Spring 2025

ME 794 Statistical Design of Experiments

Chapter 0

Introduction

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Indian Institute of Technology Bombay

ME 794 Schedule

Spring 2025, IIT Bombay

Time: Tuesdays and Fridays, 5.30 pm – 6.55 pm

F24, ME

Instructor:

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S23, Mechanical Engineering,
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Office hours: By appointment

Grading Policy

Lecture Notes:

- Take your own notes
- Lecture notes/slides and reference material will be provided as and when required via MS Teams
- **Join MS TEAMS using this code: 4jystcd**

Grading:

Quiz	50%	(Best 4/5, **preannounced**, after every 4 lectures, **NO MAKE-UP**)
Assignments --	(For your own practice, no grading)	
Project	20%	(Team project, actual physical experiments are expected)
Final Exam	30%	(Comprehensive)

- **Quiz Dates: 21 Jan, 7 Feb, MidSem, 21 Mar, 8 Apr**
- **Projects: No simulations, data collected from internet/literature is acceptable. You need to design and conduct physical experiments on your own**
- **Any student/group found to have committed or aided and abetted the offence of plagiarism will receive ZERO marks for the relevant assignment/quiz without any exceptions**

What is the NEED for experiments?

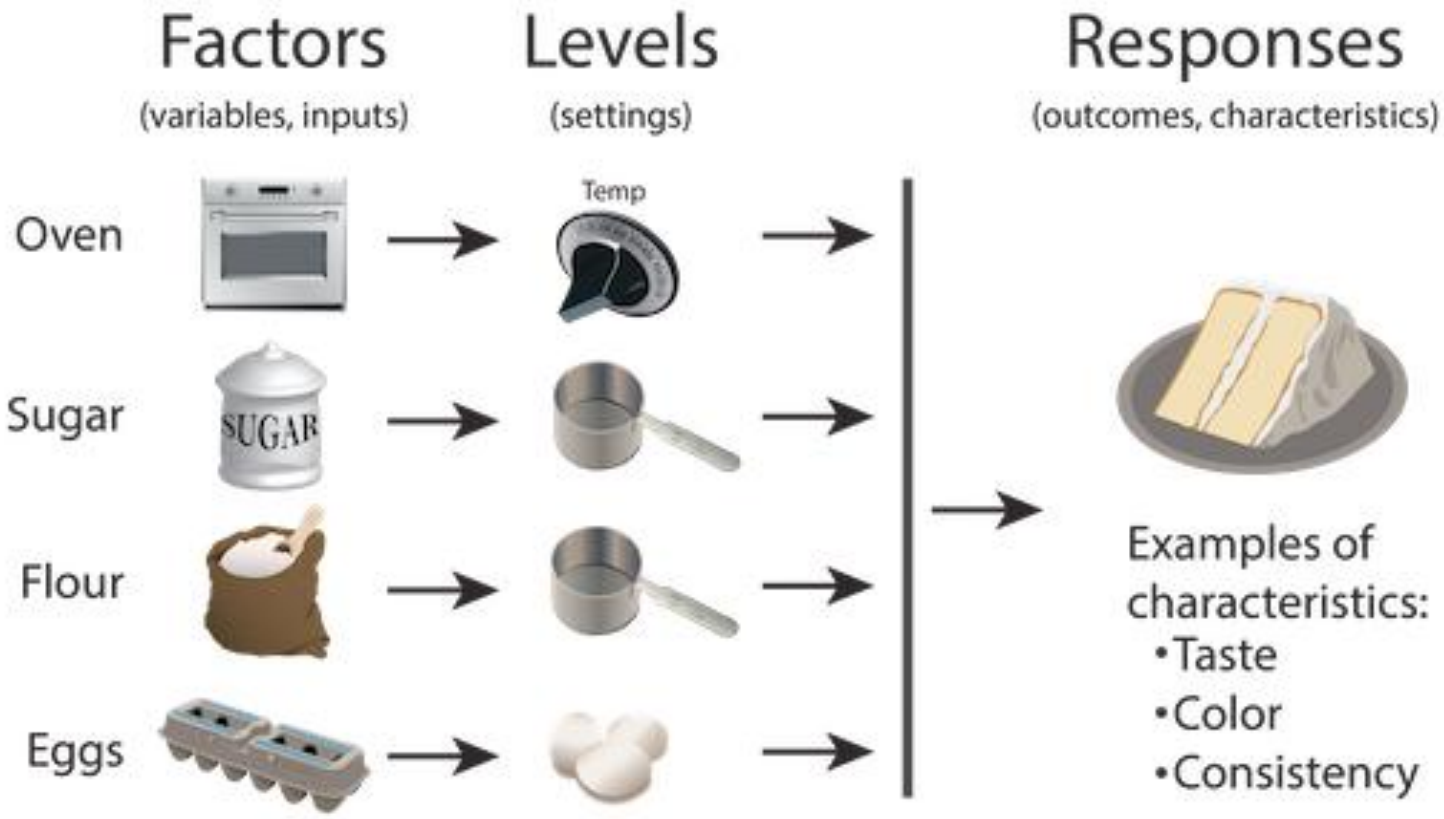
- Why do we perform experiments? (scientific or otherwise)

- Share what experiments you have performed or are currently planning

Example Experiment

https://www.youtube.com/watch?v=XtcbRuuxXpA

Example Experiment



Ref: www.morestream.com

Need for Experiments

- To understand how a product functions or a process behaves
- To discover the direction of changes that may lead to improvements in both quality and productivity.

A fundamental task in designing a (scientific) experiment is to select an appropriate arrangement of test points within the space defined by the independent variables and develop a mathematical model

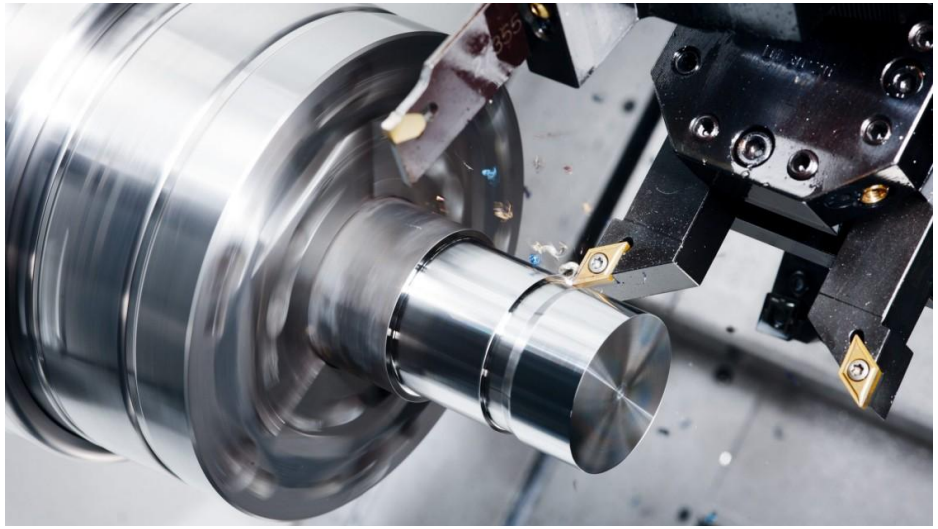
- For example, if a quadratic relationship between two variables is suspected, an experiment that studies the process at only two levels of these variables will be inadequate.
- Similarly, an experiment using four levels would be unnecessary and inefficient if the true relationship were linear.

