

17-803 Empirical Methods

Bogdan Vasilescu, Institute for Software Research

Introduction and Course Overview

Tuesday, February 2, 2021

Welcome to This Rare Course!

- ▶ This is the third time the “modern” version of this course has been offered.
 - ▶ Several offerings of the “classical” version by [Jim Herbsleb](#) and [Marcelo Cataldo](#) in the past.
 - ▶ The current version is much changed.
- ▶ Very few courses like this have been offered anywhere!
 - ▶ Notable exceptions (tell me if you know of more):
 - ▶ [Steve Easterbrook](#) & [Barbara Barbosa Neves](#), “[Empirical Research Methods for CS](#)” at UofT (-2014)
 - ▶ [Sara Kiesler](#) (prev) / [Laura Dabbish](#), “[Applied Research Methods](#)” at CMU (2015+) ([Fall '19 syllabus](#))
 - ▶ [Peggy Storey](#), “[Empirical Software Engineering: Bridging Research and Practice](#)” at UVic (2020+)
 - ▶ [Shurui Zhou](#), “[Empirical Software Engineering](#)” at UofT (2021+)
 - ▶ Particularly notable exception:
 - ▶ [Carl Bergstrom](#) & [Jevin West](#), “[Calling Bullshit: Data Reasoning in a Digital World](#)” at UW (2019+)

Outline for Today

- ▶ Introduction to the topic
- ▶ Introduction to each other
- ▶ Course logistics

Is This Your Research Plan?

- ▶ You are trying to **understand** how software engineers / designers / ... work and what challenges they face.
- ▶ You have identified some challenges (e.g., working more productively) and are looking to **inform the design** of possible solutions.
- ▶ You have creating a new algorithm / tool / process / programming language / system / ... and are looking to **evaluate** it.
- ▶ ...

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- ▶ ...

How to collect data?
How to analyze it?

How to collect evidence that
approach A is better than B?

How to draw conclusions?
What constitutes sufficient
evidence?



“Ladies and gentlemen of the jury, let me present the alternative facts of the case.”

No matter your reasons for doing a study,

How To Validate Your Claims?

* Maybe the most common reason why papers get rejected

Summary of This Course: **“It Depends”**

This Is Where Empirical Methods Come in

- ▶ A diversity of methods are available.
- ▶ They're used in many forms and phases of research.
 - ▶ Understand problem
 - ▶ Current practice
 - ▶ Demonstrate utility of solution
- ▶ Each method has its own standards and techniques for rigor.

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Bad news:

- All methods are flawed

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Good news:

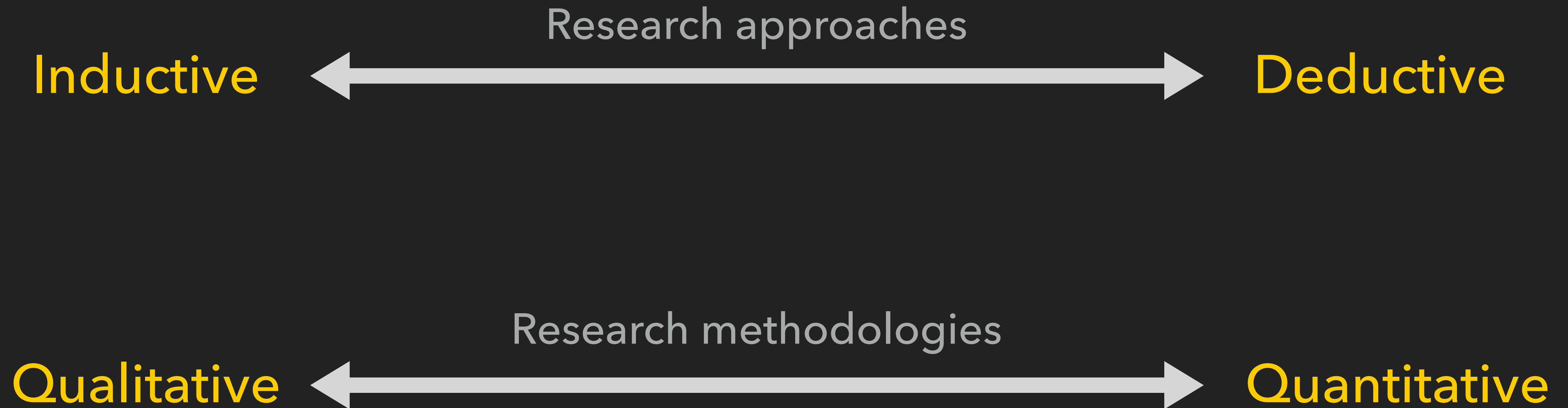
- When applied correctly, they can be useful.

