

The Scientific Process in Software Engineering

Tips for PhD Students

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Measuring and Science

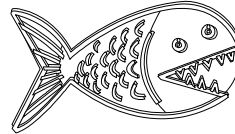
When you can measure what you are speaking about, and express it in numbers, you know something about it.

– Lord Kelvin, 1889

<http://zapatopi.net/kelvin/quotes.html>

What is a Scientific Test

- The Budweiser Test
 - In a bar, people who liked another brand best were given a “live” challenge – which beer is better?
 - Results?
 - 50% chose Budweiser over their favorite beer!!!
 - Conclusion:
 - Budweiser is better !!!
- Hmmm ... something's fishy ...



Scientific Test

- Test: Live TV, lots of noise and confusion, subjects had already been drinking ...
- Subjects wouldn't be able to tell any difference, so we should expect each beer to be chosen ...
- Half the time!
- There are three kinds of lies ...



Lies, Damn Lies, and Statistics

Eating and Talking

- Japanese eat very little fat and suffer fewer heart attacks than British or Americans
- On the other hand, French eat a lot of fat and also suffer fewer heart attacks than British or Americans

Conclusion: Eat what you like. It's speaking English that kills you.

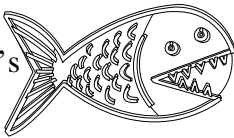
Women and Foreigners

- Analysis of results of a final exam

	Female	Male
Finished late	12	7
Finished early	6 (33%)	9 (55%)
	18	16

- Conclusion: Male students finish earlier than female

- But ... something's fishy ...



	Foreign	US
Finished late	11	8
Finished early	2 (11%)	13 (65%)
	13	21

- Conclusion: US born students finish earlier ...

	Foreign	US
F	8 (45%)	10
M	5 (33%)	11

A higher percentage of women are foreign ... in that class

Be Careful Who You Fool

The first principle is that you must not fool yourself – and you are the easiest person to fool.

– Richard Feynman (*Nobel Physics, 1965*)

Noone in this world is easier to deceive and mislead than someone who thinks that he is smarter than you are.

– David Eddings (*Author*)

We all think we're smarter than we are.

– Jeff Offutt (*Dad*)



Six Ways to Acquire Knowledge

- 1) Tenacity
- 2) Intuition
- 3) Authority
- 4) Rationalism
- 5) Empiricism
- 6) Science



1. Tenacity

Knowledge based on superstition or habit

- Examples:
 - “Good research can only be done when you’re younger than 30”
 - “Gay people are bad”
 - “Teenagers are all trouble makers”
 - “OO software is not efficient”
 - “Java does not have pointers”
- Exposure: The more we see something, the more we believe
- Tenacity has
 - No guarantee of accuracy
 - No mechanism for error correction
- Knowledge from tenacity is prejudism



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2. Intuition

Guessing: An approach that is not based on reasoning or inference

- Examples:
 - I think he is a nice person
 - It’s probably going to rain today
- We do not really understand why we believe
- No way to separate accurate from inaccurate knowledge
- Can be used to form hypotheses
- Can be very misleading



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3. Authority

Accepted because it comes from a person with authority

- Examples:
 - Rules our parents taught us
 - Religion
 - Totalitarian governments
- No evidence given
- No way to validate or question the knowledge
- Not the same as asking an expert – we can accept, reject, or challenge an expert
 - In grade school, teachers are treated as authorities
 - In college, teachers are experts



4. Rationalism (Reasoning)

Acquiring knowledge through reasoning

- Logical deduction
- Assume knowledge is correct if the correct reasoning process is used
- Middle ages relied almost exclusively on rationalism
- Important for theory and pure math
 - A mathematical proof is rationalism at its best
 - Theoretical physics ... experimental physics
- Easy to reach incorrect conclusions
 - False premises
 - Mistakes in the reasoning or steps skipped
- Use rationalism to arrive at a hypothesis, then test with the scientific method



5. Empiricism

Acquiring knowledge through experience

- “I have experienced it, therefore it is true”
- Experience is subjective and hard to control
- “I haven’t designed or tested my programs and got As, so those activities are not necessary”
 - Were you lucky ?
 - Are you extra smart?
 - How severe are the consequences of faults ?
- Much of computer “science” is just empiricism



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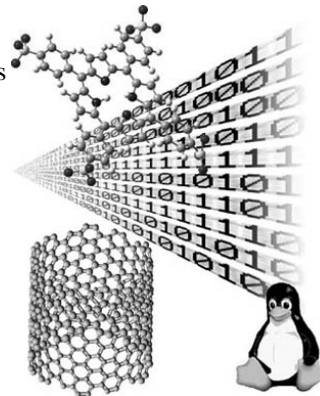
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6. Science

Testing ideas empirically according to a specific testing procedure that is open to public inspection

- Based on reality
 - Scientists have to look at the fire, not the shadows (Plato’s cave theory ...)
- Separate personal beliefs, perceptions, biases, attitudes, emotions
 - We all have biases; science helps us ignore them
- Based on objectively observed evidence