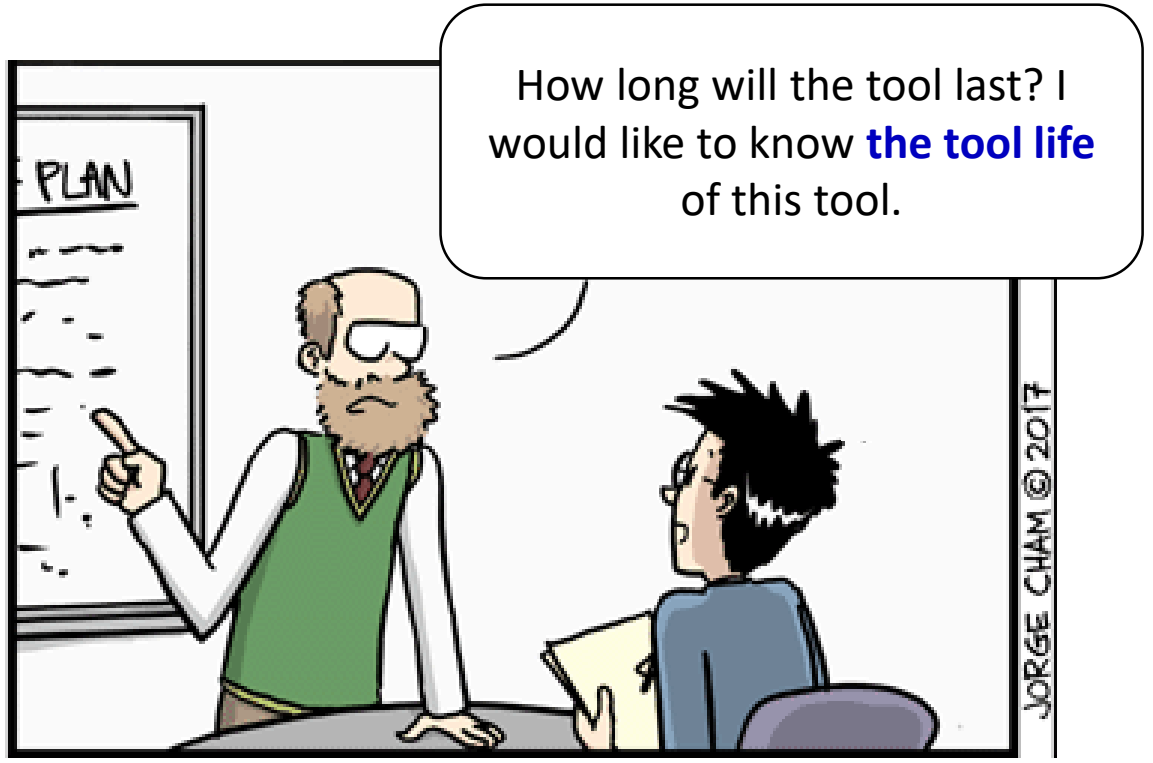
Why Statistical Methods?

- **The world around us is not deterministic!** – **Variability** is part of the natural order of things
- Variation in data is neither totally chaotic nor small enough to be ignored
- It is real, identifiable, and predictable statistically

What is variability?