Selection of Methods Depends on:

- ▶ Approach to Research
- ▶ Nature of Contribution
- ▶ Specific Research Question
- ▶ State of Knowledge
- ▶ ...

One Way To Think About Research Approaches and Methods

Research Exists Across Multiple Continua. Two Examples:



The (Objectivist) Deductive Approach to Research

- ▶ Traditional form of research, also referred to as *the scientific method*, or *empirical science*
- ▶ Assumptions:
 - ▶ (1) there is an external reality (i.e., a real world that exists independent of the researcher)
 - ▶ (2) reality can be understood by collecting objective, unbiased data about that reality
- ▶ Knowledge builds by developing increasingly better understandings of, and insights into, the causal workings of the world



The (Objectivist) Deductive Approach to Research

- ▶ Reductionistic in nature (top-down):
 - ▶ From general, abstract conceptualizations to observable and measurable data in some context
- ▶ Research questions: testing a cause-and-effect relationship underpinning a phenomenon
- ▶ Typical approach:
 - ▶ Start with some abstract conceptualization (theory)
 - ▶ Derive a hypothesis
 - ▶ Collect data, test the hypothesis
 - ▶ Findings may falsify, support, refine, challenge, or extend the conceptualization
 - ▶ Make necessary revisions, perform additional tests
- ▶ Common method: experiments



The (Subjectivist) Inductive Approach to Research

- ▶ Assumptions:
 - ▶ (1) reality is socially and experientially constructed (i.e., reality exists because individuals and social groups share interpretations and understandings of reality);
 - ▶ (2) to understand reality, researchers need to explore the meanings constructed by individuals and groups.
- ▶ Constructivist in nature (bottom-up):
 - ▶ From specific data to a general or abstract conceptualization of the phenomenon (theory).
- ▶ Knowledge is subjective.
- ▶ Collecting data from a multitude of perspectives gives a richer and more nuanced understanding of the phenomenon.



The (Subjectivist) Inductive Approach to Research

- ▶ Research questions: explore phenomena to increase our understanding of them.
- ▶ Typical approach:
 - ▶ Start with a desire to understand or explain a particular phenomenon.
 - ▶ Collect data of and/or about this phenomenon.
 - ▶ Search for patterns across the data to generate an understanding of the phenomenon.
- ▶ Common methods: interviews, focus groups, observations.



The Types of Beliefs Held by Researchers (“Philosophical Worldviews”) Influence the Practice of Research and Choice of Methods

Positivist (or “Post-positivist”)

- Knowledge is objective
- “Causes determine effects/outcomes”
- Reductionist: study complex things by breaking down to simpler ones
- Prefer quantitative approaches
- **Verifying (or Falsifying) theories**



Objectivist Deductive

Constructivist / Interpretivist

- Knowledge is socially constructed
- Truth is relative to context
- Theoretical terms are open to interpretation
- Prefer qualitative approaches
- **Generating “local” theories**



Subjectivist Inductive

Four Philosophical Worldviews Are Commonly Encountered

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Advocate / Critical Theorist

- Research is a political act
- Knowledge is created to empower groups/individuals
- Choose what to research based on who it will help
- Prefer participatory approaches
- **Seeking change in society**

Constructivist / Interpretivist

- Knowledge is socially constructed
- Truth is relative to context
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- **Generating "local" theories**

Pragmatist

- Research is problem-centered
- "All forms of inquiry are biased"
- Truth is what works at the time
- Prefer multiple methods / multiple perspectives
- **Seeking practical solutions to problems**

Q: Which Do You Subscribe to?