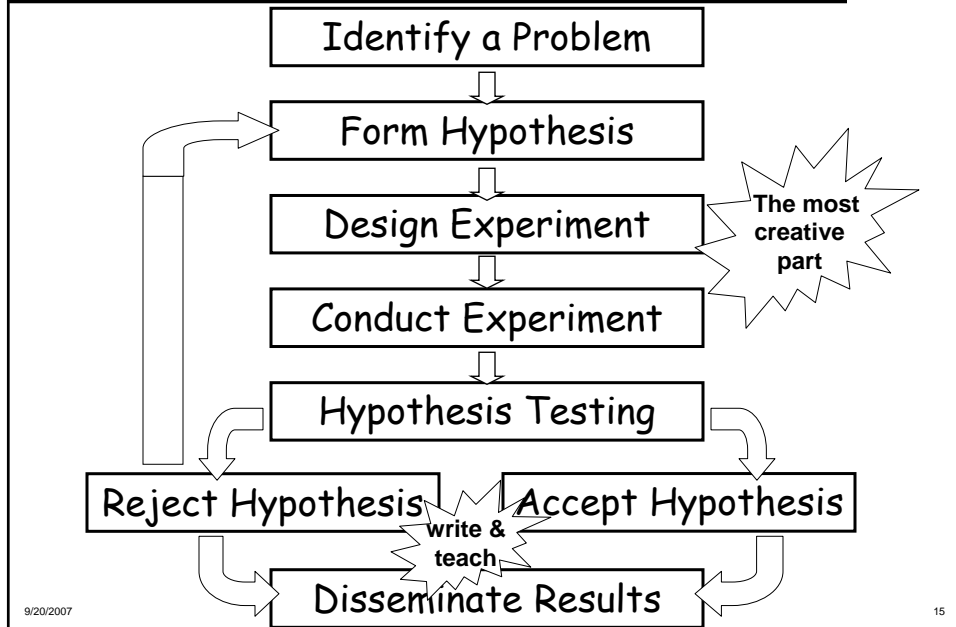


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Scientific Method



Excellent Scientists

- Lots of decent scientists who are excellent researchers and lousy writers
- Lots of decent scientists who are okay researchers and excellent writers

Excellent scientists do both well!

Science in Software

- 1) Invent a new solution
- 2) Validate the solution – usually experimentally
- 3) Publish the idea and results

Empirical Software Engineering

1. The biggest obstacle to software engineering experimentation is that our populations are unknown
 - What is a representative collection of programs?
 - What is a representative collection of bugs?
 - What is a representative collection of programmers?
2. Second : Industry won't cooperate
 - In other engineering fields, companies provide access to data, resources, processes, and people
3. Third : “Knowledge inversion”
 - young scientists know more about experimentation than senior scientists

Experimental Variables

- Independent variable : Changed by the researcher to determine if it causes a change in the dependent variable
- Dependent variable : Measured by the researcher to determine if it is affected by the IV

Does intelligence make people better drivers ?

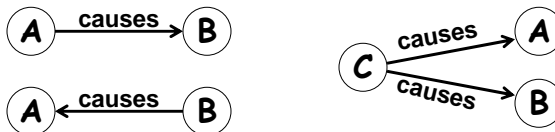
- Confounding variables : Other explanations for the results
 - Driving skills of parents, amount of time driving, emotional problems
- Measured variable : If the dependent variable cannot be directly measured, we measure a related variable to approximate
 - Accidents, tickets, attempts to pass the driving test, drivers Ed grade

How Valid are the Results ?

- External validity : Whether the results in the study will be the same in other situations
 - Were the subjects “representative” ?
 - I only looked at student programs from SWE 619
- Internal validity : Whether the change in the Dependent Variable was controlled by the Independent Variables
 - Did we miss a confounding variable ?

Correlation and Causality

- Correlated: Two things always happen at the same time
 - Brake lights and car slowing down
- Causality: Understanding what causes something to happen
 - Brake light causes the car to slow down ?
- If **A** and **B** are correlated:

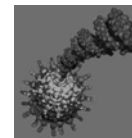
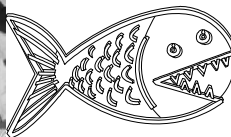


Pressing brake activates brake light AND slows car down ...



Confusing Correlation and Causality

- In “*the old days*”, we believed that being cold caused us to get colds



- Colds are caused by viruses, not temperature
- Viruses breed in warm, damp, low-oxygen, carbon-dioxide rich environments
- In cold weather, we close our windows and turn up the heat ... creating ...
- Virginia gets a secondary cold season in July-August
... when the weather turns hot and humid ...

Principles to Follow

- 1) We make progress through continuous, sustained, small, steps – not technological breakthrough
 - Scientists take baby steps
 - The “big step” is the last of many
 - The Web was the last of thousands of baby steps

- 2) Collect your data very carefully
 - Identify and control variables
 - Document all decisions
 - Save all data – you may have to repeat the experiment years later

Principles to Follow (2)

- 3) Collecting is not the goal, analysis and conclusions are the goals
 - Don't lose the forest in the trees
 - Conclusions matter more than measurement

- 4) Data are uncertain and fallible – design experiments to allow for problems
 - In real science, we always have too many variables
 - In real experiments, we always lose some data

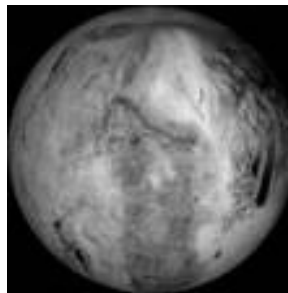
- 5) Non-inventors need to carry out experiments
 - If I validate my invention, I'm hopelessly biased

Principles to Follow (3)

- 6) The goal of an experiment in software is to help companies develop better software, cheaper
 - The goal should NOT be to publish another paper

Cognitive Dissonance

- We feel uncomfortable when new data contradicts our beliefs
- Revising our mental model to accommodate new data is hard
 - We resist new ideas
 - I miss Pluto !!!



Scientists must be open-minded

**Allow facts to replace knowledge gained by
tenacity, intuition and authority**

Be Problem Solvers

- As PhD students, you have learned to be good at solving problems
 - I cringe when I hear PhD students make unscientific claims
- Much of life is about solving problems
 - Apply the lessons in your education to your life
- Education is not about skills, it is about knowledge
- Utilize your education knowledge to help you:
 - Think rationally
 - Question authority
 - Solve all of life's problems

