

“El papel del método científico en el desarrollo del software”

Dra. Natalia Juristo
Catedrática de Ingeniería de Software de la Universidad Politécnica de Madrid

Facultad de Ingeniería
Universidad ORT Uruguay
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The Role of Scientific Method in Software Development

Natalia Juristo

Universidad Politécnica de Madrid

Spain

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State of Software Development

Some Data on Sw Development

- **16.3%** of software projects are **successful**

The project is completed on time and within budget, and has all the features and functions specified at the start

- **52.7%** of software projects cost more, take longer or do less

The project is completed and operational, but it cost more than budgeted (**189% more**), took longer than estimated and offers fewer features and functions than originally specified (**42%**)

- **31%** are **cancelled**

The project is called off at some point during development before the system is put into operation

SE Knowledge

- Do we know **why** some projects are successful and others are cancelled?
- Can we **predict** which project will fail and which one will not ?
- Do we know **why** some products (requirements, design, code) are obtained with higher quality than others?
- Can we **predict** it ?

Are we able to predict anything about software development?

State of Software Development

- State of software development knowledge
 - Today the results of applying software development methods are **unpredictable**
 - There is **no evidence** to support most of the beliefs on which software systems development is based
- State of software development practice
 - Method selection for and decision making on software production is **based on suppositions and subjective opinions**
 - When, by chance (or thanks to practitioners' personal and non-transferable know-how), the right methods are used, the software construction projects run smoothly and output the desired product
 - When the wrong methods are applied, the project develops haphazardly and the output product tends to be of poor quality

From Craft to Engineering

- SE must lay aside perceptions, bias and market-speak to provide **fair and impartial** analysis and information
 - Decisions should be based on **scientific and reasoned foundations**. The gurus' claims should not be docilely accepted
-

Other Engineering Disciplines

- All engineering disciplines have taken a similar step that has released them from the craft status

“The information used to build artefacts goes through stages, ranging from beliefs, speculations and lucky guesses to scientific knowledge by means of which an engineering discipline achieves predictable results”

Mary Shaw

Prospects for an engineering discipline of software

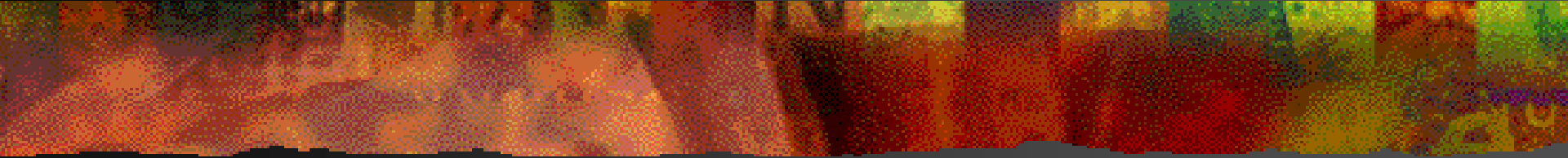
IEEE Software

1990



Perceptions vs. Objectivity

- Engineering disciplines are grounded on objectivity
 - **Objective data** are helpful for finding out more about reality, whereas subjective opinions can lead to mistaken perceptions of reality
 - Only by working with scientific **evidences** rather than assumptions will software development become a real engineering discipline
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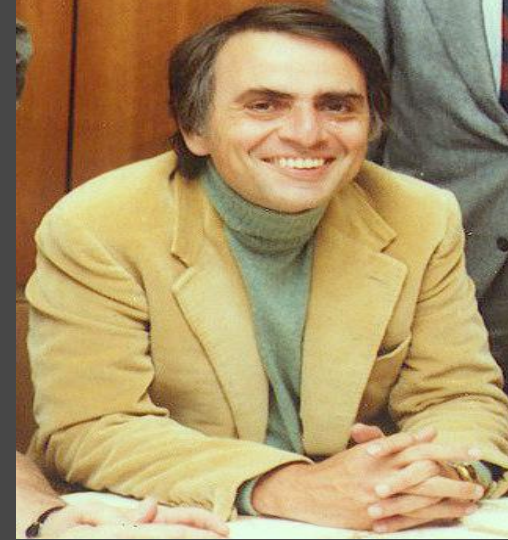