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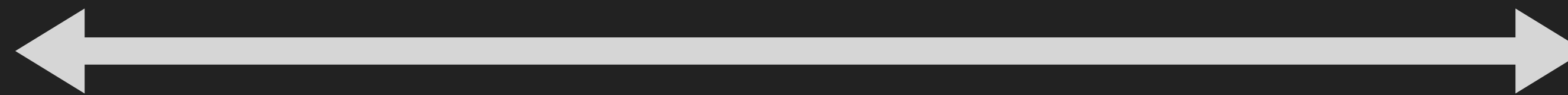
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Another Few Ways of Thinking About How Methods Are Related

Qualitative



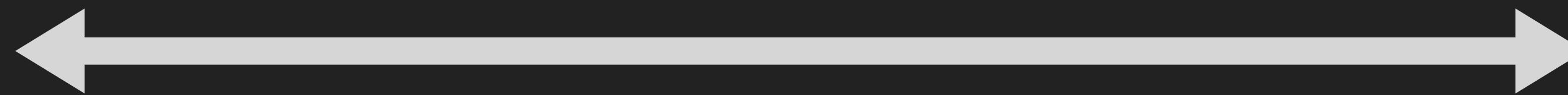
Quantitative

Very little prior knowledge:
"What's going on?"

Extensive prior knowledge:
"Precisely how is this different?"

Another Few Ways of Thinking About How Methods Are Related

Qualitative



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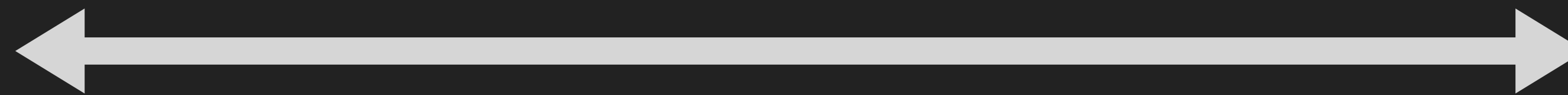
Extensive prior knowledge:
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Rich

Precise

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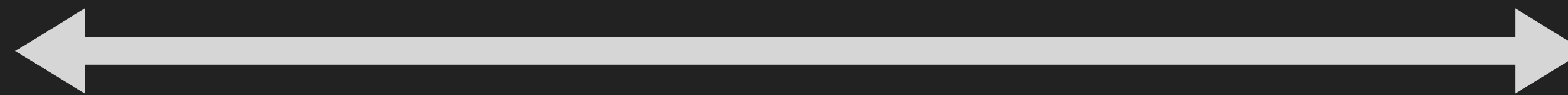
Precise

Reliance on human interpretation

Reliance on decision rules

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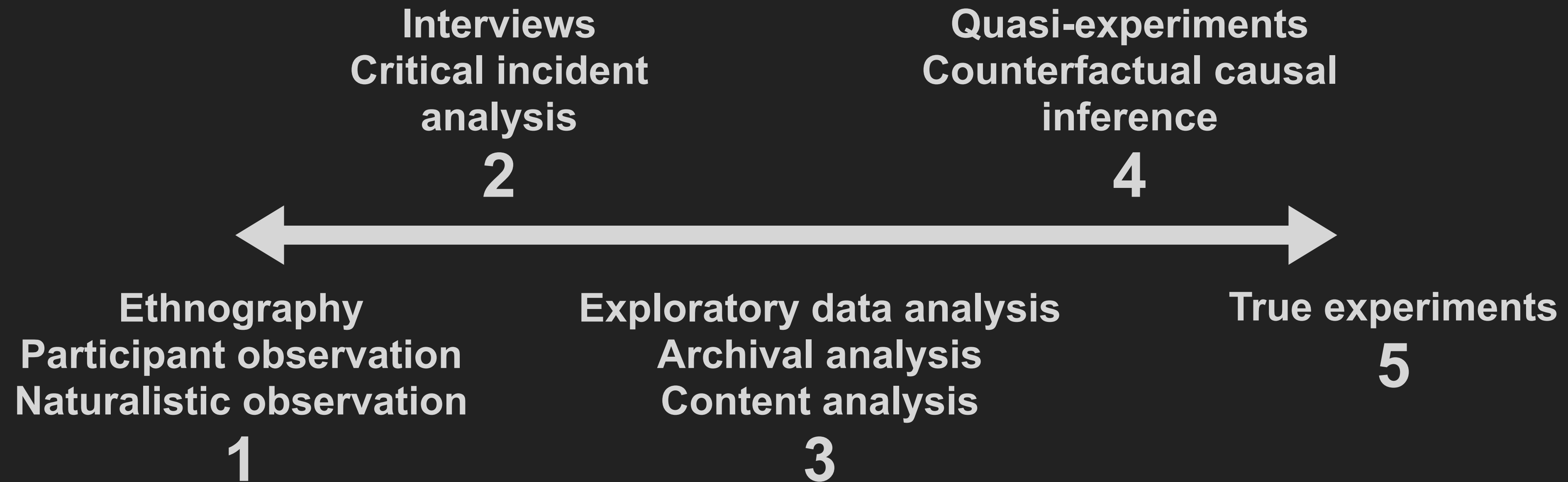
Precise

