

## Planning Checklist

- ✓ Pick a topic
- Identify the research question(s)
- Check the literature
- Identify your philosophical stance
- Identify appropriate theories
- Choose the method(s)
- Design the study
  - Unit of analysis?
  - Target population?
  - Sampling technique?
  - Data collection techniques?
  - Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## What type of question are you asking?

- Existence:
  - Does X exist?
- Description & 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?
- 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?
- Relationship
  - Are X and Y related?
  - Do occurrences of X correlate with occurrences of Y?
- 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 is Z?
  - Does X cause more Y than does Z under one condition but not others?
- Design
  - What is an effective way to achieve X?
  - How can we improve X?



## What type of question are you asking?

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li>○ Existence:                     <ul style="list-style-type: none"> <li>● Does X exist?</li> </ul> </li> <li>○ Description &amp; Classification                     <ul style="list-style-type: none"> <li>● What is X like?</li> <li>● What are its properties?</li> <li>● How can it be categorized?</li> <li>● How can we measure it?</li> <li>● What are its components?</li> </ul> </li> <li>○ Descriptive-Comparative                     <ul style="list-style-type: none"> <li>● How does X differ from Y?</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>○ Relationship                     <ul style="list-style-type: none"> <li>● Are X and Y related?</li> <li>● Do occurrences of X correlate with occurrences of Y?</li> </ul> </li> </ul>   |
| <ul style="list-style-type: none"> <li>○ Frequency and Distribution                     <ul style="list-style-type: none"> <li>● How often does X occur?</li> <li>● What is an average amount of X?</li> </ul> </li> <li>○ Descriptive Process                     <ul style="list-style-type: none"> <li>● How does X normally work?</li> <li>● By what process does X happen?</li> <li>● What are the steps as X evolves?</li> </ul> </li> </ul>   | <ul style="list-style-type: none"> <li>○ Causality                     <ul style="list-style-type: none"> <li>● Does X cause Y?</li> <li>● Does X prevent Y?</li> <li>● What causes X?</li> <li>● What effect does Y have on Y?</li> </ul> </li> <li>○ Causality-Comparative                     <ul style="list-style-type: none"> <li>● Does X cause more Y than does Z?</li> <li>● Is X better at preventing Y than is Z?</li> <li>● Does X cause more Y than does Z under one condition but not others?</li> </ul> </li> </ul> |
|  | <ul style="list-style-type: none"> <li>○ Design                     <ul style="list-style-type: none"> <li>● What is an effective way to achieve X?</li> <li>● How can we improve X?</li> </ul> </li> </ul>  |



## Putting the Question in Context

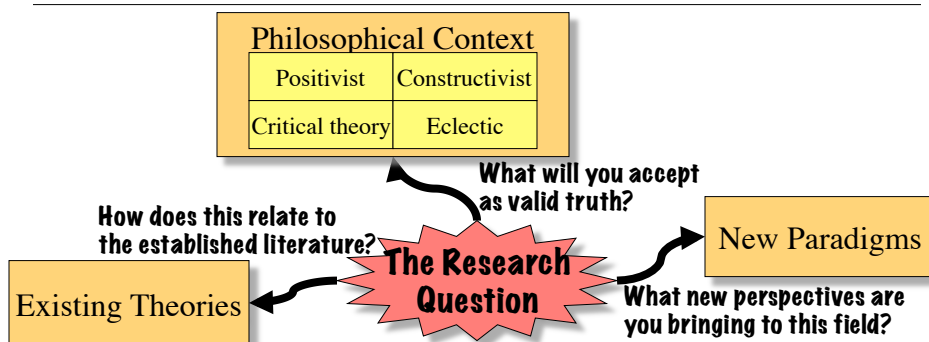


## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- Identify your philosophical stance
- Identify appropriate theories
- Choose the method(s)
- Design the study
  - Unit of analysis?
  - Target population?
  - Sampling technique?
  - Data collection techniques?
  - Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Putting the Question in Context



## What will you accept as knowledge?

### ○ 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

### ○ Constructivist/Interpretivist

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

### ○ 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

### ○ Eclectic/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



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- Identify appropriate theories
- Choose the method(s)
- Design the study
  - Unit of analysis?
  - Target population?
  - Sampling technique?
  - Data collection techniques?
  - Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Identify Appropriate Theories

- Where do theories come from?