The Scientific Method

Science

- Science is a **process to understand** the world
 - To understand a phenomenon, it is necessary to conduct methodical, thorough, meticulous and objective study
-

In Search of Knowledge



*Science is a way of thinking,
more than a set of
facts*

Carl Sagan
1934 – 1996

Science

- Science seeks **explanations** about
 - **how** the world works
 - **why** the world works as we perceive
 - Such explanations are known as **laws or theories**
-

Scientific Laws

- Are patterns of behaviour
 - Describe **cause-effect relationships**
 - Explain
 - **why** some events are related
 - **how** the mechanism linking the events behaves
-

Scientific Law



- The concept of law took a long time to come to fruition in human thought
 - Aristotle² discussed the motion of material bodies, but his natural laws of motion were just descriptions of how the *final causes* were supposed to behave

“A stone falls because the “natural place” for heavy objects is the centre of the Earth”
 - Appreciate the difference on how Galileo studied that same topic

Galileo³ dropped balls of the same material, but different masses, from the Leaning Tower of Pisa and observed that their time of descent was independent of their mass.

This was contrary to what Aristotle had taught: that heavy objects fall faster than lighter ones, in direct proportion to weight

² 384BC – 322BC

³ 1564 - 1642

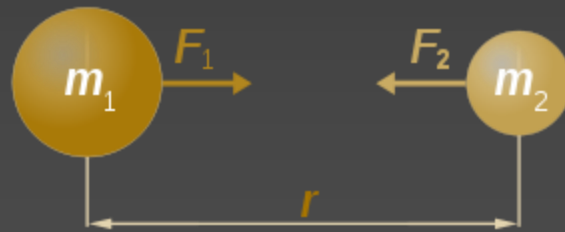
Scientific Law



- Newton's gravitation and motion laws ushered in the scientific era
 - Newton's postulate of an **invisible force** able to act over vast distances led to him being criticized for introducing "occult agencies" into science
- We **cannot perceive laws directly** through our senses
 - Anyone can see an apple fall, but Newton's inverse-square law of gravitation only becomes apparent through special systematic measurements

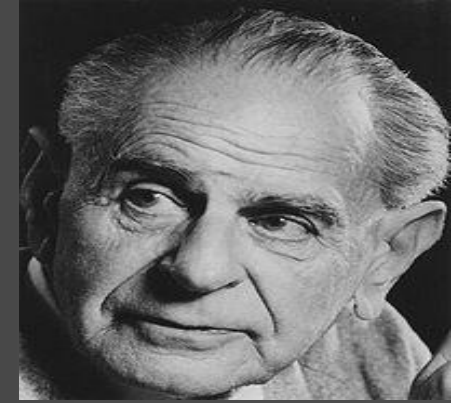
Causal Understanding

- Gravity is the **explanation** of why bodies fall
- The **relationships** between the two bodies: the one falling and the one attracting it