Reliance on human interpretation

Reliance on decision rules

- ▶ Often most effective to use methods in combination or in sequence (rich to precise)

Points on the Spectrum



Example: Ethnography Rich Precise

- ▶ What is it?
 - ▶ Immersion in the environment, group
 - ▶ Attempt to see the world through their eyes
- ▶ What questions can it answer?
 - ▶ How do the participants think about their work?
 - ▶ What are the problems?
- ▶ What makes it rigorous?
 - ▶ Constantly testing interpretations
 - ▶ Triangulation – multiple sources of data

Example: Ethnography Rich Precise

- ▶ What contributions can it support?
 - ▶ Problem as seen by persons of interest
 - ▶ Work in context
- ▶ What are its limitations?
 - ▶ May get trapped by participants' perceptions
 - ▶ Small samples, no causality
- ▶ What resources are needed?
 - ▶ Time and labor intensive
 - ▶ Access to right people
 - ▶ Willingness and ability to join group

Example: Interviews Rich Precise

- ▶ What is it?
 - ▶ Structured interaction
 - ▶ Questions, answers, followup
- ▶ What questions can it answer?
 - ▶ Perceptions, opinions, processed observations
 - ▶ How things are done, exceptions, problems
- ▶ What makes it rigorous?
 - ▶ Preparation with well thought-out topics
 - ▶ Cross-validation in questions, interviewees, checking interpretations

Example: Interviews **Rich** Precise

- ▶ What contributions can it support?
 - ▶ Nature of problem, as perceived, current process
 - ▶ Examples, exceptions, incidents
- ▶ What are its limitations?
 - ▶ Information is processed, filtered by interviewees
 - ▶ May be inappropriately biased by questions
- ▶ What resources are needed?
 - ▶ Willing interviewees, correctly positioned
 - ▶ Ability to sample all relevant perspectives
 - ▶ Preparation, follow-up

Example: Quasi-Experiment Rich Precise

- ▶ What is it?
 - ▶ Naturally-occurring differences
 - ▶ Examination of effects of variables in situ
- ▶ What questions can it answer?
 - ▶ What are the effects of introducing X?
 - ▶ What is the difference between X and Y?
- ▶ What makes it rigorous?
 - ▶ Good quasi-control groups
 - ▶ Access to data for control variables

Example: Quasi-Experiment Rich Precise

- ▶ What contributions can it support?
 - ▶ Value of tool, method, process, training
 - ▶ Influence of context factors
- ▶ What are its limitations?
 - ▶ Never sure cause-effect relation is established
 - ▶ Relying on luck, that situation occurs naturally
- ▶ What resources does it take to do it well?
 - ▶ Sophisticated statistics (e.g., multiple regression)
 - ▶ Contextual knowledge of experimental situation

Example: True Experiment Rich Precise

- ▶ What is it?
 - ▶ Comparison that is engineered
 - ▶ Random assignment of values of independent vars
- ▶ What questions can it answer?
 - ▶ Cause and effect
 - ▶ Size of effect, interaction of factors
- ▶ What makes it rigorous?
 - ▶ Well designed experimental and control conditions
 - ▶ Attention to reliability, validity

Example: True Experiment Rich Precise

- ▶ What contributions can it support?
 - ▶ Value of tool, method, process, training
 - ▶ Influence of context factors
- ▶ What are its limitations?
 - ▶ Must be able to isolate critical variables
 - ▶ Limited by ability to create situations that manipulate people
- ▶ What resources does it take to do it well?
 - ▶ Access to appropriate subjects
 - ▶ Statistics, measurement instruments

