long running in vivo/situ experiments
    - subparts; subject rights; know when to stop

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## Concrete Steps

- Collecting the data
  - retrospective artifact analysis
    - eg, version management systems
  - simulation and modeling
    - eg, integration studies of Solheim and Rowland
- Involving others
  - meta-analysis
    - Porter/Johnson
  - educational laboratories
    - teach empirical studies basics (a la physics)
    - populate lab with appropriate data/designs/equipment

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## Conclusions

- Good empirical studies enable us to
  - encode knowledge more rapidly
  - prune low payoff ideas rapidly
  - recognize and value high payoff ideas
  - exploit important practical ideas

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