## WHAT'S ALL THIS ABOUT **SCIENCE?**

Monday, August 26, 2013



### Eugene H. Spafford Purdue CS

Last update: 8/25/13

Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



Epistemology is the field of Philosophy devoted to the study of what can be known and the nature of knowledge

- Epistemology is the field of Philosophy devoted to the study of what can be known and the nature of knowledge
- Why do we care about Philosophy?

- Epistemology is the field of Philosophy devoted to the study of what can be known and the nature of knowledge
- Why do we care about Philosophy?
  - Some (most?) of you want to get a PhD Doctor of Philosophy!

- Epistemology is the field of Philosophy devoted to the study of what can be known and the nature of knowledge
- Why do we care about Philosophy?
  - Some (most?) of you want to get a PhD Doctor of Philosophy!
- Computer Science is similar: the study of what can be computed, and the bounds and methods of those computations

## WHAT DO YOU KNOW?

- Does the world really exist?
  - No (solipsism)
  - If I think it, it does (idealism)
  - Yes (materialism)
- Do we have a shared reality?
- What really exists? (metaphysics)





Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:
  - *Natural* -- knowledge of reality

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:
  - *Natural --* knowledge of reality
  - Social -- knowledge of people and their behaviors

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:
  - *Natural --* knowledge of reality
  - *Social --* knowledge of people and their behaviors
  - *Formal* or *Synthetic* -- knowledge about abstractions and artifacts

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:
  - *Natural* -- knowledge of reality
  - *Social* -- knowledge of people and their behaviors
  - *Formal* or *Synthetic* -- knowledge about abstractions and artifacts
- Religion/mysticism address knowledge about what we cannot observe.

- Our view of science derives (partially) from Immanuel Kant (1724–1804): reality is that which we can observe.
- Science is a systematic method of obtaining *propositional knowledge* about reality. Science can be:
  - *Natural --* knowledge of reality
  - Social -- knowledge of people and their behaviors
  - *Formal* or *Synthetic* -- knowledge about abstractions and artifacts
- Religion/mysticism address knowledge about what we cannot observe.

Copyright © 2007-2013 by E. H. Spafford

# Empirical sciences, based on observation

A Priori





Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



- "Ground"
- Hypotheses (or Theses)



- "Ground"
- Hypotheses (or Theses)
- Proof or Refutation



- "Ground"
- Hypotheses (or Theses)
- Proof or Refutation
- Presentation



- "Ground"
- Hypotheses (or Theses)
- Proof or Refutation
- Presentation
- Theory formation



- Ground"
- Hypotheses (or Theses)
- Proof or Refutation
- Presentation
- Theory formation
- Refinement



- Ground"
- Hypotheses (or Theses)
- Proof or Refutation
- Presentation
- Theory formation
- Refinement





### **SCIENTIFIC DISCIPLINE?**

- Common terminology
- Common literature
- Shared metrics
- Historical development
- Skepticism, challenge, refinement, refutation [Karl Popper (1902–1994)]
  - What separates science from pseudoscience and faith

## **KEY CONCEPTS**

No knowledge is absolute – it is only consistent with observation, experiment, and reasoning. Science does not produce absolute truth.

Every theory and "law" (model based on hypotheses) must be open to refutation!

Any theory for which there is no possible independent refutation is a matter of faith, not science.

### TERMS

- *Hypotheses* are confirmed to validate
  - *Theories* which embody
    - *Models* which, with sufficient evidence and testing, derive
      - Scientific Laws

But none of these are *truth*! All may be refuted or else they are not science.