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

26

## The Theoretical Lens

- Our Theories impact how we see the world
  - Real-world phenomena too rich and complex
  - Need a way of filtering our observations
  - The theory guides us, whether it is explicitly stated or not
- In Quantitative Methods:
  - Theoretical lens tells you what variables to measure...
  - ...and which to ignore or control
- In Qualitative Methods:
  - Theoretical lens usually applied after data is collected
  - ...and used to help with labeling and categorizing the data



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

27

## Theories are good for generalization...

### Statistical Generalization

- Generalize from sample to population
- Can only be used for quantifiable variables
- Based on random sampling:
  - Test whether results on a sample apply to the whole population
- Not useful when:
  - You can't characterize the population
  - You can't do random sampling
  - You can't get enough data points

### Analytical Generalization

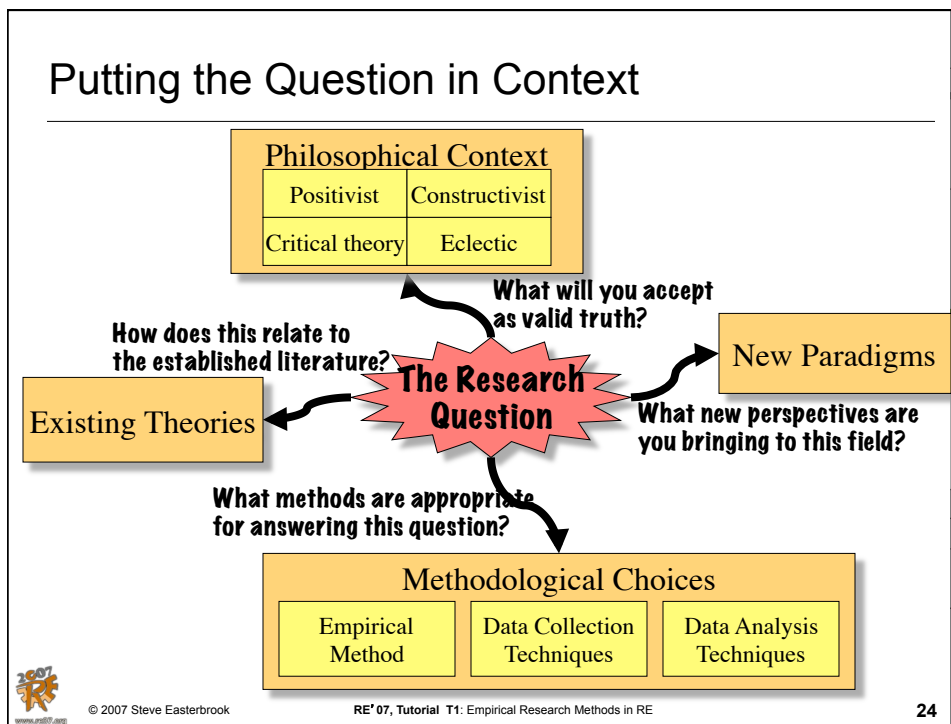
- Generalize from findings to theory
- Applicable to quantitative and qualitative studies
- Compares findings with theory
  - Do the data support/refute the theory?
  - Do they support this theory better than rival theories?
- Supports empirical induction:
  - Evidence builds if subsequent studies also support the theory
- More powerful than stats
  - Doesn't rely on correlations
  - Examines underlying mechanisms



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- Choose the method(s)
- Design the study
  - Unit of analysis?
  - Target population?
  - Sampling technique?
  - Data collection techniques?
  - Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate





## Choose a Method...

- **Exploratory**  
Used to find new theories where we don't have any yet
  - E.g. What do CMM level 3 organizations have in common?
  - E.g. What are the experiences of developers who have adopted Ruby?
- **Causal**  
Determines whether there are causal relationships between phenomena
  - E.g. Does tool X lead to software with fewer defects?
  - E.g. Do requirements traceability tools help programmers find information more rapidly?
- **Descriptive**  
Describes sequence of events and underlying mechanisms
  - E.g. How does pair programming actually work?
  - E.g. How do software immigrants naturalize?
- **Explanatory**  
Adjudicates between competing explanations (theories)
  - E.g. Why does software inspection work?
  - E.g. Why do people fail to document their requirements?