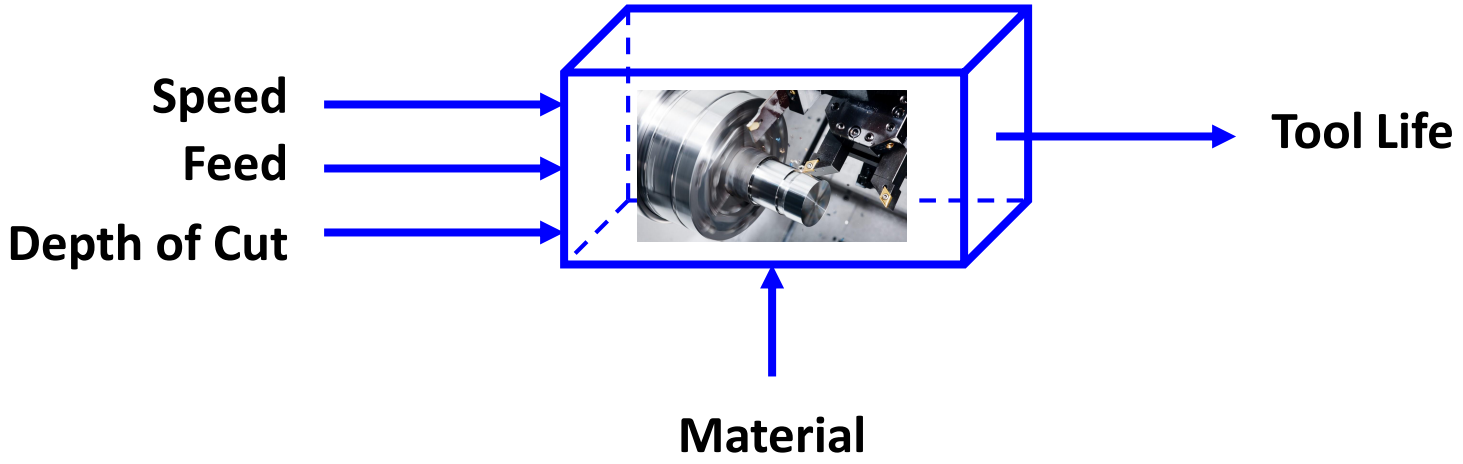
Example

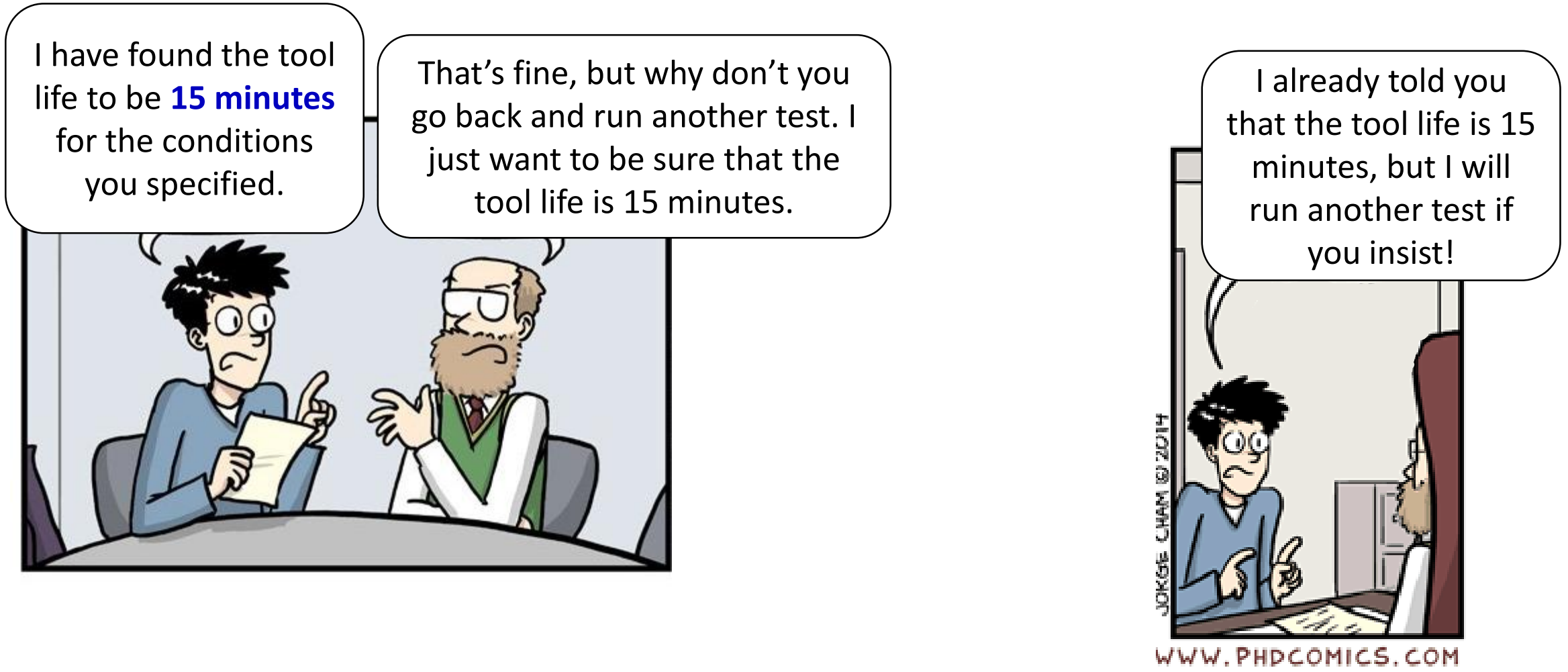




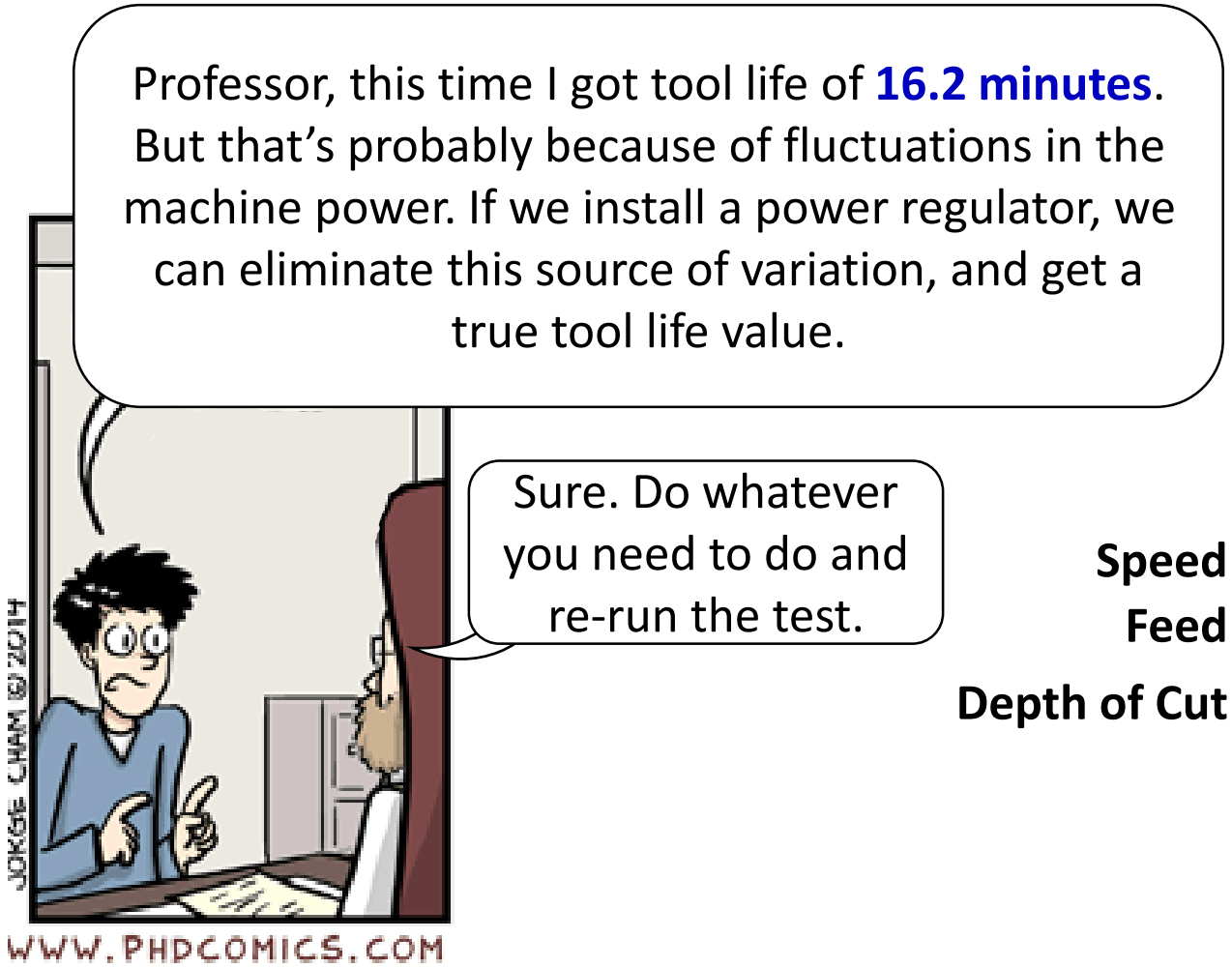
Turning operation under following conditions