$$F_1 = F_2 = G \frac{m_1 \times m_2}{r^2}$$

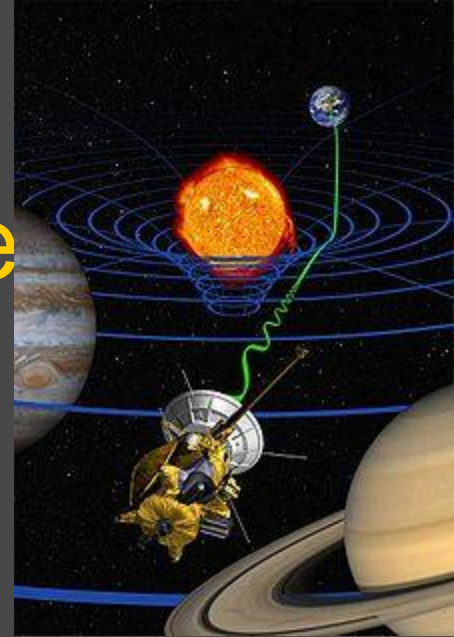
Falsification



- Falsification is the refutation of a hypothesis or theory by empirical evidence
- Karl Popper:
 - Universal hypotheses are falsifiable, but not verifiable
 - “All swans are white” can be accepted as a tentative hypothesis, until the first non-white swan is sighted
 - The longer a (falsifiable) hypothesis resists falsification, the more reliable it is seen

Knowledge can Always Improve

- Einstein's relativity revised Newton's theory of gravity
 - With **better predictions under new conditions** (light speed, etc.) that Newton's gravitation Law did not consider
 - Deeper understanding
 - In a way gravity does not exist. Gravity is a subproduct of the spacetime warping produced by heavy objects
- Newton's gravitation law are still used today for non-relativistic gravitational calculations



From Nexus to Laws

- We cannot perceive laws directly through our senses
 - Two activities are necessary
 - Systematic objective observation
 - Inference of links between cause & effect
-

The Scientific Method

■ Collection of Empirical Data

- Systematic **observation** to appreciate the nexus

■ Theoretical Interpretation of Data



- Form a hypothesis (right or wrong) about the **mechanism** relating the events

■ Collection of Empirical Data

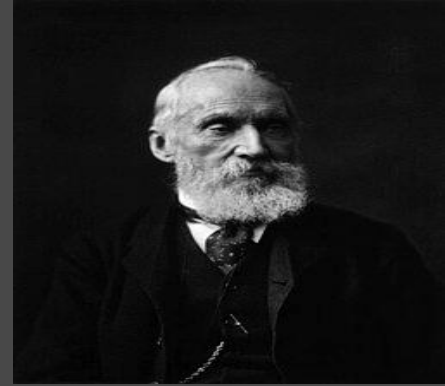
- Hypothesis must be **tested** against reality to know if they are true or not



What Makes a Method Scientific?

- Exploration of causality 
 - Objective observation 
 - Methodic variation and control of variables
 - Repeatability
-