© 2007 Steve Easterbrook RE'07, Tutorial T1: Empirical Research Methods in RE 28

## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - Unit of analysis?
  - Target population?
  - Sampling technique?
  - Data collection techniques?
  - Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Unit of Analysis

- Defines what phenomena you will analyze
  - Choice depends on the primary research questions
  - Choice affects decisions on data collection and analysis
  - Hard to change once the study has started (but can be done if there are compelling reasons)
  - If possible, use same unit of analysis as previous studies (why?)
- Often many choices:
  - E.g. for an exploratory study of extreme programming:
    - Unit of analysis = individual developer (study focuses on a person's participation in the project)
    - Unit of analysis = a team (study focuses on team activities)
    - Unit of analysis = a decision (study focuses on activities around that decision)
    - Unit of analysis = a process (study examines how user stories are collected and prioritized)
    - ...



## Examples of Units of Analysis

- For a study of how software immigrants naturalize
  - Individuals?
  - ... or the Development team?
  - ... or the Organization?
- For a study of pair programming
  - Programming episodes?
  - ... or Pairs of programmers?
  - ... or the Development team?
  - ... or the Organization?
- For a study of software evolution
  - A Modification report?
  - ... or a File?
  - ... or a System?
  - ... or a Release?
  - ... or a Stable release?



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

31

## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
    - Target population?
    - Sampling technique?
    - Data collection techniques?
    - Metrics for key variables?
    - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

21

## Target Population

- Determines scope of applicability of your results
  - If you don't define the target population...
  - ...nobody will know whether your results apply to anything at all
- From what population are your units of analysis drawn?
  - UoA = "developer using XP"
  - Population =
    - All software developers in the world?
    - All developers who use agile methods?
    - All developers in Canadian Software Industry?
    - All developers in Small Companies in Ontario?
    - All students taking SE courses at U of T?
- Choice closely tied to choice of sampling method...



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
    - Sampling technique?
    - Data collection techniques?
    - Metrics for key variables?
    - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Sampling Method

- Used to select representative set from a population
  - Simple Random Sampling - choose every kth element
  - Stratified Random Sampling - identify strata and sample each
  - Clustered Random Sampling - choose a representative subpopulation and sample it
  - Purposive Sampling - choose the parts you think are relevant without worrying about statistical issues
- Sample Size is important
  - balance between cost of data collection/analysis and required significance
- Process:
  - Decide what data should be collected
  - Determine the population
  - Choose type of sample
  - Choose sample size



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

33

## Purposive Sampling

- Typical Case
  - Identify typical, normal, average case
- Extreme or Deviant Case
  - E.g outstanding success/notable failures, exotic events, crises.
- Critical Case
  - if it's true of this one case it's likely to be true of all other cases.
- Intensity
  - Information-rich examples that clearly show the phenomenon (but not extreme)
- Maximum Variation
  - choose a wide range of variation on dimensions of interest
- Homogeneous
  - Instance has little internal variability - simplifies analysis
- Snowball or Chain
  - Select cases that should lead to identification of further good cases
- Criterion
  - All cases that meet some criterion
- Confirming or Disconfirming
  - Exceptions, variations on initial cases
- Opportunistic
  - Rare opportunity where access is normally hard/impossible
- Politically Important Cases
  - Attracts attention to the study
- ...Or any combination of the above



**Do not use:** Convenience sampling

- Cases that are easy/cheap to study
- low credibility!