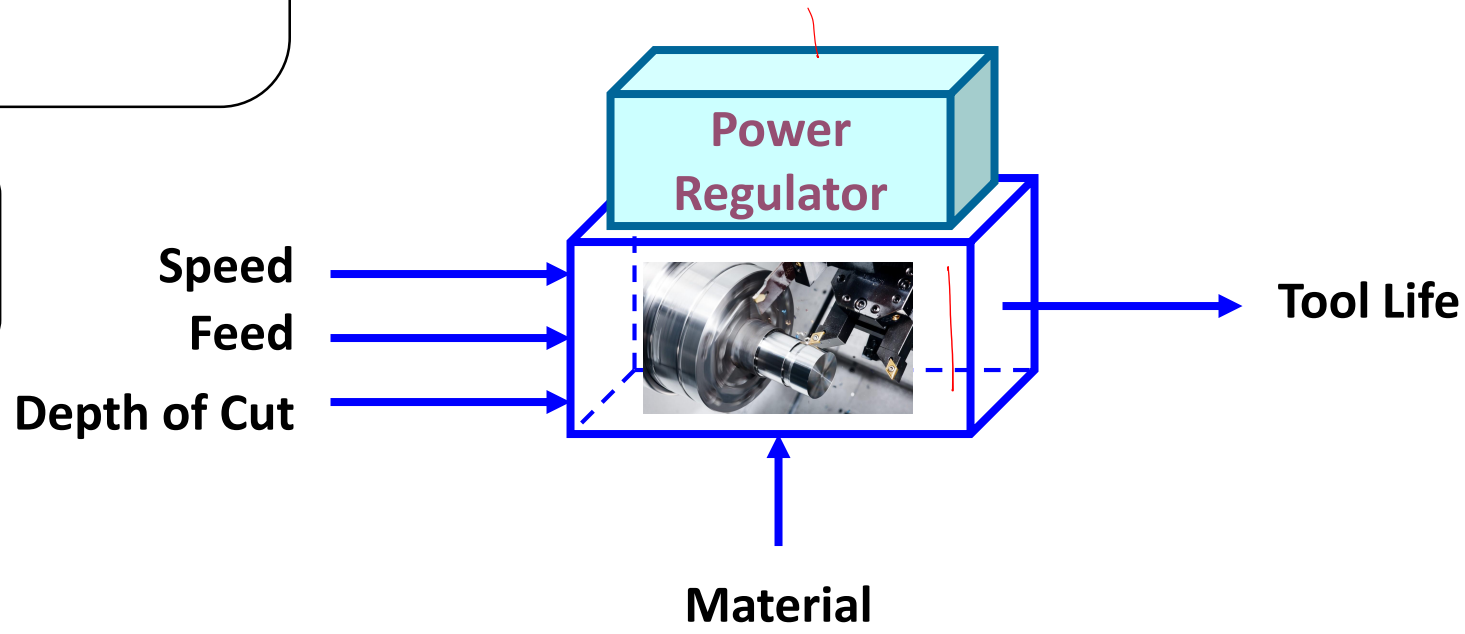
Speed:	170 FPM
Feed:	0.017 IPR
Depth of Cut:	0.07 IN
Workpiece:	1018 Steel of 6 IN Dia, 24 IN Length





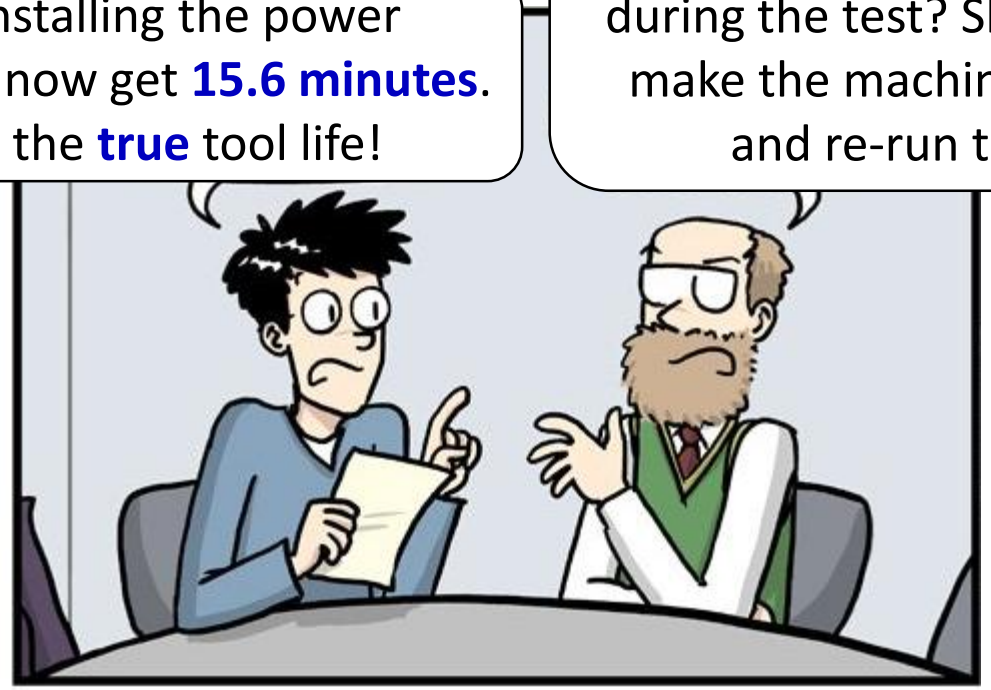
After running another test …



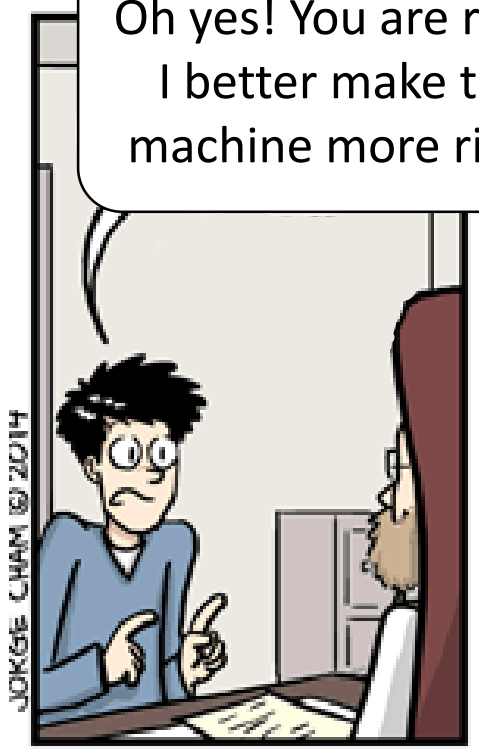


After installing the power regulator, I now get **15.6 minutes**. This is the **true** tool life!

