Design Science, Engineering Science and Requirements Engineering

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1. The design science debate in the computing sciences

Software engineering (Department of computer science)

- 1980s
  - "Empirical software engineering; separate from design" community
- 1990s
  - Complaints about lack of validation
  - Papers about how to do experimental and case study research
- 2000s
  - Increasing number of papers validate their solution
  - Complaints about transfer of solutions to practice

ICSE 2003:

Improving web application testing with user session data

Constructing test suites for interaction testing

Improving test suites via operational abstraction

Recovering documentation-to-source-code traceability links using latent semantic indexing

Computer-assisted assume/guarantee reasoning with VeriSoft

``How to do X, or how to do X better''

Information systems (Department of management science)

- 1980s
  - Complaints about lack of empirical rigour
  - Papers about empirical methods for IS research
- 1990s
  - Empirical papers
- 2000s
  - Complaint about lack of relevance
  - Attempt to include design in IS research

ICIS 1997:

Successful IS innovation: the contingent contributions of innovation characteristics and implementation process

The effects of task interruption and information presentation on individual decision making

The impact of CASE on IS professionals' work and motivation to use CASE

The impact of information technology on coordination costs: implications for firm productivity

....

Other responses in IS to increase relevance

- Context-rich research methods
  - Case study research, pilot projects
  - Action research

Design & Research

- SE:
  - Lack of relevance (transfer) of design results
  - Let's do more empirical research to validate our results!
- IS:
  - Lack of relevance (use) of empirical research results.
  - Let's include more design!
- So let's do both research and design
  - How to combine?

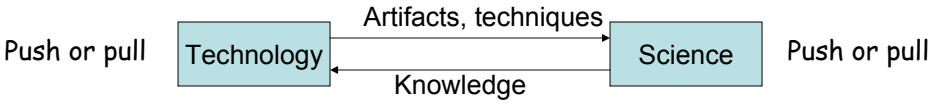
2. Lessons from the history of technology & science

Linear model of tech transfer

Science Design

- Basic science → Applied science → Engineering → Production
  - Vanevar Bush 1946
  - Engineering schools late 19th century
  - Francis Bacon early 17th century
- If true then funding of basic science would be the best way to stimulate economy,
- and general theory would be more useful than special theory
- Supporting evidence has been extremely difficult to find
  - where found, it is controversial
- Falsifying evidence is amply available
- However:
  - Encoded in OECD statistics
  - And in policy thinking

Concurrent model



- Instruments transferred/developed for to science
  - Telescopes, barometers
- Theory applied to develop artifacts
  - Ultrasound theory and artifacts (echo)
  - E.g. Telephone, Radio
  - But needed entrepeneurs (Bell, Marconi) to do that
- Theory developed by investigating artifacts
  - Steam machines & thermodynamics

3. Rigor “versus” relevance

Relevance of artifacts

- Engineers may develop artifacts & techniques to
  - solve some actual or expected problem
  - or to achieve actual or expected stakeholder goals
- Relevance of artifacts & techniques may come and go
  - E.g. crystal detectors
- Relevance is the result of problem choice, not of validation
  - Validation reduces risk of promising what you cannot deliver

Curiosity & utility

- Researchers may investigate phenomena for various reasons
  - Curiosity (Max Born)
  - Curiosity and utility (Pasteur)
- Engineers may develop artifacts for various reasons
  - Utility (Edison)
  - Utility and curiosity (Myth Busters)
- Motives versus effects

- For relevant and irrelevant knowledge, the evaluation criterion is:
  - Is the truth claim justified?
  - Researchers should never claim more than they can justify

Rigor

of knowledge production and of artifact development

- In research:
  - Not claiming more than you can justify
  - “In which way can I be wrong?”
  - “In which way find a better approximation of the truth?”
- In engineering:
  - Not specifying more than you can achieve
  - “In which way could this artifact fail?”
  - “In which way can this artifact be improved?”
- Same kind of critical attitude

Rigor “versus” relevance

- Dilemma introduced by Donald Schön in 1983
  - He believed that physical science and engineering follow the linear model
  - Lamented that following this model in social science has not produced useful results.
  - Did not realize that this model does not generally produce useful results in physical and technical science either
    - Even though the results satisfy our curiosity
  - He proposed reflective practice as relevance-enhancing alternative
    - But this is exactly as it works in technical sciences!
    - Using rigorous scientific methods

4. Conditions of practice

Investigating artifacts

- Conditions of practice
  - Context of use contains many variables
  - Standards, norms, legal criteria
  - E.g. thermodynamics & combustion technology
  - Bridge (Polya)
- Non-analytical solutions
  - Approximate computations
  - Modeling and simulation
- Context-rich research methods
  - Pilot projects
  - Test flights
- No difference in research methods

5. Conclusions

1. Not a linear but a concurrent model of science-technology interaction
2. Knowledge claims should be valid (rigorous methods), regardless of their relevance
3. Conditions of practice call for context-rich methods
4. “Design science” proposals ignore problem choice, are complicated and simplistic
5. RE is the attainment of relevance of artifacts
   - Mutually aligning artifacts and stakeholder goals

Theses

1. Design and research are separate activities

- May be interleaved, but still separate
  - Production of artifacts or knowledge
  - Need to do different things to solve design or research problems
- Solving a technical problem
  - Solution evaluation by utility
  - Stakeholder goals to be analyzed
- Answering a research question
  - Answer evaluation by truth
  - Phenomena to be investigated

2. “Design science ” is an ill-defined concept

- Scientific study of the design process?
- Using scientific knowledge in the design process where needed?
- Research within a design process?
  - e.g. diagnosis of problematic phenomena,
  - investigation of solution prototypes
  - evaluation of implementations

3. Engineering is not the application of basic science

- It is the application of “the” scientific method in the development of artifacts
  - only promise what you can deliver
  - validation before implementation
  - use available validated knowledge

4. Research should be avoided by engineers when possible

- Balance the risk of wasting money on research against the risk of delivering a faulty product
  - Use available knowledge
  - Make educated assumptions

4. Statistical validity is not relevant when validating a design

- We need to understand the **mechanisms** by which the design in its intended environment will achieve its goals
- "A sample of 56 propeller had property P in wind tunnel, so all propellers on planes have property P (95% confidence interval)"
  - Not convincing.
  - Need to understand turbulence phenomena in wind tunnel, in the air, and their relation
  - Law of similitude
  - Analytical generalization (Yin)

5. There is little reward in validating designs

- Harley Davidson Effect:
  - Designers are interested in presenting their new design
  - Readers are interested in reading about new designs
  - Industry is interested in unconstrained designs
- Irrelevant designs are fine as long as someone wants to pay the bill
  - They may become relevant at any later time
  - And vice versa

6. The dilemma of rigor versus relevance is neither rigorous nor relevant

- Relevance is the match between a solution and stakeholder goals
- Rigor is the use of sound methods to produce results (knowledge or artifacts)
- There is no dilemma
- There are nor general norms for relevance
- And not for rigor either

7. There no scientific method

- There not one single scientific method, not even per discipline
- Research method should be driven by research problem
  - Number of variables
  - Available resources for research
  - Intended use of knowledge
- Any method could be used, but do not claim more than you can justify
  - Away with “nothing but” ideologies
    - Positivism
    - Interpretativism

8. Relevance of designs is not increased by validation

- Relevance is the result of problem choice, not of validation
- Tech transfer is caused by *perceived relevance*
  - hype
  - groupthink
  - crowd behavior
  - or entrepeneurial risk taking
  - rational decision