All Methods Are Flawed

This course teaches strategies to overcome weaknesses

Course Overview

Coordinates



- ▶ Instructor: Bogdan Vasilescu, ISR
- ▶ Class meets twice a week, Tuesdays / Thursdays 2:20-3:40pm, Zoom
- ▶ Communication: Slack & email
- ▶ Materials:
 - ▶ Most public on course webpage: <https://bvasiles.github.io/empirical-methods>
 - ▶ Assignments / private on Canvas

Guiding Principle: Prioritize Supporting Each Other as Humans



Format

- ▶ Seminar style
- ▶ Most work happens on your own, outside class
 - ▶ Curated readings, due each class
 - ▶ Method descriptions, how-tos, standard of rigor (the “theory”)
 - ▶ Example research papers applying that method (the “practice”)
- ▶ Typical class:
 - ▶ Lecture/discussion of a new method, summarizing the readings (Bogdan)
 - ▶ In-class practice with the method (everyone)
 - ▶ Presentations of the example papers (students) – sign up sheet

Three Sets of Homework Assignments

- ▶ (1) A **research project** using empirical component(s) from the course
 - ▶ Deliverables:
 - ▶ Short **kick-off presentation + video** (~1 month in)
 - ▶ Research question(s), overview of study design, rough plan for data collection and analysis
 - ▶ **Final report**
 - ▶ Thorough literature review, detailed description of methods, results, discussion

Notes:

- ▶ Should be of publishable quality
- ▶ Final report will be graded as research proposal (i.e., okay if results are preliminary)
 - ▶ Grading based on motivation, soundness of methodology, quality of writing
- ▶ Individual / pairs both ok
 - ▶ But: clear description of contributions
- ▶ Best if aligned with your current research
 - ▶ Alternatively, I have some cool bibliometrics data you can use for a quant-flavored project
 - ▶ Alternatively, talk to me about your idea for a data source

Three Sets of Homework Assignments

- ▶ (2) Occasional **small assignments** throughout the semester, to get hands-on experience with some of the methods.
 - ▶ For example:
 - ▶ Design an interview protocol or a survey instrument
 - ▶ Apply a particular statistical analysis technique to an existing dataset
- ▶ (3) **Blog posts** summarizing the assigned example research papers and the main critique points.
 - ▶ Will be posted publicly on the course website.

Grading

- ▶ 50% research project
 - ▶ 10% kick-off presentation
 - ▶ 10% final presentation
 - ▶ 30% final report
- ▶ 30% blog posts and in-class presentations
- ▶ 20% other homework assignments

Tentative Schedule

Date	Topic
Tue, Feb 2	Introduction
Thu, Feb 4	Literature reviews. Formulating research questions
Tue, Feb 9	The role of theory
Thu, Feb 11	Conducting interviews
Tue, Feb 16	Qualitative data analysis (part I - coding)
Thu, Feb 18	Qualitative data analysis (part II - reliability, trustworthiness)
Tue, Feb 23	Break Day; No Classes
Thu, Feb 25	Designing surveys
Tue, Mar 2	Designing experiments
Thu, Mar 4	Intro to measurement. Basic statistics
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Thu, Apr 1	Causal inference part 2 (causal impact)
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Thu, Apr 8	Big data vs thick data
Tue, Apr 13	Researchers are human, too
Thu, Apr 15	Spring Carnival; No Classes
Tue, Apr 20	Agree to disagree
Thu, Apr 22	Stepping up your typesetting and graphics game
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What This Class Is and Isn't About