© 2007 Steve Easterbrook

RE'07, Tutorial T1: Empirical Research Methods in RE

34

## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
    - Data collection techniques?
    - Metrics for key variables?
    - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Data Collection Techniques

- Direct Techniques
  - Brainstorming and Focus Groups
  - Interviews and Questionnaires
  - Conceptual Modeling
  - Work Diaries
  - Think-aloud Sessions
  - Shadowing and Observation
  - Participant Observation
- Indirect Techniques
  - Instrumenting Systems
  - Fly on the wall
- Independent Techniques
  - Analysis of work databases
  - Analysis of tool usage logs
  - Documentation Analysis
  - Static and Dynamic Analysis



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
  - ✓ Data collection techniques?
    - Metrics for key variables?
    - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## How will you measure things?

Type	Meaning	Admissible Operations
Nominal Scale	Unordered classification of objects	=
Ordinal Scale	Ranking of objects into ordered categories	=, <, >
Interval Scale	Differences between points on the scale are meaningful	=, <, >, difference, mean
Ratio Scale	Ratios between points on the scale are meaningful	=, <, >, difference, mean, ratio
Absolute Scale	No units necessary - scale cannot be transformed	=, <, >, difference, mean, ratio



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
  - ✓ Data collection techniques?
  - ✓ Metrics for key variables?
  - Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## What could go wrong?

- Many phenomena might affect your results
- Must be able to distinguish:
  - My results follow clearly from the phenomena I observed
  - My results were caused by phenomena that I failed to observe
- Identify all (likely) confounding variables
- For each, decide what to do:
  - Selection/Exclusion
  - Balancing
  - Manipulation
  - Ignore (with justification)



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
  - ✓ Data collection techniques?
  - ✓ Metrics for key variables?
  - ✓ Handle confounding factors
- Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Validity (positivist view)

- Construct Validity
  - Are we measuring the construct we intended to measure?
  - Did we translate these constructs correctly into observable measures?
  - Did the metrics we use have suitable discriminatory power?
- Internal Validity
  - Do the results really follow from the data?
  - Have we properly eliminated any confounding variables?
- External Validity
  - Are the findings generalizable beyond the immediate study?
  - Do the results support the claims of generalizability?
- Empirical Reliability
  - If the study was repeated, would we get the same results?
  - Did we eliminate all researcher biases?



## Construct Validity

- E.g. Hypothesis: “Inspection meetings are unnecessary”
  - Inspection -> Perspective-based reading of requirements docs
  - Meeting -> Inspectors gather together and report their findings
  - Unnecessary -> find fewer total # errors than inspectors working alone
- But:
  - What’s the theory here?
  - E.g. Fagin Inspections:
    - Purpose of inspection is process improvement (not bug fixing!)
    - Many intangible benefits: staff training, morale, knowledge transfer, standard setting,...



## Validity (Constructivist View)

- Repeatability is suspect:
  - Reality is “multiple and constructed”, same situation can never recur
  - Researcher objectivity is unattainable
  - E.g. successful replication depends on tacit knowledge
- Focus instead on “trustworthiness”:
  - Credibility of researchers and results
  - Transferability of findings
  - Dependability - results are robust across a range of situations
  - Confirmability
- Identify strategies to increase trustworthiness...



## Strategies for constructivists

- Triangulation
  - Different sources of data used to confirm findings
- Member checking
  - Research participants confirm that results make sense from their perspective
- Rich, thick descriptions
  - As much detail as possible on the setting and the data collected
- Clarify bias
  - Be honest about researcher's bias
  - Self-reflection when reporting findings
- Report discrepant information
  - Include data that contradicts findings as well as that which confirms
- Prolonged contact with participants
  - Spend long enough to ensure researcher really understands the situation being studied
- Peer debriefing
  - A colleague critically reviews the study and tests assumptions
- External Auditor
  - Independent expert reviews procedures and findings



## Validity (Critical theorist's view)

- Validity depends on utility of the knowledge gained
  - Research is intended to challenge perspectives, shift power, etc.
  - Problems tackled are context sensitive...
  - ...repeatability not an issue
- Criteria (e.g. for action research)
  - Problem tackled is authentic
  - Intended change is appropriate and adequate
  - Participants are authentic (real problem owners)
  - Researcher has appropriate level of access to the organization
  - Planned exit point
  - Clear knowledge outcomes for participants



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
  - ✓ Data collection techniques?
  - ✓ Metrics for key variables?
  - ✓ Handle confounding factors
- ✓ Critically appraise the design for threats to validity
- Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate



