# Course Introduction and Empirical Methods

Idaho State University | Computer Science

Isaac Griffith

CS 6620 - Empirical Software Engineering
Department of Computer Science
Idaho State University



ROAR

# A Thought

"Science, done right, works hard to respect absolutely no authority at all other than experience and empirical data. It never succeeds entirely, but it comes closer and has a better track record than any other method we apes have found for learning about the world around us." – Adam Becker

# Syllabus Review

Idaho State University
Computer Science

# Course Outline

**Part 1:** The Basics

- Wk 01: Introduction
- Wk 02: Measurement, Validity, GQM, and Replication
- Wk 03: Scientific Writing

**Part 3:** Evaluation

- Wk 11: Case Study Discus
- Wk 12: Experiment Discus
- Wk 13: Survey/Interview Discus
- Wk 14: Secondary Study Discus

**Part 2:** Empirical Methods

- Wk 04: Case Studies
- Wk 05: More on Case Studies
- Wk 06: Experiments
- Wk 07: More on Experiments
- Wk 08: Surveys, Focus Groups and Interviews
- Wk 09: Secondary Studies
- Wk 10: Simulations

**Part 4:** Final Project Presentation

- Wk 15: Presentations

ROAR

# Course Evaluation

- Students will be evaluated in the following ways:
  - 60% of your grade is based on the Research Project
  - 28% of your grade is based on discussion leadership (4)
  - 12% of your grade is based on class participation

# Research Project

- As this is a 6000 level graduate course, you are expected to complete an individual research project focused on empirical evaluation within the domain of software engineering.
- The project requires that you apply one of the following 5 research methods:
  - Experiment
  - Case Study
  - Secondary Study (SLR/SMS)
  - Simulation Study
  - Replication Study
- The research you conduct must be novel or present novel results.

Idaho State University
Computer Science

# Research Project

- The research project is subdivided into 3 components each with 2 graded events:
  - Project Topic Selection
    - Topic Selection Report (12.5%)
    - Topic Selection Presentation/Discussion (7.5%)
  - Project Proposal
    - Project Proposal Report (25%)
    - Project Proposal Presentation/Discussion (7.5%)
  - Final Project
    - Final Project Report (40%)
    - Final Project Presentation/Discussion (7.5%)



ROAR

# Conducting Research

Idaho State University
Computer Science

# Is this your research plan?

1. Build a new tool
2. ??
3. Profit



ROAR

# Engineering vs. Science

**Traditional View:**

Scientists…

- Create knowledge
- Study the world as it is
- Are trained in scientific method
- Use explicit knowledge
- Are thinkers

Engineers…

- Apply that knowledge
- Seek to change the world
- Are trained in engineering design
- Use tacit knowledge
- Are doers

Idaho State University
Computer Science

# Engineering vs. Science

**More Realistic View:**

Scientists...

- Create knowledge
- Are problem-driven
- Seek to understand and explain
- Design experiments to test theories
- Prefer abstract knowledge
- But rely on tacit knowledge

Engineers...

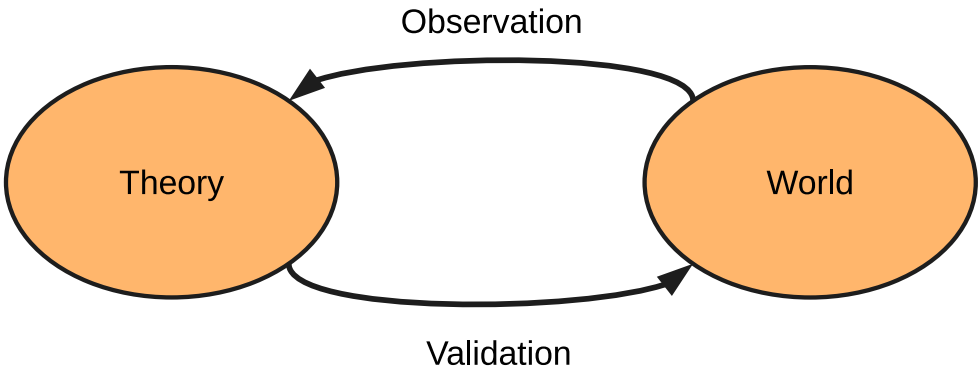
- Create knowledge
- Are problem-driven
- Seek to understand and explain
- Design devices to test theories
- Prefer contingent knowledge
- But rely on tacit knowledge