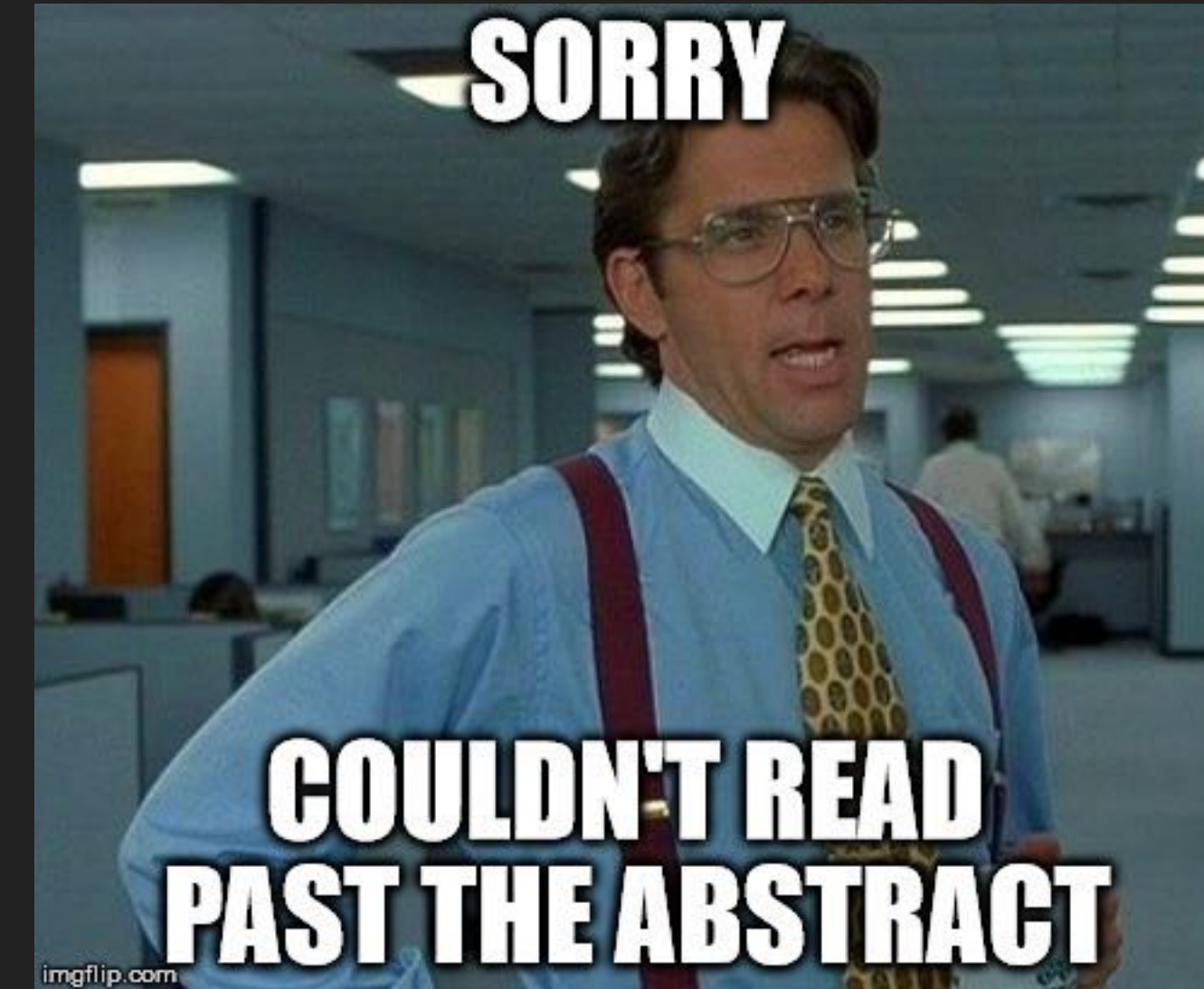
- ▶ This class is not about software engineering.
 - ▶ In fact, this is more a **science class** than a class about any CS discipline.
 - ▶ But because I am most familiar with SE, you will see many readings from SE venues.
 - ▶ No prior knowledge of SE or SE research experience is expected to digest these.

What This Class Is and Isn't About

- ▶ This class is ~~secretly~~ about **communication**.
 - ▶ You will practice:
 - ▶ Articulating what the problem is
 - ▶ Articulating why the problem is important
 - ▶ Articulating your vision and plan for solving the problem
 - ▶ Disseminating (your) results
 - ▶ Oral presentations throughout the semester
 - ▶ Blog posts
 - ▶ A research project report at the end
 - ▶ Effective (oral & written) communication is:
 - ▶ Necessary for successful research
 - ▶ Much harder than you think

What This Class Is and Isn't About

- ▶ This class is ~~secretly~~ about **peer review**.
 - ▶ You will read and critique (in writing) many research papers throughout the semester



What This Class Is and Isn't About

- ▶ This class is ~~secretly~~ about **developing a healthy dose of skepticism.**
 - ▶ All fields of science use (the same) empirical methods
 - ▶ By learning about empirical research in CS you'll also get better at recognizing strengths and weaknesses in any scientific paper
 - ▶ Tune your scientific BS meter!

Anecdotal evidence reliable? One man says "yes".

A STUDY CONDUCTED YESTERDAY by a man on himself concluded that self-reported anecdotal evidence is, in fact, both reliable and relevant.

