Research EE and CpE

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October 2011

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Do you know?

- Today is a Holiday…
  - Which one?

Research

- Systematic inquiry aimed at the discovery of new knowledge.
  - Operationalization
    - The process of translating a hypothesis into specific testable procedures that can be measured and observed.

Not all research are created equal

- Science
- Engineering
- Social Sciences
- Humanities

Exercise

- Fishbowl
  - 10 students
  - Two groups of 5
- Sit in two concentric circles
  - Group inside discusses
  - Group outside listens
- Switch positions

Read the document and answer

- Compare and contrast research in science and in engineering

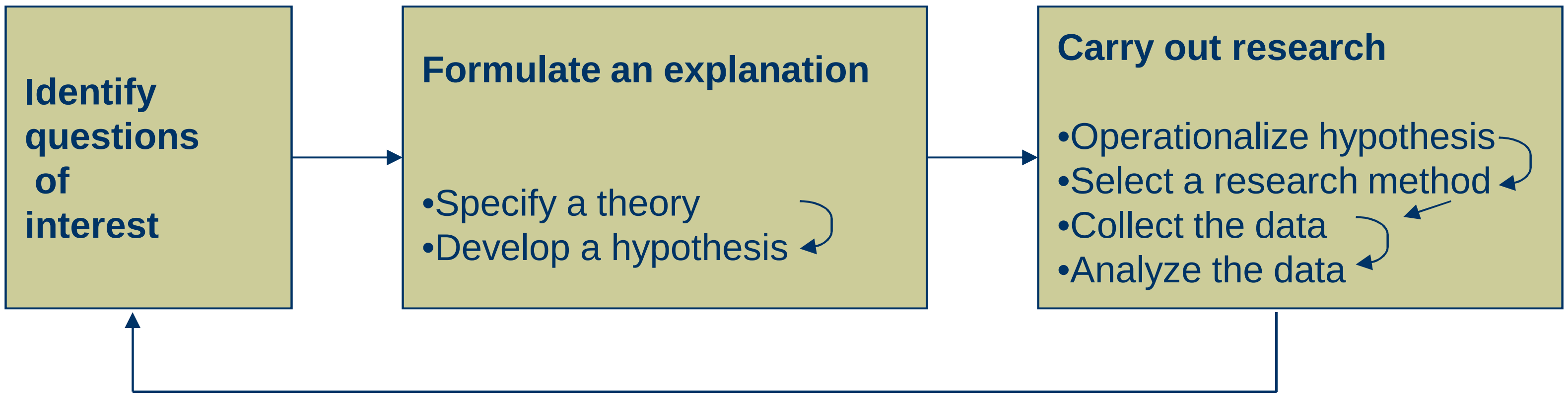
Not all research are created equal

- Quantitative Research
  - Numbers
- Qualitative Research
  - Observations
- Mixed methods