**Both involve a mix of design and discovery**

ROAR

# Scientific Method

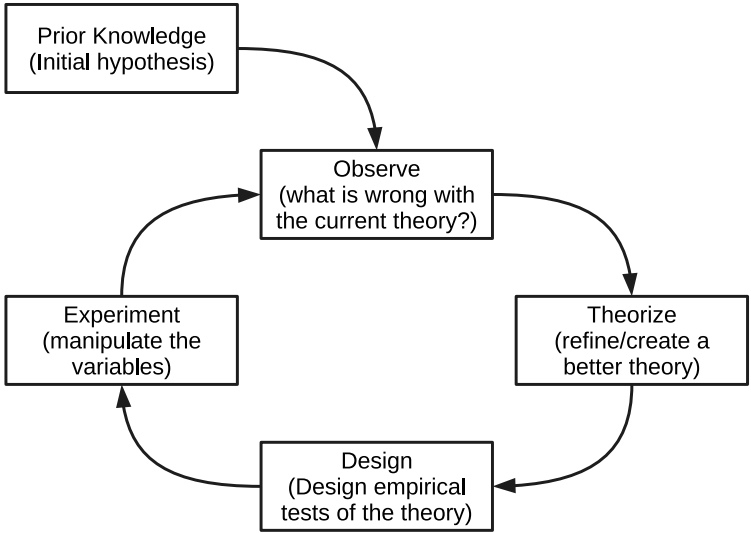
- No single “official” scientific method
- Somehow, scientists are supposed to this:



# Observe!

Idaho State University
Computer Science

# Scientific Inquiry






ROAR

Idaho State University
Computer Science

# Some Characteristics of Science

- Science seeks to improve our understanding of the world.
- Explanations are based on observations
  - Scientific truths must stand up to empirical scrutiny
  - Sometimes “scientific truth” must be thrown out in the face of new findings
- Theory and observation affect one another:
  - Our perceptions of the world affect how we understand it
  - Our understanding of the world affects how we perceive it
- Creativity is important
  - Theories, hypotheses, experimental designs
  - Search for elegance, simplicity

# All Methods are Flawed

- E.g. Laboratory Experiments
  - Cannot study large scale software development in the lab!
  - Too many variables to control them all
- E.g. Case Studies
  - How do we know what's true in one project generalizes to others?
  - Researcher chose what questions to ask, hence biased the study
- E.g. Surveys
  - Self-selection of respondents biases the study
  - Respondents tell you what they think they ought to do, not what they actually do
- ...etc...

Idaho State University
Computer Science

# Strategies to overcome weaknesses

- Theory-building
  - Testing a hypothesis is pointless (single flawed study!)…
  - …unless it builds evidence for a clearly stated theory
- Empirical Induction
  - Series of studies over time…
  - Each designed to probe more aspects of the theory
  - …together build evidence for a clearly stated theory
- Mixed Methods Research
  - Use multiple methods to investigate the same research question
  - Each method compensates for the flaws of the other
  - …together build evidence for a clearly stated theory



ROAR

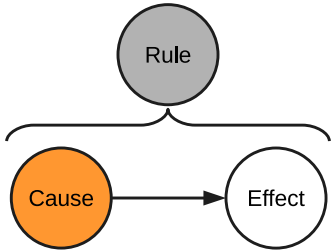
# Reasoning

The 3 Types of Reasoning

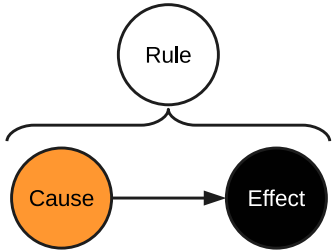
- Deductive - Making an inference based on widely accepted facts or premises
- Inductive - Making an inference based on an observation, often a sample
- Abductive - Making a probable conclusion from what you know.