But what about machine vibrations? Was it vibrating during the test? Should you not make the machine more rigid and re-run the test?

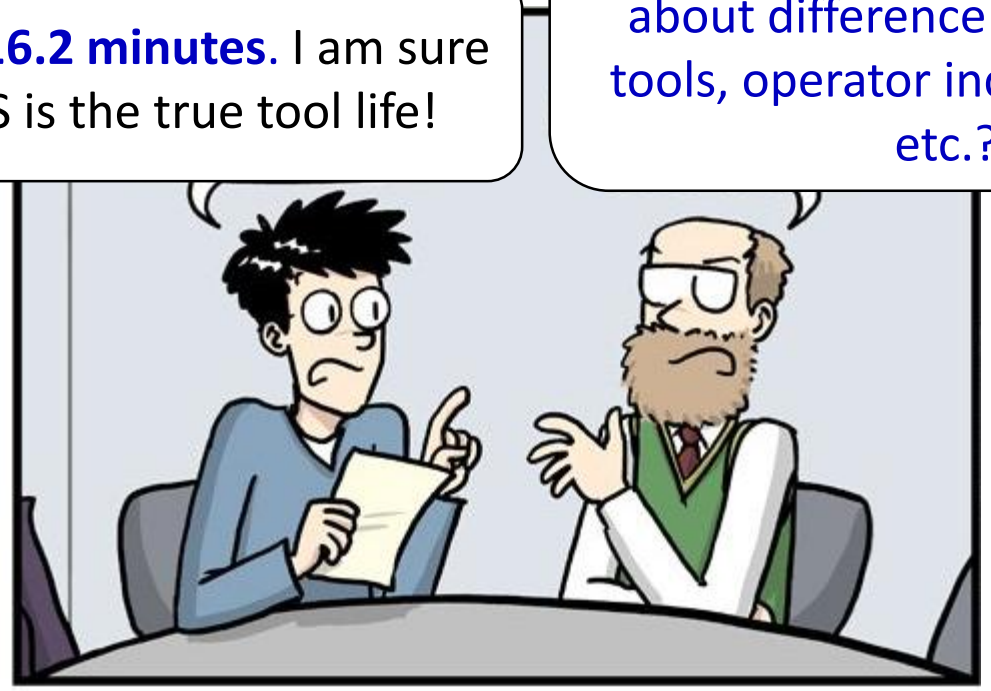


Oh yes! You are right. I better make the machine more rigid.

