

CMPT 880/890  
The Scientific Method

# MOTD

- The scientific method is a valuable tool
- The SM is not the only way of doing science
- The SM fits into a larger research process
- There are several specific ways to do CS research
- Find the science behind the invention

# Outline

- Reminders about science
- Overview of the research process
- What is the scientific method
- Controversy about the scientific method
- Research methods in CS

# Remember 'science'

- ““A connected body of demonstrated truths or observed facts”
- “Science is the systematic study of the properties of the physical world, by means of repeatable experiments and measurements, and the development of universal theories that are capable of describing and predicting observations.”
  - (Dodig-Crnkovic)

# Scientific knowledge and truth

- How do we add to scientific knowledge?
- How do we determine whether to believe someone's claim of new scientific knowledge?

# The research process

- Scientific knowledge has two parts
  - raw information
  - theories that explain and predict
- How do these fit together?

# The research process

- Observation of the world
  - gathering raw data
- Modeling and theory formation
  - grouping and classifying observations
  - thinking about underlying principles and generalization
  - proposing explanations for observations
- Theory testing
  - predictive hypothesis generation
  - experimental testing
  - observation of experimental results

# The research process

- Observation of the world
  - “Here is some information about the world”
- Modeling and theory formation
  - “Here is a way of organizing our observations”
  - “I think this is why things happened the way they did”
- Theory testing
  - “I think this will happen when I try it this way”
  - “Was I right?”
  - “Here is some more information about the world”



# How does this fit with CS?

- What kinds of research were in the five papers?

# Problem/Question based research

- A different view of the research process:
  - 1. What's the problem?
  - 2. Who cares about this problem and why?
  - 3. How can the problem be solved?
  - 4. What has to be done to solve the problem?
  - 5. How can you show that your solution is a good solution to the problem?

# The scientific method

- “A body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge” (Wikipedia)
- “The logical scheme used by scientists searching for answers to the questions posed within science” (Dodig-Crnkovic)
- “Hypothesis testing”

# Hypothesis testing

- Define the question
- Gather information and resources (observe)
- Form hypothesis
- Perform experiment and collect data
- Analyze data
- Interpret data and draw conclusions that serve as a starting point for new hypothesis
- Publish results
- Replicate (done by other scientists)

# Hypothesis → theory

- “When consistency is obtained, the hypothesis becomes a theory and provides a coherent set of propositions that define a new class of phenomena or a new theoretical concept” (Dodig-Crnkovic)
- Note that theories can never be proved
  - they accumulate more and more evidence
  - they *can* be disproved

# Attributes for the scientific method

- Objectivity
- Precision
- Honesty and openness
- Peer review
- Full disclosure

# Does it really work that way?

- “The ‘hypothetico-deductive’ schema was not developed as a method at all: It was intended as a logical analysis of how scientific theories derive support from evidence, and it was developed in a process that intentionally excluded consideration of the process of discovery in science.” (Halwes)
- Step 1 is “define the question”...how do you do that?

# The role of observation

- Until 1803, occasional reports of rocks falling from the sky were not believed by scientists. Then, in late August of that year, many people in the Village of Laigle, France, saw bright lights streaking across the sky, followed by "three violent detonations," after which "nearly 3000 stones fell into the fields with loud hissing noises." Each of the stones was found resting in the center of a small crater: the stones smelled of sulfur. Scientists heard the report and investigated the site, and proposed that the stones had come from space. (Halwes)



# The role of theory in modeling

- Not all revisions of theories are based on new evidence; for example, an improved theory may result from logical and mathematical work that makes possible a better understanding of the existing evidence. (Halwes)

# The role of interest and fun

- Scientists don't only test hypotheses in order to test theories. Scientists explore their world, just like children do. When a good theory is available to serve as a map, is gets used. If no theory / map is available, the exploration goes on anyway. (Halwes)

# Another traditional criticism...

- “The scientific method is not open to new kinds of knowledge, and puts too much emphasis on experimentation, evidence and repeatability”  
(An ESP researcher)
- Is this a valid criticism?

# Summary

- There are legitimate concerns with the method
  - not enough focus on observation
  - ‘a fiction constructed at the end of the project’
  - ignores other aspects of scientific practice
- BUT – it is still the best way of assessing truth
- Compare with other methods of determining truth:
  - The method of tenacity
  - The method of authority
  - The method of congruity
- The attributes of the SM are critical

# Problem/Question based research

- What about problem solving in CS?
  - 1. What's the problem?
  - 2. Who cares about this problem and why?
  - 3. How can the problem be solved?
  - 4. What has to be done to solve the problem?
  - 5. How can you show that your solution is a good solution to the problem?

# Research methods in CS

- Observation
- Modeling
- Theory
- Experimentation
- Simulation (?)
- Invention (?)
- Design (?)

# Observational methods in CS

- Informal and introspective observation
  - Keep your eyes open, think about your own experiences
- Case studies
  - Detailed observation / analysis of a particular situation
- Field methods
  - Methods from anthropology and sociology
- Observation of traces
  - System logs and records
- “This is the way one part of the world acts”

# Modeling

- Modeling is simplification:
  - what's important in this set of observations?
  - what's not important?
- Formal models: descriptions in precise language with rules about how the descriptions work
- What is the right level of abstraction?
- “These are the underlying principles”



# Theory

- A CS theory is different from a scientific theory
  - Mathematics rather than natural sciences
- Theorem and proof, not hypothesis and test
- Why?
  - “logical systems with stringent definitions of axioms and rules for deriving and proving theorems” (Dodig)
- “Here are truths in a formal system”

# Experimentation

- Two purposes:
  - exploration (observation) (“formative”)
  - testing (“summative”)
  - the latter first with the classical scientific method
- Many different experimental methods
  - more on this in a later class
- “Here is evidence for (or against) a hypothesis”

# Those other methods...

- Simulation
  - Really a modeling or experimentation tool
- Invention and design
  - “I have built an X that solves problem Y”
  - Where is the scientific knowledge?
  - What is the reason that X is able to solve Y?
  - Try to identify the science behind the invention

What methods were in the papers?