Experimental and Non-Experimental Methods in Computer Science Research

CSCI 16: Intro to the CS Research Process

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Attribution

Except where otherwise noted, ERSP and all associated resources were developed by Christine Alvarado, UC San Diego, Department of Computer Science and Engineering.

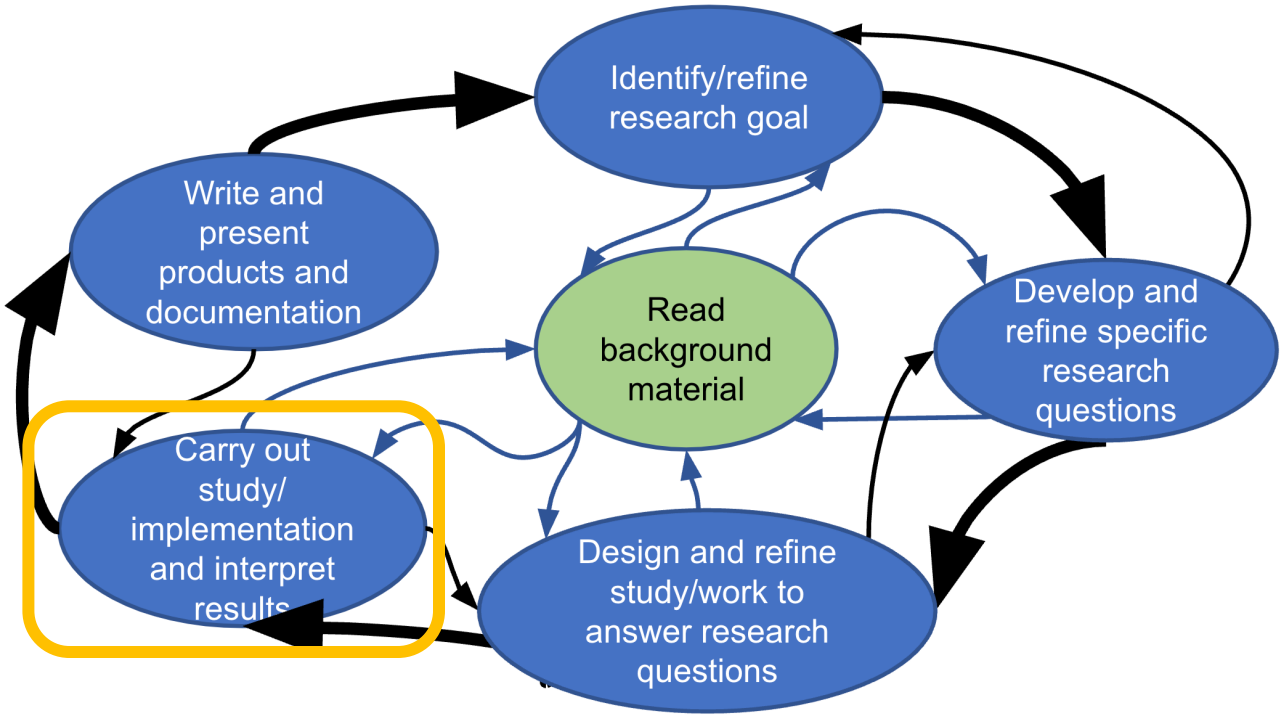
These slides were originally jointly developed by Christine Alvarado and Mai ElSherief. They have been adapted by Kelly Shaw for CSCI 16 at Williams College.

Today's Plan

- How do you know that your approach works?
  - Identify and describe types of research in Computer Science
    - Experimental and Non-Experimental
- Experimental Research in Computer Science
- Non-Experimental Research in Computer Science
- Read "Should Computer Scientists Experiment More?"

For further reading: https://www.scribbr.com/category/methodology/

Overview of the Research Process



Language of Research

- Variable = changeable/unsteady

- A **dependent** variable represents the measure that reflects the outcome of a research study
  - the outcome that may depend on the experimental treatment or on what the researcher changes or manipulates.

- An **independent** variable represents the treatments or conditions that the researcher has either direct or indirect control over to test their effects on a particular outcome.
  - Aka treatment variable

Language of Research

- **Control** variable: is a variable that has a potential influence on the dependent variable; consequently, the influence must be removed or controlled.

- Example: examining the relationship between reading speed and reading comprehension
  - Dependent Variable: reading comprehension
  - Independent Variable: reading speed (WPM)
  - Control Variable:

    You may want to control for differences in intelligence, because intelligence is related both to reading speed and to reading comprehension. Intelligence must be held constant for you to get a good idea of the nature of the relationship between the variables of interest.