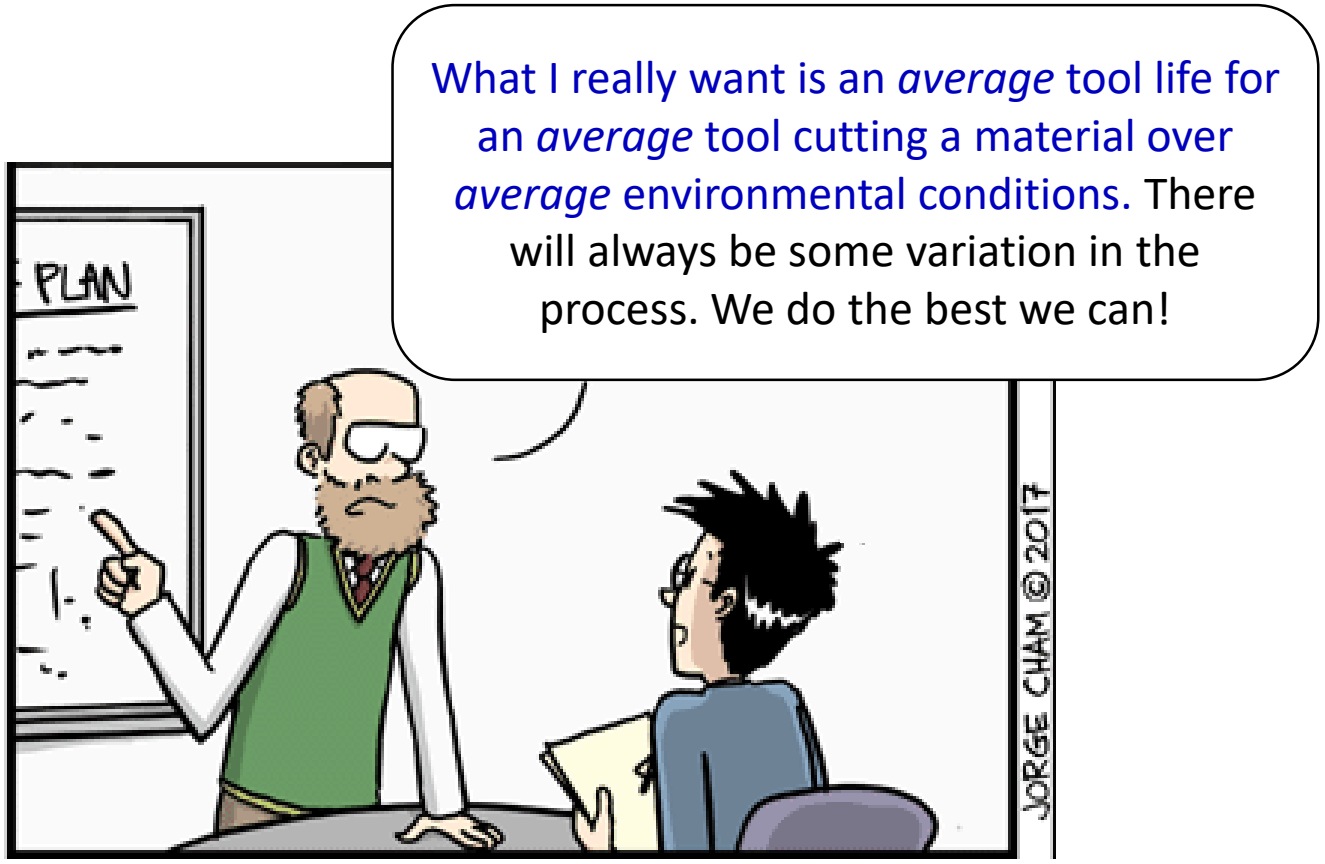


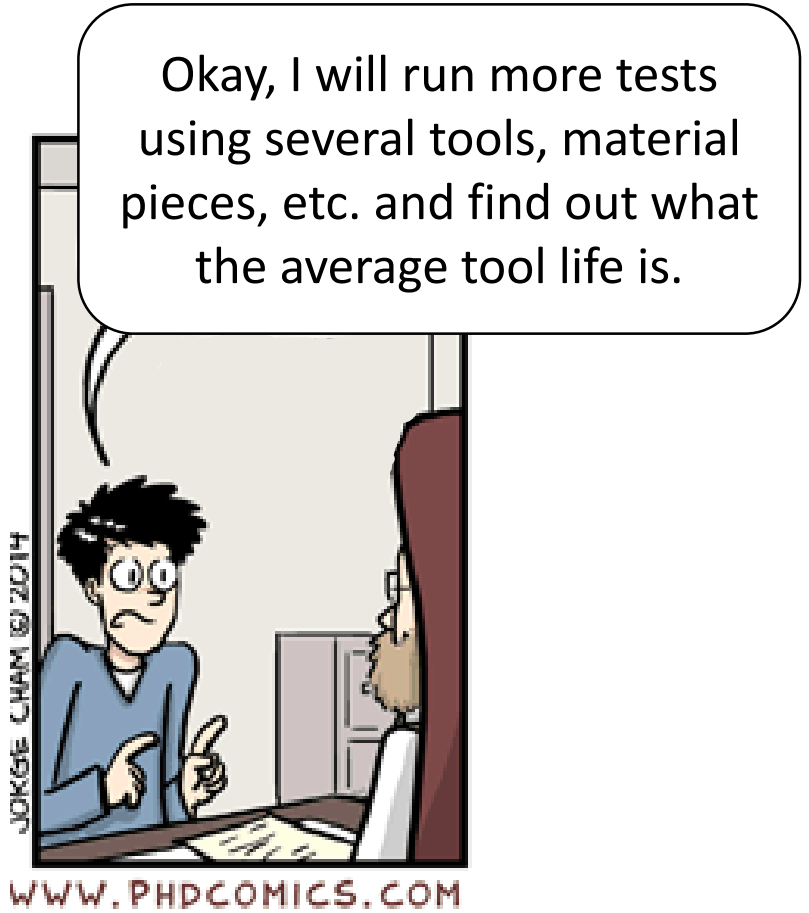
Now I get **16.2 minutes**. I am sure that THIS is the true tool life!

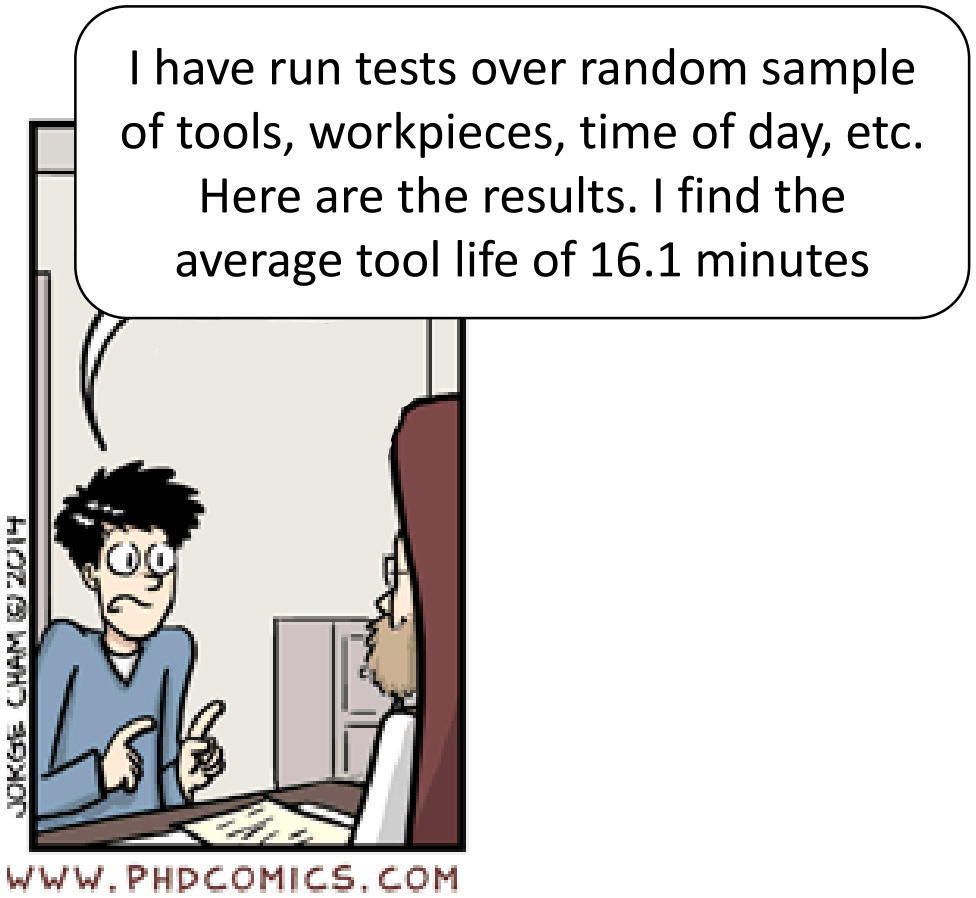
How can you be sure you have eliminated ALL variation? What about difference in materials, tools, operator inconsistencies, etc.?