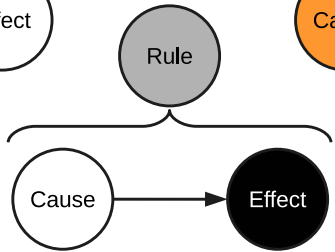
# Reasoning

**Deduction:** Given the rule and the cause, deduce the effect.




**Induction:** Given a cause and an effect, induce a rule.



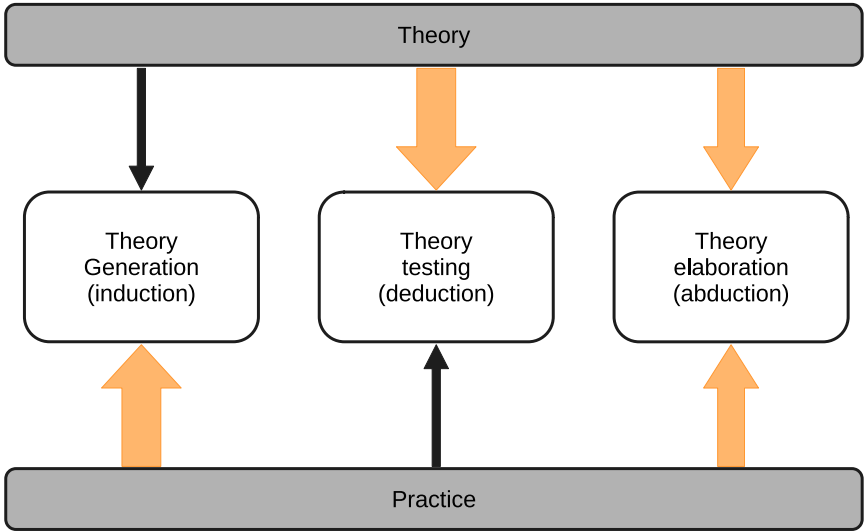

**Abduction:** Given a rule and an effect, abduce a cause.

# Example

- Deduction:
  - Rule: All swans are white
  - Fact: Daisy is a swan
  - Conclusion: Daisy is white
- Induction:
  - Case 1: Daisy is a swan & white
  - Case 2: Danny is a swan & white
  - Case 3: Dante is a swan & white
  - Rule: All swans are white
- Abduction:
  - Rule: All swans are white
  - Case: Daisy is white
  - Conclusion: Daisy is a swan

Idaho State University
Computer Science

# Reasoning and Empiricism

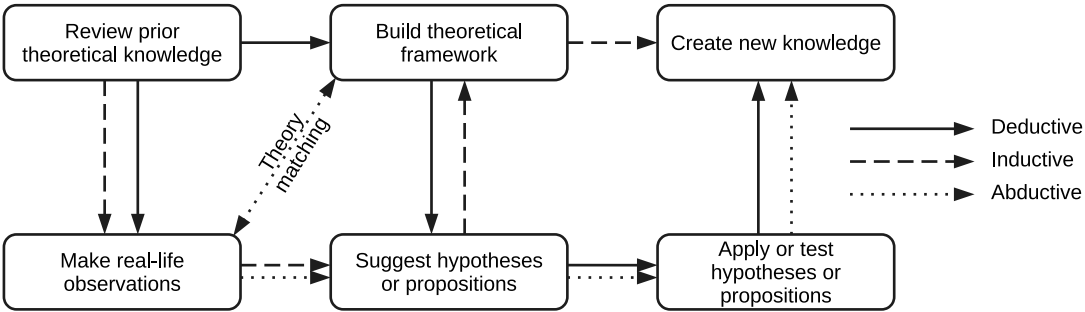





ROAR

Idaho State University
Computer Science

# Reasoning and Empiricism






ROAR

Idaho State University
Computer Science

# What is a research contribution?

- A better understanding of how people use software technology?
- Identification of problems with the current state-of-the-art?
- A characterization of the properties of new tools/techniques?
- Evidence that approach A is better than approach B?