## Research Ethics

- Reasons to take ethics seriously:
  - Funding depends on it
  - Relationship with research subjects/organisations depends on it
  - Legal issues (e.g. liability for harm to subjects/organisations)
  - Compliance with privacy and data protection laws
  - ...and it's the right thing to do!
- Institutional Review Boards (IRB)
  - Approval usually needed for all studies involving human subjects
  - Every IRB has it's own rules...
    - A study approved at one university may be disallowed at another!
    - Design of the study might have to be altered
  - Institutional research funding may depend on this process!
  - Note: guidelines from other fields may not apply to Software Engineering
    - E.g. use/ownership of source code
    - E.g. effect of process improvement on participants



## Informed Consent

### ○ Elements

- Disclosure - participants have full information about purpose, risks, benefits
- Comprehension - jargon-free explanation, so participants can understand
- Competence - participants must be able to make rational informed choice
- Voluntariness - no coercion or undue influence to participate
- Consent - usually indicated by signing a form
- Right to withdraw
  - participant can withdraw from study at any point without having to give reasons
  - Participants can request their data to be excluded (might not be possible!)

### ○ Challenges:

- Student participants
  - Perception that their grade will be affected if they don't participate
  - Perception that it will please the course instructor if they participate
- Industrial participants
  - Perception that the boss/company wants them to participate



## An Ethical Dilemma..

You are doing a study of how junior analysts use new requirements tool at a leading consultancy company. As part of informed consent, staff are informed that they will remain anonymous. During the study, you notice that many of the analysts are making data entry errors when logging time spent with clients. These errors are causing the company to lose revenue. Company policy states clearly that workers salaries will be docked for clear mistakes leading to loss of revenue.

### Questions:

- Would you alter the results of your study to protect the people who helped you in the study?
- How can you report results without causing harm to the participants?
- Would you cancel the study as soon as this conflict of interest is detected?



## Should you pay your participants?

- Arguments in favour
  - Can help with recruitment
  - Compensate participants for their time
- Arguments against
  - May induce participants to take risks they otherwise would not take
  - May get expensive (esp if rates are to be more than a token)
- Issues
  - IRB might have standard rate; might be too low for professional SE
- Alternatives:
  - All participants entered into draw for some new gadget



## Beneficence

- Risk of harm to Participants
  - Disrupts participant's work
  - Results of the research may devalue participants' work
  - Publication of study may harm the company's business
- Benefits of study
  - Scientific value: useful to society?
  - Depends on importance of the research topic!
  - Note: validity is crucial - invalid results means the study has no benefits
  - May also be specific benefits to participants
    - e.g. training, exposure to state-of-the art techniques, etc
- Beneficence: Benefits should outweigh the risks
  - Understand and justify any tradeoffs in the design of the study



## Confidentiality

- Protecting Anonymity
  - Do not collect any data (e.g names) that allow participants to be identified
  - But you need a signed consent form, so...
  - Sever participants' identity from their data before it is stored and analyzed
  - Researcher-subject interactions should be held in private
- Protecting the data
  - Consent form states who will have access to the data, and for what purpose
    - Do not stray from this!
  - Raw data should be kept in a secure location
  - Reports should only include aggregate data
- Exceptions:
  - When it is impossible to identify individuals from the raw data
  - When more harm results from maintaining confidentiality than breaching it



## Planning Checklist

- ✓ Pick a topic
- ✓ Identify the research question(s)
- ✓ Check the literature
- ✓ Identify your philosophical stance
- ✓ Identify appropriate theories
- ✓ Choose the method(s)
- ! ➔ Design the study
  - ✓ Unit of analysis?
  - ✓ Target population?
  - ✓ Sampling technique?
  - ✓ Data collection techniques?
  - ✓ Metrics for key variables?
  - ✓ Handle confounding factors
- ✓ Critically appraise the design for threats to validity
- ✓ Get IRB approval
  - Informed consent?
  - Benefits outweigh risks?
- Recruit subjects / field sites
- Conduct the study
- Analyze the data
- Write up the results and **publish** them
- Iterate