Hmm. I suppose they could cause some variation,

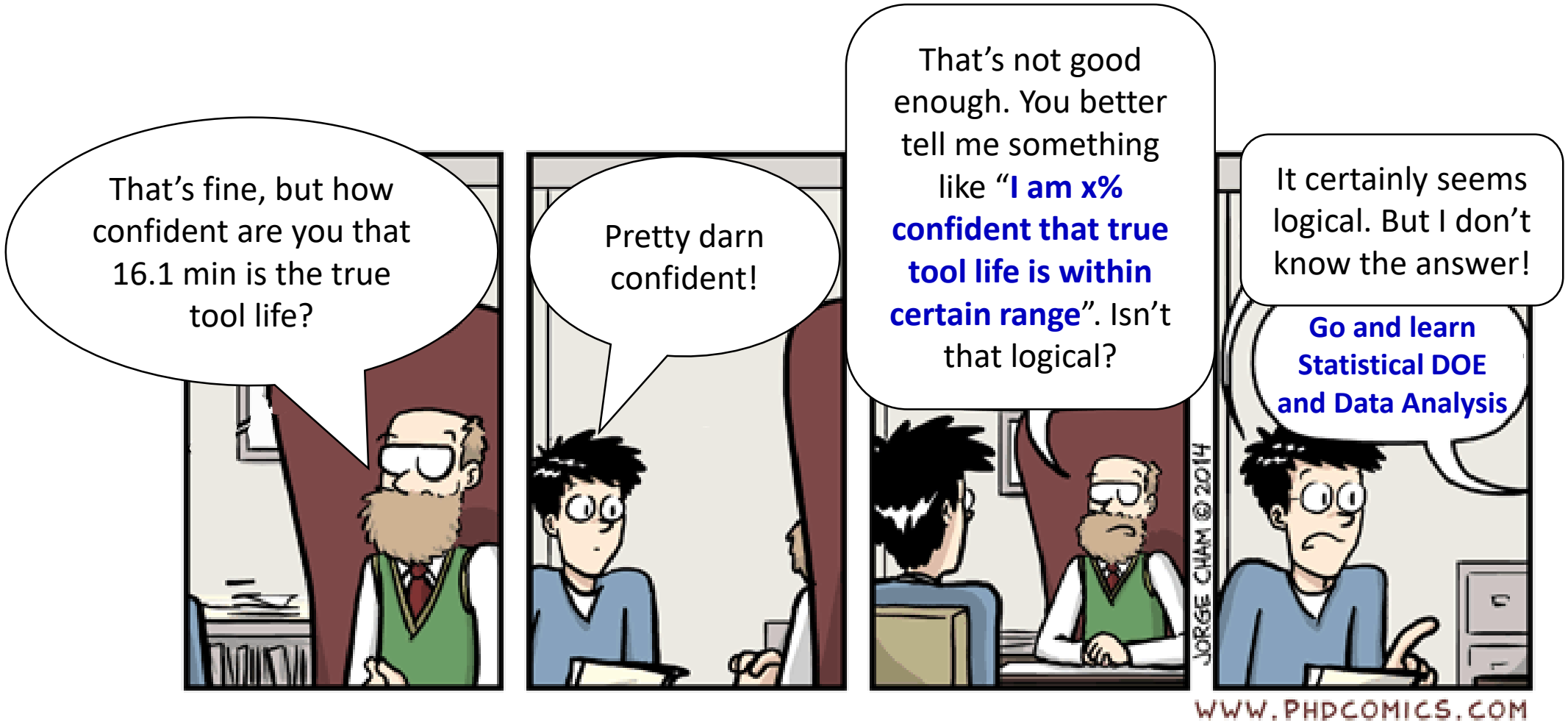






Test #	Tool Life	Test #	Tool Life
1	15	7	15
2	15.6	8	16.7
3	16.2	9	16
4	16.5	10	16
5	16.2	11	16.7
6	16.5	12	16.8

Average of 12 tests = 16.1 minutes



Why Statistical Methods?

- **The world around us is not deterministic!** – **Variability** is part of the natural order of things
- It is real, identifiable, and predictable statistically
- We can easily define many factors of potential significance but only a few accounts for the vast majority of the structure/variation in the data.
- But, the problem is to screen from a large group of potentially important factors those few, which are worthy of continuing study.
- All processes are subject to identifiable and unidentifiable disturbances which can totally invalidate results.
- The world around us is non-linear.

Experimental Difficulties

Experimental Error

- Composed of many minute disturbances which individually have little effect on the outcome of the experiment.
- Collectively these small chance occurrences may increase the dispersion or spread of the results to the point where real variable effects are masked
- Composed of more than errors of measurement – not all instrumentation oriented. A good measurement system accounts for no more than 10-15% of the total error.
- Can be a function of both unknown and known sources.

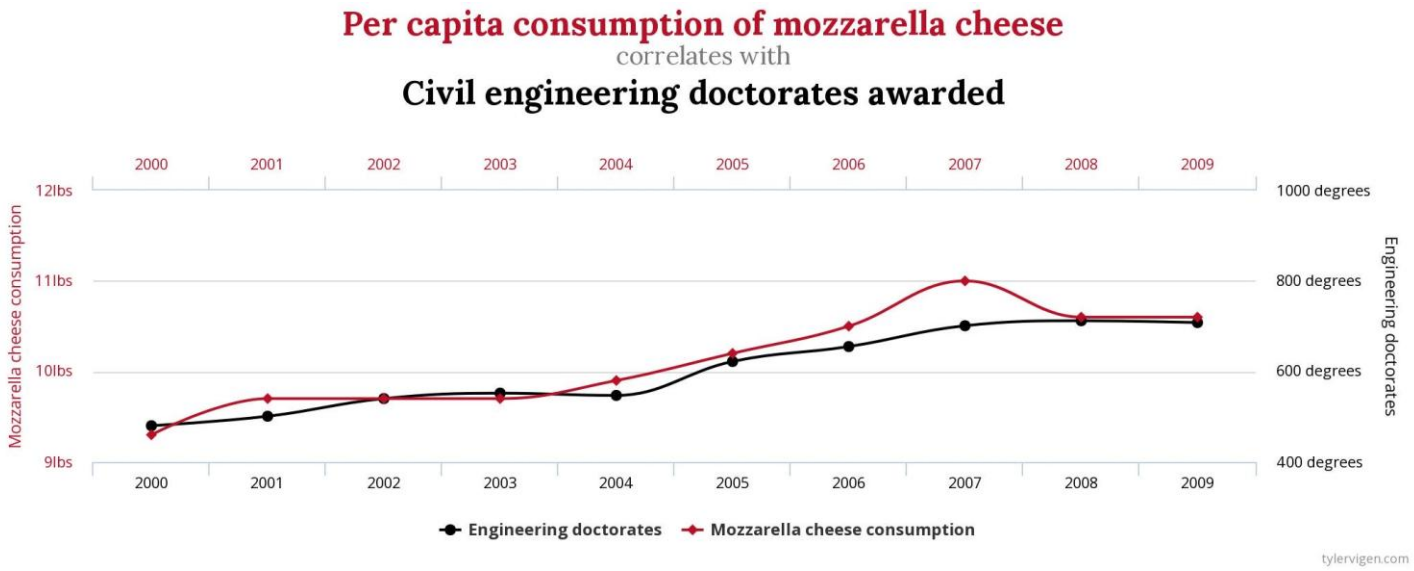
Here, statistical methods can help. They will tell us,