How will you validate your claims?



ROAR

Idaho State University
Computer Science

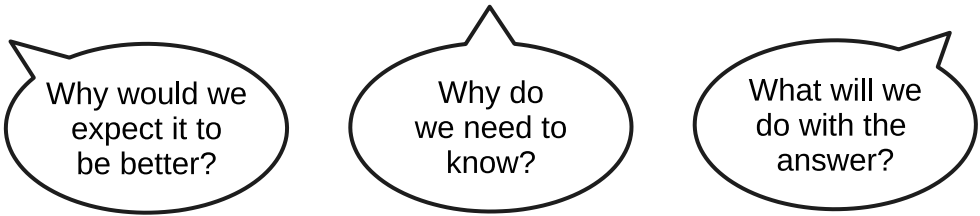
# Thinking about Research

- What was the research question?
  - i.e. “Is tool A better than tool B?”
- What would count as an answer?
- What use would the answer be?
  - How is it a “contribution to knowledge”?
- How does this evaluation relate to the existing literature?

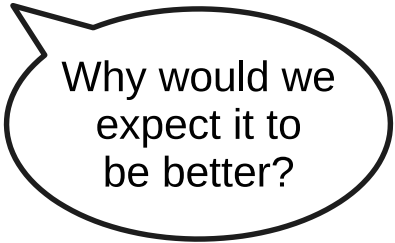


ROAR

# Experiments as Clinical Trials




Is drug A better than drug B?




You gotta have a theory!

# Some Definitions

- A model is an abstract representation of a phenomenon or set of related phenomena
  - Some details included, others excluded
- A theory is a set of statements that explain a set of phenomena
  - Serves to explain and predict
  - Precisely defined terminology
  - Concepts, relationships, causal inferences
  - (operation definitions for theoretical terms)
- A hypothesis is a testable statement derived from a theory
  - A hypothesis is not a theory!
  - It does not predict but simply states how the world apparently is.
- In CS, we have mostly folk theories

# A Simpler Definition

A (good) Theory is the best explanation of all the available evidence

Idaho State University
Computer Science

# The Role of Theory Building

- Theories lie at the heart of what is means to do science.
  - Production of generalizable knowledge
- Theory provides orientation for data collection
  - Cannot observe the world without a theoretical perspective
- Theories allow us to compare similar work
  - Theories include precise definition for the key terms
  - Theories provide a rationale for which phenomena to measure
- Theories support analytical generalization
  - Provide a deeper understanding of our empirical results
  - …and hence how they apply more generally
  - Much more powerful than statistical generalization



ROAR

# What Type of Question are you asking?

- Exploratory
- Baserate
- Correlation
- Causal Relationship
- Design

# Exploratory Questions

- Existence:
  - Does X exist?
- Description and Classification
  - What is X like?
  - What are its properties?
  - How can it be categorized?
  - How can we measure it?
  - What are its components?
- Descriptive-Comparative
  - How does X differ from Y?

# Baserate Questions

- Frequency and Distribution
  - How often does X occur?
  - What is an average amount of X?
- Descriptive-Process
  - How does X normally work?
  - By what process does X happen?
  - What are the steps as X evolves?

# Correlation Questions

- Relationship
  - Are X and Y related?
  - Do occurrences of X correlate with occurrences of Y?