Experimental Research Methods

- Objective: test for the presence of a distinct cause and effect
  - Experimental Group: receives treatment
  - Control Group: receives no treatment
    - Measure difference on a specified test score

Step 1	Step 2	Step 3	Step 4
Random assignment of participants to a control group	A pretest is administered	No treatment is administered	A posttest is administered
Random assignment of participants to the experimental (or treatment) group(s)	A pretest is administered	A treatment is administered	A posttest is administered

Salkind, Neil J., and Terese Rainwater. *Exploring research*. Upper Saddle River, NJ: Pearson Prentice Hall, 2006.

- Assuming that the two groups were equivalent from the start, observed differences at the end must be due to treatment

Internal Validity vs. External Validity

- It is not enough to come up with different experimental designs
  - We need a way to evaluate these designs
- Validity: extent to which results measure what they are intended to measure
- Internal Validity: quality of experimental design such that the results obtained are attributed to the manipulation of the independent variable
  - What you see is really a function of what you did

- External Validity: quality of experimental design such that results from the original sample can be generalized to another sample
- Tradeoff between internal/external validity: The more you control extraneous factors, less you can generalize your findings.

Some Threats to Internal Validity

- Pretest presence: Subjects increase or decrease performance because of exposure to a pretest.
- Reactive arrangements: Simply knowing that one is being observed affects performance.
- Instrumentation: Changes in the system used to score the dependent variable.
- Mortality: The dropout rate or reduction in a sample size over time.

Worksheet exercises

- Case 1: Even if the criteria do not change, simple fatigue is likely to cloud the scorer's judgment and result in differences due to **instrumentation**, not the actual effects of the program

Worksheet exercises

- Case 3: Those who are dropped may indeed be substantively different from those who remain, and thus the final sample of subjects may no longer be equivalent to the initial sample, which raises questions about the effectiveness of the treatment on this different sample.

Worksheet exercises

- Case 4: The problem was that the participants in the study knew about Mayo's intent. Because the workers received special attention from the researchers, which resulted in changes in productivity; lighting and working-hour conditions were found to be secondary in importance.
  - Reactive Arrangements: In many experiments, subjects are not told the true nature of the study until its conclusion.

Non-Experimental Research: Qualitative Methods

- Non-experimental Research: examines the relationship between variables, without any attention to cause and-effect relationships

- Qualitative Methods:
  - Research that explores the processes that underlie human behavior
  - exploratory techniques such as interviews, surveys, case studies, and other relatively personal techniques

- Research Resources
  - Documentation, Archival Records, Physical Artifacts, Direct Observation, Participant Observation, Focus Groups
- Case Studies
- Ethnographies
- Historical Research

Focus Groups

- A focus group is a gathering of people
  - moderated by a member of a research team and perhaps observed, either openly or secretly, by other members of the research team.

- Discussion is encouraged
  - Moderator's job is
    - to ensure that participation in the process isn't "hijacked" by one or several members of the group
    - shy members are included in the discussion

Function of a Focus Group

Function	Example
Gather information	Asked of parents of junior high students: "How effective do you think it would be if the last period in the school day were not used for instruction, but for community activities?"
Generate insight	Asked of preschool workers: "It seems that in the last few weeks, parents are forgetting to sign their children out. What do you think might be the cause of their forgetting?"
Determine how group members reach decisions	Asked of nurses: "How did you reach a decision as to how you will share information about your patients when shift changes occur?"
Encourage group interaction	Asked of police officers: "We'd like to know how you as a group feel about the new health benefits programs and how they might be an incentive to add new men and women to the force?"

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Case Studies

- A method used to study an individual or an institution in a unique setting or situation in as intense and as detailed a manner as possible

- Takes a long time to complete but can yield a great deal of detail and insight.

Examples of Case Studies

- Examples:
  - The Journal of the American Medical Association or JAMA (published weekly by the American Medical Association) regularly offers case studies of individuals whose conditions are so unusual that their symptoms and treatment demand special attention, and information about their cases needs to be disseminated
  - The Harvard Business School makes a regular practice of including case studies of businesses that fail, as well as those that succeed, as a staple of its graduate students' diet of materials to study

Case Study Advantages and Disadvantages

- Advantages:
  - Close examination, collection of detailed data
  - Encourage several different techniques
    - Interview of others
  - Rich interpretation

- Disadvantages:
  - One subject
  - Time consuming
  - Biased conclusions
  - No cause-effect relationship
  - Limited Generalizability

Mixed-method models

- Both experimental and non-experimental methods are combined
  - Some researchers feel that this type of approach lacks clarity and precision
  - Others feel it is the best way to look at a phenomenon of interest from a variety of perspectives and thereby be more informative

Activity: Experiments in CS Worksheet

- Describe the design and results of the experiments in the “Fine Grained Recognition in the Wild” paper

Activity: Experiments in CS

- Read “Should Computer Scientists Experiment More?”