Objective Observation



When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science

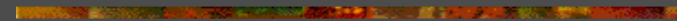
Lord Kelvin

1824 - 1907

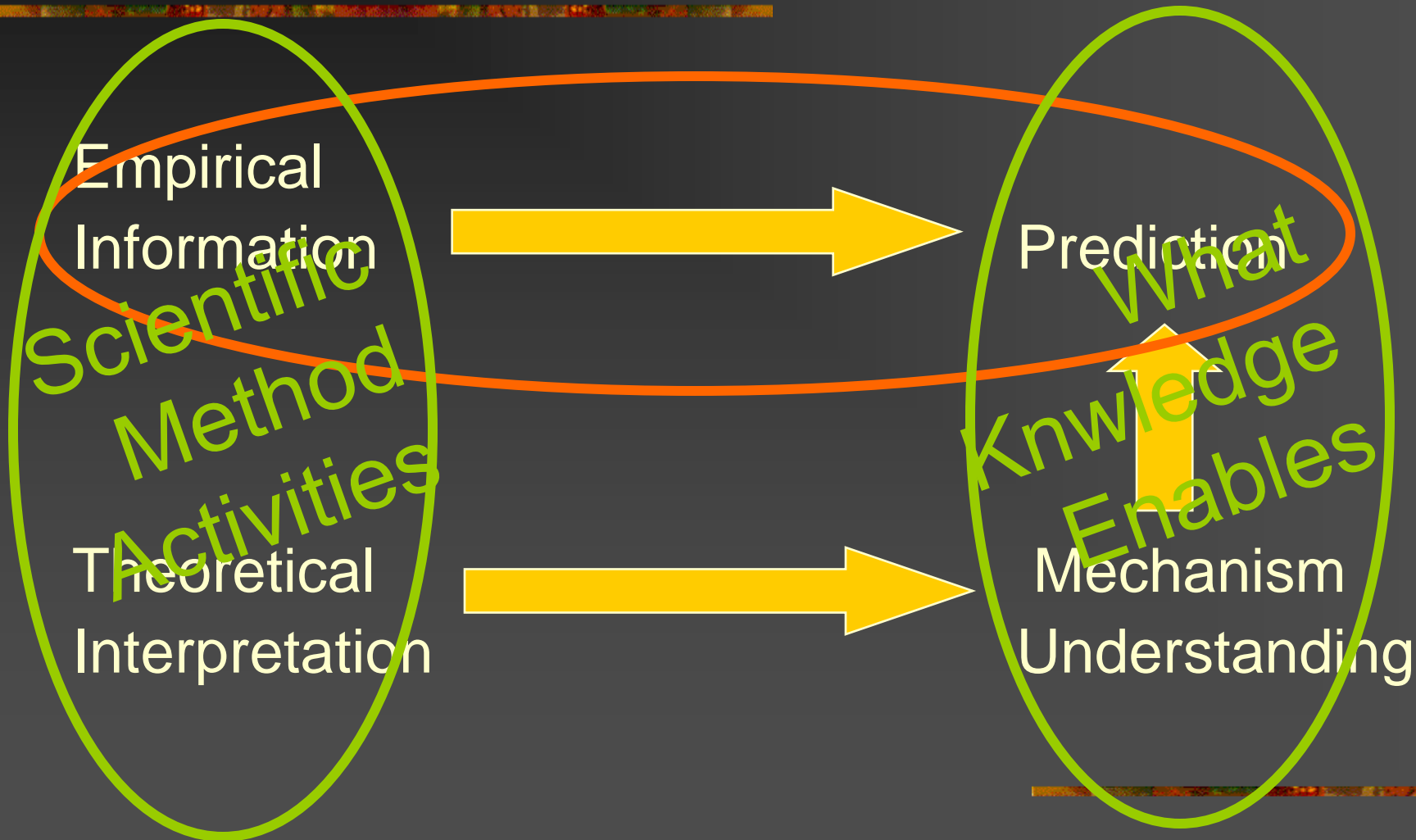
Prescientific Stages

- Before existing scientific knowledge humans are able to build interesting artifacts
 - Building does not mean understanding the mechanisms
-

Building without Understanding



1st Step: Objective Observation



Predicting without Understanding



Data ↔ Theory

- The accumulation of data, without inferential leap to the theory, never reaches a mechanism understanding
 - In the absence of empirical data, theories are moving in the realm of speculation
-

2nd Step: Objective Observation

Empirical
Information



Prediction



Theoretical
Interpretation



Mechanism
Understanding

Even wrong theories are better than none

Wrong but Useful

- Even shallow causal understanding is much better than nothing
- Ptolemaic Planets (wrong explanation based on data) were useful for prediction
 - Antikythera mechanism (an ancient mechanical calculator built about 150–100 BC) was designed to calculate astronomical positions based on Ptolemaic Planet System
 - Predicted solar eclipses
 - Calculated the timing of the Ancient Olympic Games
 - ...



Scientific Method: A Definition

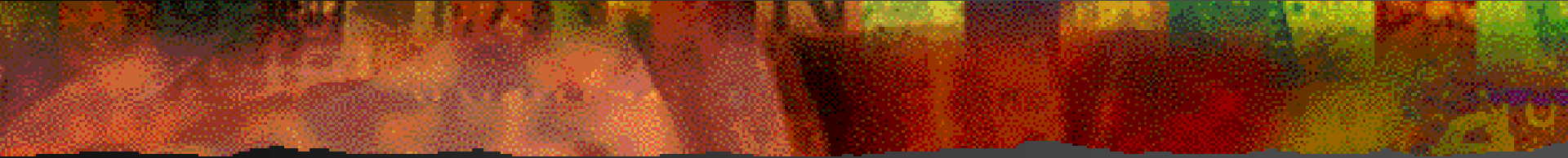
- A body of techniques for investigating phenomena and acquiring new knowledge
- To be termed scientific, a method of inquiry must be based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning

Sounds useful for software research?