# Causal Relationship Questions

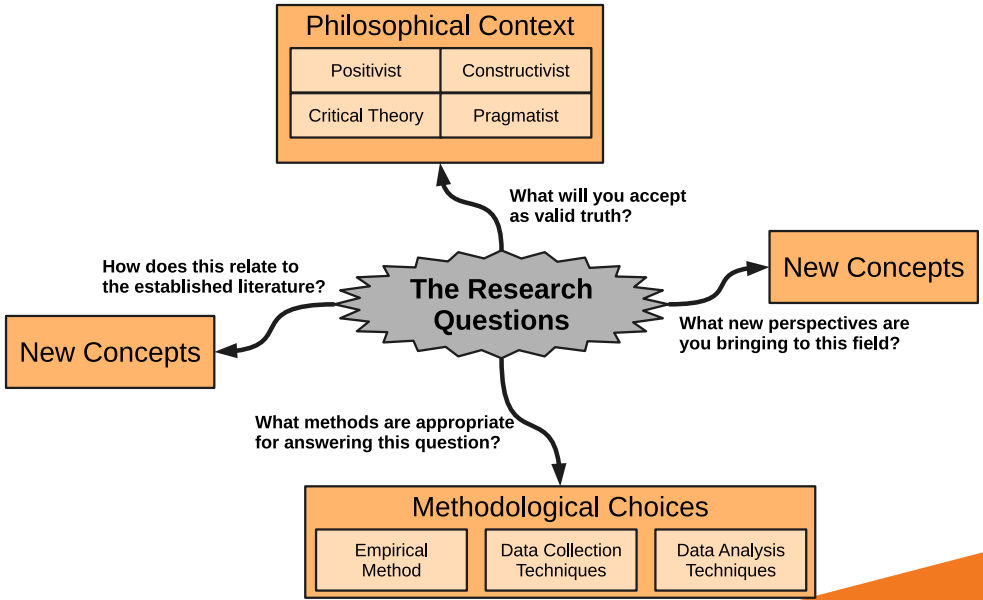
- Causality
  - Does X cause Y?
  - Does X prevent Y?
  - What causes X?
  - What effect does X have on Y?
- Causality-Comparative
  - Does X cause more Y than does Z?
  - Is X better at preventing Y than does Z?
  - Does X cause more Y than does Z under one condition but not others?

# Design Questions

- What is an effective way to achieve X?
- How can we improve X?

Idaho State University
Computer Science

# Putting the Question in Context




ROAR

Idaho State University
Computer Science

# Many Available Methods

## Common “in the lab” methods

- Controlled Experiments
- Rational Reconstructions
- Exemplars
- Benchmarks
- Simulations
- Artifact/Archive analysis (“mining”!)

## Common “in the wild” methods

- Quasi-experiments
- Case studies
- Survey research
- Ethnographies
- Action research



ROAR

# Warning

- No method is perfect
- Don’t get hung up on methodological purity
- Pick something and get on with it
- Some knowledge is better than none

# Why build a tool?

- Build a tool to test a theory
  - Tool is part of the experimental materials needed to conduct your study
- Build a tool to develop a theory
  - Theory emerges as you explore the tool
- Build a tool to explain your theory
  - Theory as a concrete instantiation of (some aspect of) the theory

# Myths about Science

- “It’s just a theory”
  - Theory = “best explanation for the available evidence”
  - Overwhelming evidence doesn’t stop it being a theory…
  - …but lack of evidence does.

Examples:
We have a “law of gravity” …but no “theory of gravity”
We have a “theory of evolution” …but no “law of evolution”

# Myths about Science

- "Scientists follow the scientific method"
  - There is no one method
  - Many methods available…
  - …and all of them have known flaws
  - Scientists use imagination, creativity, prior knowledge, perseverance…
- "Scientific knowledge is general and absolute"
  - Empirical Induction used to build evidence
  - Scientists often get it wrong
  - …but Science (as a process) is self-correcting
  - All scientific laws and theories have limited scope
    - E.g. biological theories probably only apply on our own planet
    - E.g. laws of classical physics don't apply at the subatomic level

# Are there any questions?