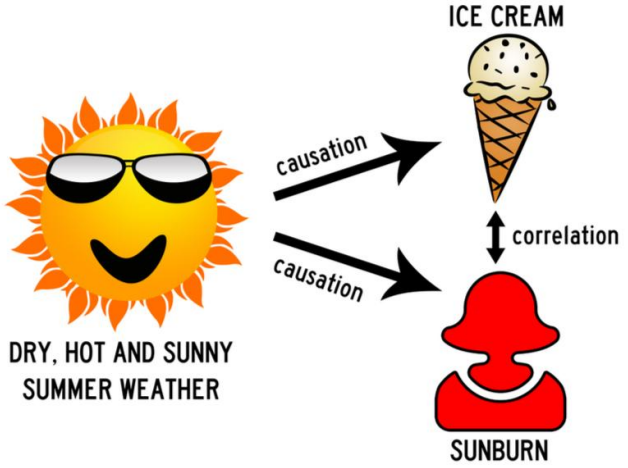
- Can the results be explained solely by chance causes?
- How much data is required to reveal the existence of true effects in light of chance error?

Experimental Difficulties

Correlation vs. Causation

- Two factors are highly related only because they are related to a third common (often unidentified) factor. Deliberate change in one may not lead to a change in the other- The concept of planned versus passively observed
- To really find out how changes in some factor affect the output, you have to change that factor deliberately and observe the change.





Experimental Difficulties

Complexity of Variable Effects

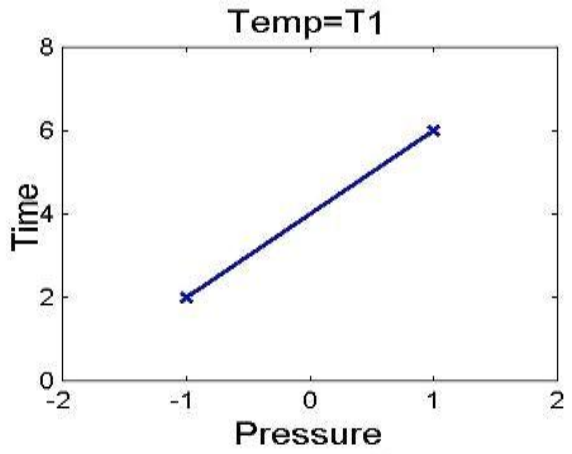
- Ideal scenario: variable effects are linear and additive! Generally not the case!
  - Example: Effects of aspirin and coffee on driving reaction time: aspirin – increase Δ, coffee – reduce 2Δ.
  - Will one aspirin and one cup of coffee reduce reaction time by 1Δ? Additive: Will 10 aspirins and 5 cups of coffee keep reaction time constant? Linear?
- Need to plan experiments to reveal variable interactions and nonlinear variable effects

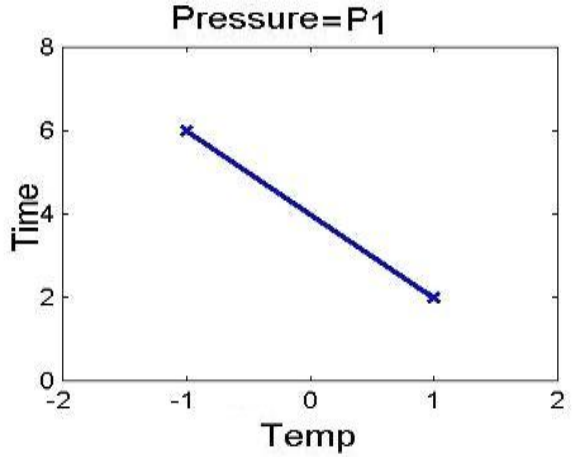
Experimental Difficulties

Example of Variable Interactions:

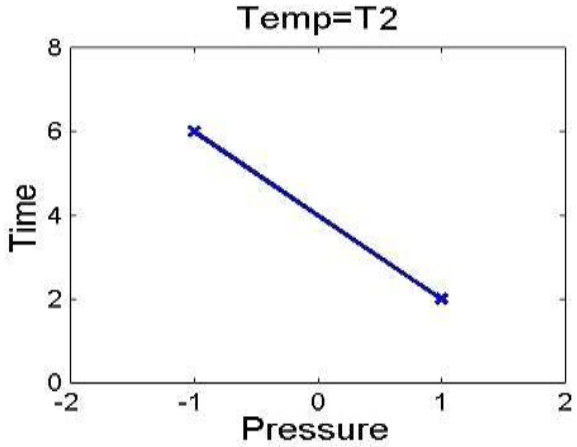
Temperature and Pressure are thought to affect the chemical reaction rate/time

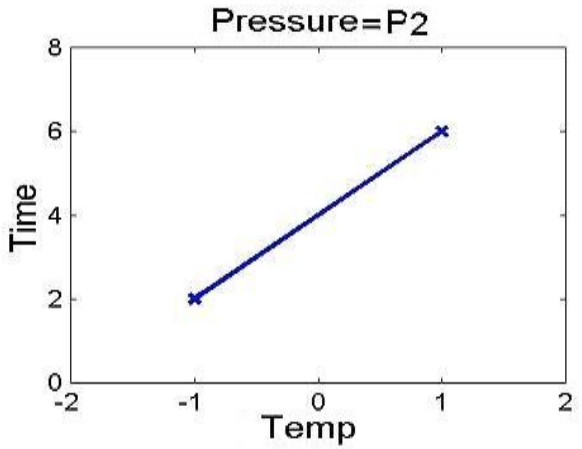
Mr. X's Experiment





Mr. Y's Experiment





Why Statistical Methods?

- We know much less about what makes things work than we think.
- Experimentation is a costly and time-consuming business. We better do it right.

Statistical tools can help us navigate through experimental problems

A myth: "Everything he is saying sounds logical and probably works fantastically for some people – but my specific problem simply doesn't lend itself to this approach and/or simply doesn't need it anymore."