

Lecture 3: Empirical Studies

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The Scientific Method

“History of science is a story of a continuous attempt to use the scientific method to arrive at a rational comprehension of the world we live in and to construct a logically consistent picture of that world.”

The Scientific Method

- ➔ More a philosophical outlook than a single fixed procedure
- ➔ Not one thing but many things
- ➔ Explanatory, predictive, descriptive
- ➔ Arsenal of methods:
 - ↳ Logical
 - ↳ Mathematical
 - ↳ Instrumentive

Some Characteristics of Science

- ➔ **Relies on methods of empirical enquiry**
 - ↳ Not armchair theorizing
 - ↳ Not political/religious persuasion
 - ↳ Not personal positioning

- ➔ **Characterized by**
 - ↳ Domain specific rhetoric, technical terms
 - ↳ Various kinds of analyses
 - ↳ Hypotheses and theories
 - ↳ Methodological standards based on logic and experience

- ➔ **Goal for the course is to determine what is appropriate for empirical SWE**

Some Characteristics of Science

➔ A number of hidden assumptions or regulative principles

↪ Strict determinism

- Carry over from classical physics
- A causal law for every behavior/action

↪ Heisenberg: uncertainty, probabilistic

↪ Behavioral sciences:

- Not strictly deterministic, but variable

- ✓ Conscious events

- ✓ Voluntary decisions vary from person to person

➔ Explanations are based on observations

↪ A way of thinking

↪ Relationships are perceptible in a way that has to make sense given accepted truths

➔ Creativity is as important as in art

↪ Hypotheses, experimental designs

↪ Search for elegance, simplicity

Some Characteristics of Science

- ➔ **There are limits, boundaries - eg,**
 - ↳ Cognitive capacity to visualize/express our experiences fully
 - ↳ Natural limits - bending elbow backwards
 - ↳ Logical and temporal boundaries of certain empirical methods
 - ↳ Some aspects of reality are always beyond the bounds of particular methods

- ➔ **All scientific enquiry is subject to error**
 - ↳ Be aware of it
 - ↳ Study its sources in order to reduce it
 - ↳ Eliminate/reduce the magnitude of such errors in our findings

- ➔ **Sometimes success occurs only all the rules are broken and new rules created**

Behavioral Sciences

➔ Umbrella concepts for fields traditionally grouped together

- ↪ Behavior of people in various contexts
- ↪ Differences in these various contexts

➔ Traditional areas

- ↪ Cultural anthropology: most macro, societal systems
- ↪ Sociology: macro, relationships among groups
- ↪ Social psychology: micro, interpersonal behavior
- ↪ Personal psychology: most micro, traits, dispositions

➔ Traditional differences in tactics

- ↪ Sociologists use questionnaires and survey sampling procedures
- ↪ Social psychologists prefer controlled experiments
- ↪ Borrowed from each other

Behavioral Sciences

- ➔ **Current trend - more multiplistic**
 - ↪ Multiple methods of observation, explanation
 - ↪ Interdisciplinary, more ecumenical
 - ↪ New fields from combining methods/theories

- ➔ **Not *methodological behaviorism***
 - ↪ Not pure empiricism confined only to fully observable
 - ↪ Allows cognitive functioning as legitimate
 - ↪ Liberalizes what is analyzable

- ➔ **Methods differ but goals are the same**
 - ↪ To describe and explain
 - How and why people think the way they do
 - How and why they feel and think about things

Analogs in SWE

➔ CS/SWE as empirical enquiry

↳ CS: study of phenomena surrounding computers

↳ SWE: study/practice of building software systems

➔ Both experimental, but have unique forms of observation, experience

↳ CS/SWE: Building a new *machine* can be an experiment

➤ Newell & Simon, 1975 Turing Award, CACM 19:3 (3/76)

➤ Poses a question to nature

➤ We observe and experience by

✓ Watching machine in operation

✓ Analyzing and measuring it

➤ Design artifacts that can be opened up and observed

➤ Relate structure to behavior and draw lessons

↳ SWE: Various forms of testing are experiments to test the theory (requirements) and its model (implementation)

➤ Independent and dependent variables

➤ Manipulations

➤ Data collection and analysis

Analogs in SWE

➔ SWE doubly rich

- ↪ Machines/systems execute programs/processes
- ↪ People designing machines
- ↪ People using machines
- ↪ Processes are analogous to machines
 - People use processes
 - People execute processes

➔ Technology

- ↪ Anthropology: families of systems, collections of systems
- ↪ Sociology: systems in context
 - Relationships among systems
 - Centralized, distributed, networked
- ↪ Social psychology: individual systems
 - Component interaction
- ↪ Personal psychology: individual systems
 - Characteristics

Analogs in SWE

➔ People and processes

- ↪ Anthropology: projects and organizations
- ↪ Sociology: interactions among teams, projects, etc
- ↪ Social psychology: interactions
 - People in teams
 - People and technology
- ↪ Personal psychology: traits, dispositions
 - Of developers and managers etc

Empirical Approaches

➔ Three approaches

- ↳ Descriptive
- ↳ Relational
- ↳ Experimental

➔ Descriptive

- ↳ Goal: careful mapping out a situation in order to describe what is happening
- ↳ Necessary first step in any research
 - Provides the basis or cornerstone
 - Provides the what
- ↳ Rarely sufficient - often what to know why or how
- ↳ But often provides the broad working hypothesis

Empirical Approaches

➔ Relational

- ↪ Need at least two sets of observations so that some phenomenon can be related to each other
- ↪ Two or more variables are measured and related to each other
- ↪ Coordinated observations -> quantitative degree of correlation
- ↪ Not sufficient to explain why there is a correlation

➔ Experimental

- ↪ Focus on identification of causes, what leads to what
- ↪ Want *X is responsible for Y*, not *X is related to Y*
- ↪ Experimental group versus control group
- ↪ Watch out for problems

Empirical Approaches

➔ Terms you will find

↳ Predictor and criterion variables

➤ Eg, assessment predicting performance

↳ Construct - an abstract idea that is used as an explanatory concept

➤ Eg, need for social approval

↳ Reliable measurement - consistency

↳ Validity in various forms

Empirical Approaches

➔ Aspects of empirical reasoning

- ↳ Empirical principles: accepted truths justified on the basis of observations
- ↳ Deductive-statistical reasoning - universal laws
- ↳ Inductive-statistical reasoning - probabilistic assertions
 - They deal with uncertainty
 - They are not absolute, invariant rules of nature

➔ Behavioral Sciences are not sufficient to determine exactitude

- ↳ Human values and individual states of mind
- ↳ Unique nature of the situation which is usually not static
- ↳ Historical and social factors

Good Research Practices

- ➔ **Enthusiasm** - an enjoyable endeavor
- ➔ **Open-mindedness** - keen, attentive, inquisitive
- ➔ **Common sense** - avoid looking under the lamppost
- ➔ **Inventiveness** - creative
 - ↪ Not only in experimental work
 - ↪ In resource management as well
- ➔ **Confidence in ones own judgment**
 - ↪ Despite detractors when right
 - ↪ Know when you are wrong
- ➔ **Consistency and care about detail**
 - ↪ No substitute for accuracy - keep complete records, organize and analyses accurately/carefully
- ➔ **Ability to communicate**
 - ↪ Writing is a superb, essential research technique
 - ↪ Make your discoveries known to others
- ➔ **Honesty** - integrity and scholarship