The landmark study, conducted by Mark Mattingly of Virginia Beach in his apartment, concluded with 100% accuracy that data collected from personal experience can disprove other data conducted by reputable scientific institutions, thereby proving once and for all that "statistics can't be trusted".

In a press release Mr. Mattingly took aim at his detractors saying that "...this study shows what I've been telling people on the internet for years: all your fancy evidence and statistics don't mean nothing in the real world."

A frequenter of internet forums, comment sections, and social media, Mr. Mattingly recounts that he was inspired to undertake the study when someone reportedly kept insisting that he provide evidence for his claims. "I think everyone's entitled to an opinion, and that my opinion is worth just as much as anyone else's" Mr. Mattingly said.

Academic types have criticised the study, and papers who are publishing it, saying that it lacks everything and makes no sense. When shown the study, Emeritus Professor James Albrecht of Carnegie Mellon University looked all confused and hopeless before making pining, guttural sounds.



Mr. Mattingly in his apartment looking all smug.

Mr. Mattingly has responded saying that this is just the first of many studies he intends to conduct, and that a meta-analysis of people who have opinions and anecdotal experiences independent of controls, methodological rigor, blinding and peer review are soon to be published, adding further weight to his initial findings.

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Photo: Weasello

Skeptics Are Welcome!



"I tend to prefer formal methods and **really did not like the survey and interview portions of the class** [as] I would **never need these methods in the real-world.**

So, I just started a new job this fall, and [...] I got assigned to [do X]. As I pondered this, I realized, albeit begrudgingly, that this would be a great opportunity to do a survey. So, **having just arrived in the real-world from doing a Ph.D., one of my first studies has been to design and implement a survey...**

I thought you might appreciate hearing that story, both because I am no-kidding using the skills you taught me (whether I liked it or not) and because the irony is pretty rich."

Summary:

All Methods Are Flawed

Selection of Methods Depends on:

- ▶ Philosophical Worldview
- ▶ Approach to Research
- ▶ Nature of Contribution
- ▶ Specific Research Question
- ▶ State of Knowledge
- ▶ ...

Credits

▶ Graphics:

- ▶ New Yorker magazine cartoons
- ▶ “This if fine” meme by K.C. Green
- ▶ Steve Easterbrook slides

▶ Content:

- ▶ Chapter 1 - Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- ▶ Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, 95(7), 989-994.
- ▶ Young, M., Varpio, L., Uijtdehaage, S., & Paradis, E. (2020). The spectrum of inductive and deductive research approaches using quantitative and qualitative data. *Academic Medicine*, 95(7), 1122.

Bonus Slides

Q: What's the Relationship?

Does Inductive \rightarrow Qualitative? Deductive \rightarrow Quantitative?



A: No. These Perspectives Are Frequently (and Falsely) Conflated

Inductive approaches to research

Deductive approaches to research

Quantitative (numerical) data

Qualitative (non-numerical) data

Exploratory factor analysis¹:

A set of statistical techniques, typically applied to assessment- or survey-generated data, that identifies the underlying theoretical constructs (i.e., “factors”) of the phenomena of interest, which researchers then name inductively.

Traditional grounded theory²:

A research methodology aimed at generating a local theory using qualitative data collected with participants. The researcher acts as a tabula rasa (blank slate), making sense of a phenomenon without biasing that interpretation.

Structural equation modeling³:

A set of approaches to analysis whereby several statistical models are built based on theory and then tested with an appropriate dataset. The model that best fits the data is considered superior.

Ethnography⁴:

This approach often combines existing exploratory theories about human social behavior and collects data to observe and describe the culture of a group.

Bayesian approaches to analysis⁵:

These analytic approaches use previous knowledge, available data, or beliefs, to acknowledge the a priori likelihood of findings. The strength of prior evidence influences analysis.

Constructivist grounded theory⁶:

This approach analyzes data with the goal of contributing to previous understandings of a phenomenon, building explicitly on others’ work.

Analysis of hypothesis-driven experimental studies¹:

Among the most familiar, these approaches result in a test of significance, which leads to the rejection of, or failure to reject, the null hypothesis (that the findings are due to chance).

Deductivist content analysis⁷:

Qualitative data are analyzed using a predetermined theory or theoretical framework, to find examples of constructs and support or challenge them.

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