## **GOOD THEORIES**

- Testable/Observable
- Falsifiable
- Minimal/Simple (think "Occam's Razor" or "Law of Parsimony")
- Predictive
- Explanatory
- Appropriate in scope

Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



### Testable

Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



### Testable

### Refutable



- Testable
- Refutable
- Simple (parsimonious)



- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)



- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others



- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others



Testable

Consistent

- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others



- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others

- Consistent
- Corrigible & Correctable



- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others

- Consistent
- Corrigible & Correctable
- Integrative of other theories

- Testable
- Refutable
- Simple (parsimonious)
- Pertinent (applies to evidence)
- Reproducible by all others

- Consistent
- Corrigible & Correctable
- Integrative of other theories
- reference

Copyright © 2007-2013 by E. H. Spafford

### Observed from similar frames of



Confirming theories is usually simple



- Confirming theories is usually simple
- Confirmation via risky predictions is better



- Confirming theories is usually simple
- Confirmation via risky predictions is better
- Refutation must be possible



- Confirming theories is usually simple
- Confirmation via risky predictions is better
- Refutation must be possible
- Theories that prohibit are better



- Confirming theories is usually simple
- Confirmation via risky predictions is better
- Refutation must be possible
- Theories that prohibit are better
- Every experiment must be a true test, and only evidence from a true test is valuable

- Confirming theories is usually simple
- Confirmation via risky predictions is better
- Refutation must be possible
- Theories that prohibit are better
- Every experiment must be a true test, and only evidence from a true test is valuable
- Ad hoc alterations to rescue a theory diminish its value

### WHAT IS ENGINEERING?

"The creative application of scientific principles to design or develop" structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property." [ABET]

*Engineering is artifacts, and science is principles* 

## SCIENCE VS. ENGINEERING

- A scientist will create and operate an artifact to validate a theory.
- An engineer will develop a theory to better understand how to build and operate artifacts.
- A technician will operate artifacts without necessarily understanding the underlying principles or design elements.

Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



- Analytic (math-style proofs)
- By construction (existence proof)

- Analytic (math-style proofs)
- By construction (existence proof)
- By counter-example (not universally accepted)

- Analytic (math-style proofs)
- By construction (existence proof)
- By counter-example (not universally accepted)
- By simulation (requires validated model)

- Analytic (math-style proofs)
- By construction (existence proof)
- By counter-example (not universally accepted)
- By simulation (requires validated model)
- By enumeration (must show completeness)

- Analytic (math-style proofs)
- By construction (existence proof)
- By counter-example (not universally accepted)
- By simulation (requires validated model)
- By enumeration (must show completeness)
- Stochastic (must validate metrics; not universally accepted)

- Analytic (math-style proofs)
- By construction (existence proof)
- By counter-example (not universally accepted)
- By simulation (requires validated model)
- By enumeration (must show completeness)
- Stochastic (must validate metrics; not universally accepted)

*Note that the artifacts used in the proof are not the hypothesis!* 

Copyright © 2007-2013 by E. H. Spafford

Monday, August 26, 2013



Propositional hypothesis in most cases



- Propositional hypothesis in most cases
- Grounded in accessible, existing work



- Propositional hypothesis in most cases
- Grounded in accessible, existing work
- Advances the state-of-the-art



- Propositional hypothesis in most cases
- Grounded in accessible, existing work
- Advances the state-of-the-art
- Is clearly and succinctly stated (often "It is possible to...")



- Propositional hypothesis in most cases
- Grounded in accessible, existing work
- Advances the state-of-the-art
- Is clearly and succinctly stated (often "It is possible to...")
- Is independent of implementation and timeframe



- Propositional hypothesis in most cases
- Grounded in accessible, existing work
- Advances the state-of-the-art
- Is clearly and succinctly stated (often "It is possible to...")
- Is independent of implementation and timeframe
- Is moderate in scope



- Propositional hypothesis in most cases
- Grounded in accessible, existing work
- Advances the state-of-the-art
- Is clearly and succinctly stated (often "It is possible to...")
- Is independent of implementation and timeframe
- Is moderate in scope
- **Is good science!** (see all the preceding)



# **BROADENING YOUR HORIZONS**

- <u>Philosophy of Science: The Central Issues</u>, edited by Curd and Cover
- The Structure of Scientific Revolutions, by Thomas Kuhn
- <u>Gödel, Escher, Bach: An Eternal Golden Braid</u>, by Douglas Hofstadter
- <u>The Logic of Scientific Discovery</u>, by Karl Popper
- Information at <<u>http://spaf.cerias.purdue.edu/grads.html</u>>