Scientific Method: Another View

- A rigorous process for properly developing and evaluating explanations for observable phenomena based on reliable empirical evidence and neutral, unbiased independent verification
- Not based on arguments from authority or popular preferences

Sounds useful for software research?



Experimental Software Engineering

Experimental SE

- Brings the scientific method through the experimental paradigm into SE
 - Generate **scientific statements about software** building through experimentation
-

Why Experimenting in SE?

- Too many methods and tools exist to allow each developer or software industry to determine the best choice of tools and methods by trial and error
 - Yet this choice is obviously important
 - A general feeling of unease with the “advocacy style” of software research
 - The “Try it, you’ll like it”-method is not feasible anymore: too many alternatives to try
-

Claims for SE Experimentation: Old

- Did Anyone Study Any real Programmers?
 - Bill Curtis, Paper tile at Empirical Studies of Programmers Workshop, 1986
 - Experimentation can help build a reliable base of knowledge and thus reduce uncertainty about which theories, methods, and tools are adequate
 - Tichy, Computer, 1998
 - Experimentation in SE is necessary, common wisdom, intuition, speculation, and proofs of concepts are not reliable sources of credible knowledge
 - Vic Basili, TSE, 1999
-

Claims for SE Experimentation: New

- The actual software construction isn't necessarily experimental, but its conception is. An this is where our focus ought to be. It's where our focus always ought to have bee
 - Tom de Marco, IEEE Software, 2009
 - The empirical side of software engineering should become a full member of empirical sciences
 - Bertrand Mayer, Communications ACM, 2009
-

Experimentation to the Rescue!

- Experiments determine whether claimed differences among alternative SE techniques are actually observable
 - For instance with respect to quality, cost, maintainability of the software...
 - Experimentation is maturing
 - Fraction of empirical studies is rising
 - More laboratories, more sophistication
 - More and more papers contain empirical validation
-

Gaining SE Scientific Knowledge

- Identify and understand
 - the **variables** that play a role in software development
 - the **connections** between variables
 - Learn **cause-effect relationships** between the development process and the obtained products
 - Establish laws and theories about software construction that **explain** development behaviour
-

What can we hope?

- Knowledge about which methods work better than others, under what circumstances, and why
- Trustworthy theoretical models that explain and predict
- Professional developers who can judge the validity of empirical studies...
- ... who can ask meaningful questions about experiments and theories and understand the answers
- New methods and tools that provably simplify the programmers work and we know why

Experimentalism is central to Software Research!



ESE Brief History

ESE: Origins

- The **origins** of ESE can be traced back to Weinberg and Tichy's work in the 1970s advocating scientific approaches that encouraged careful observation and evaluation of software development methods
 - The **first experiments** were not run until the early 1980s by Victor Basili's group at the University of Maryland with NASA's Software Engineering Laboratory
 - Since then the use of experiments to examine the applicability of SE technologies has gradually gained in importance as a research methodology
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ESE At Present

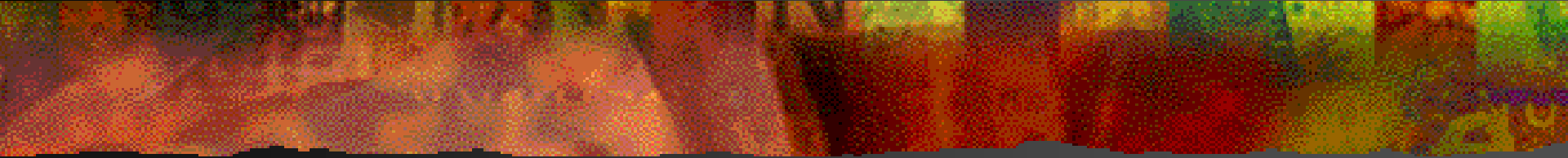
Journals & Conferences

- A specialized journal and conference have been founded over recent years
 - Empirical Software Engineering Journal
 - Empirical SE and Measurement Conference
- Experiments are reported in leading SE journals and conferences
 - For example, as many as 93 experiments were published in journals and conferences from 1993 to 2003

ESE At Present

Textbooks

- There are also a couple of books that explain how to apply experimental tests to software development
 - *Experimentation in SE: An Introduction*
Wohlin, Runeson, Höst, Ohlsson, Regnell, Wesslén
2000
 - *Basics of SE Experimentation*
Juristo & Moreno
2001



The SE Lab

What makes a Method Scientific?

- Exploration of causality
- Objective observation
- Methodic variation and control of variables
- Repeatability

Do you remember?

Experiment

■ Experiment

- Models **key characteristics** of a reality in a **controlled** environment and **manipulating them iteratively** to investigate the **impact** of such variations and get a better understanding of a phenomenon
 - Formal, rigorous and controlled investigation in which the variables under study are given different values to find out what effect each value has
 - The properties of a complex system are explained by analysing the behaviour of its parts
-

The Laboratory

- Laboratory
 - Simplified and controllable reality where the phenomenon under study can be manipulated and studied
 - Chemistry laboratory
 - Flasks and pipettes where temperatures and pressures are controlled
 - Real world: Real substances with temperature and pressures
 - Economics laboratory
 - Sets of individuals playing games to earn toy benefits
 - Real-world: Markets (built of thousands of agents) where real rewards are pursued
-

SE Experiment

- Development decomposed into its parts
 - Manipulated variables
 - Techniques (design, testing, etc.),
 - Developers (experience, knowledge, etc.)
 - ...
 - Impacts investigated
 - Effectiveness, efficiency, productivity, quality
 - Depending on the experiment, these response variables can be instantiated as, for example, number of detected defects, number of code lines, etc.
-

SE Laboratory

- Students rather than professionals
 - Toy software rather than real systems
 - Exercises rather than real projects
 - Academy or a tutorial in industry rather than real life in industry
 - Phases, techniques rather than project
 - ...
-

Perceptions vs. Facts: Example

- An experiment in our V&V course which studies techniques effectiveness
- Are perceptions reliable?
 - Perception
 - Students like much more functional testing technique
 - They hate reading technique
 - Facts
 - Functional and structural are equally effective
 - Reading usually are more effective
- Tastes, previous knowledge, easiness, laziness are influencing their perceptions

Other Examples

- Experiments falsify hypotheses
 - *E.g. the assumption of failure independence in multi-version programming*
 - John Knight and Nancy Leveson (1986) -- An experimental evaluation of the assumption of independence in multiversion programming. *IEEE TSE*
-

From Lab to Clinic

- Any lab finding has problems with representativeness of reality
 - Different levels of experimental studies
 - In vitro experiments
 - In vivo experiments
 - Clinical trials
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THE ROLE OF SCIENTIFIC METHOD IN SOFTWARE DEVELOPMENT

Natalia Juristo

Universidad Politécnica de Madrid

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There is a lot more to say about this...

- Lakatos' "Research programs"
 - Theory needs time and space to develop
 - Falsification attempts should be delayed until it is well developed
- Kuhn's "Paradigms"
 - Science does not follow the falsification path
 - Instead, there are "revolutions", in which an established theory is replaced by a different one
 - Between revolutions, there is "normal science" (extension, strengthening, application, rounding out of accepted theory.)
- Feyerabend's "Anarchy"
 - From a historic perspective, there is no "scientific method"
 - "anything goes" to find new theories
 - The scientist must be competent, informed and follow scientific standards.

Prediction vs. Understanding