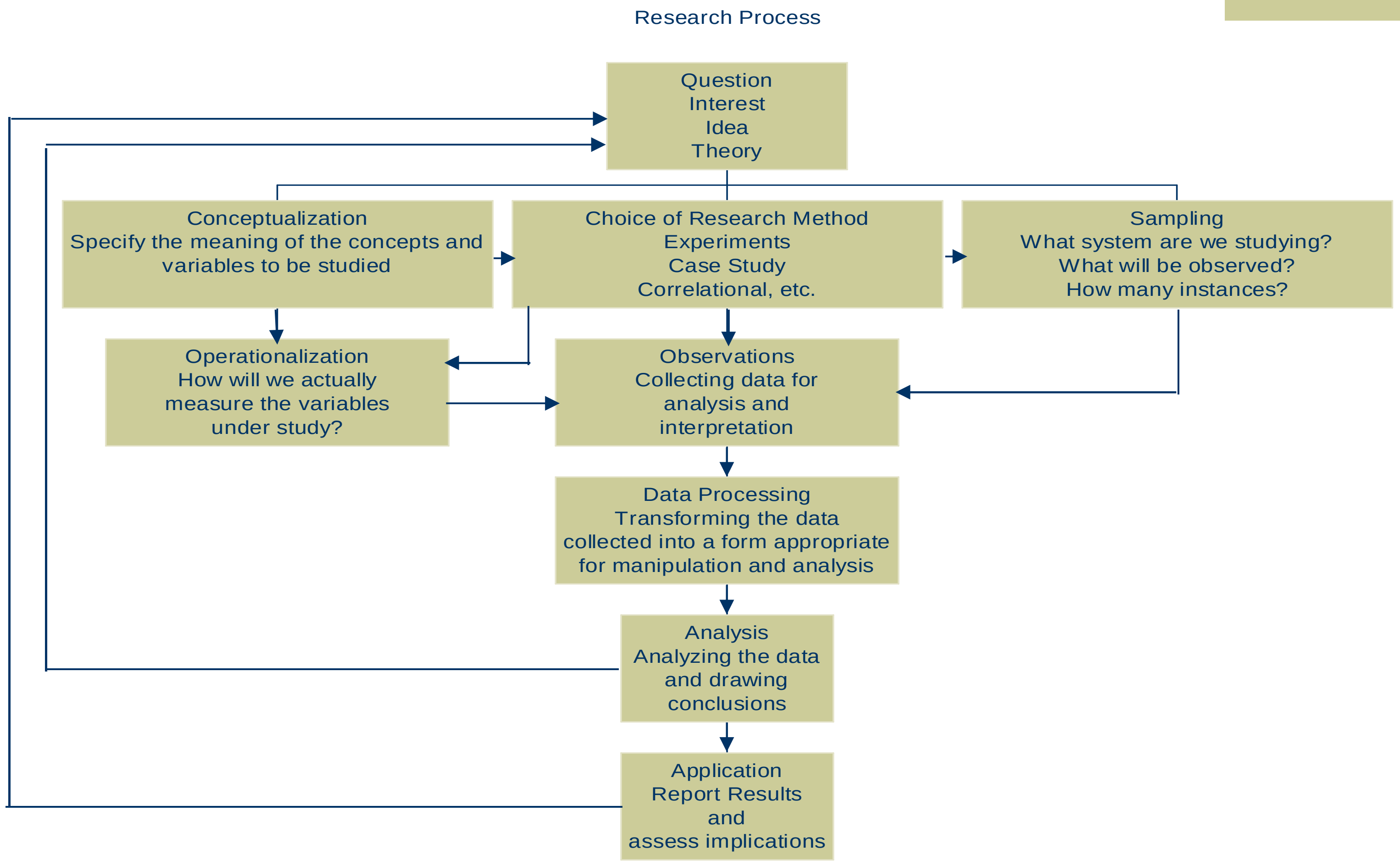
- Reporting is not equal

Scientific Method

- The approach used to systematically acquire knowledge and understanding about the phenomena of interest



The ResearchProcess



Examples of Research Methods in Engineering and Science

- Survey
- Case Study
- Correlational Research
- Experimental Research

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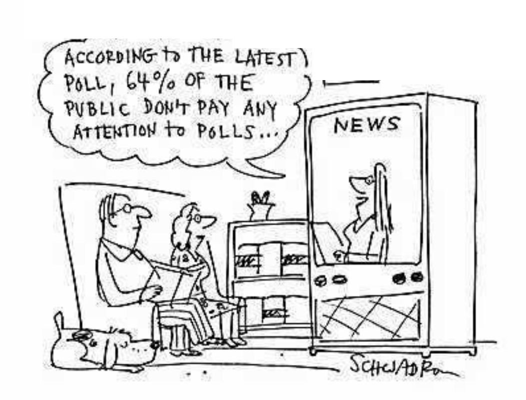
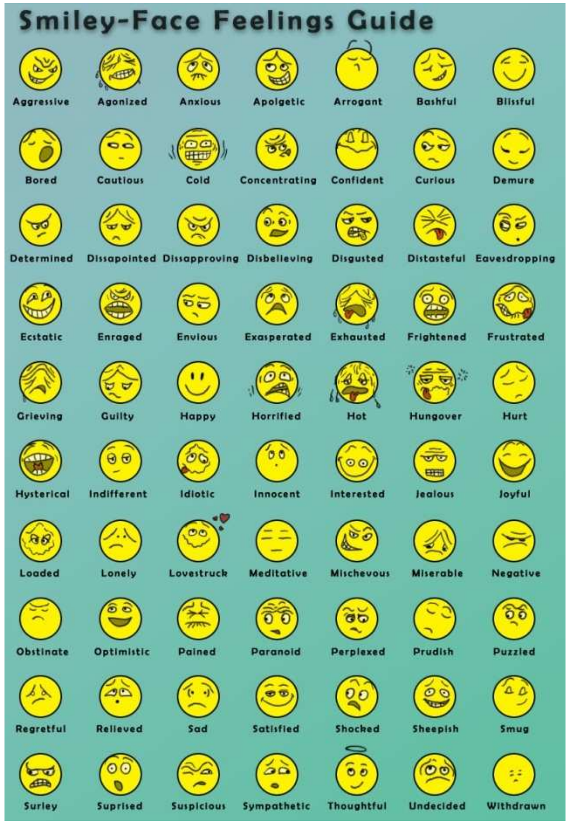
Survey Research

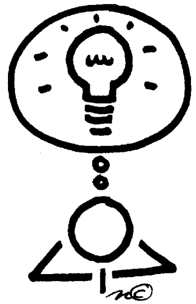
- Research in which people chosen to represent a larger population are asked a series of questions about their behavior, thoughts, or attitudes.
  - Infer how a larger group would respond



Survey Research

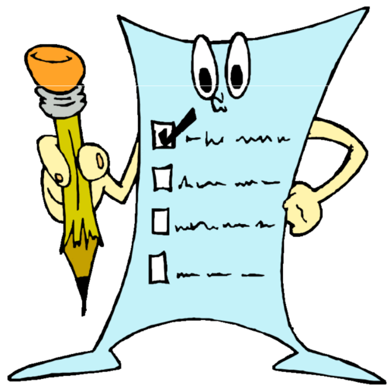
- You want to know
- What people are
  - Thinking
  - Feeling
  - Doing
  - Behaving
  - Interacting
  - others





Survey Research

- Three key objectives
  - Must know your research hypothesis
  - Questionnaire, test or interview must be accurate measuring thoughts, feelings or behavior of interest.
  - Be able to generalize to a certain group
    - Population

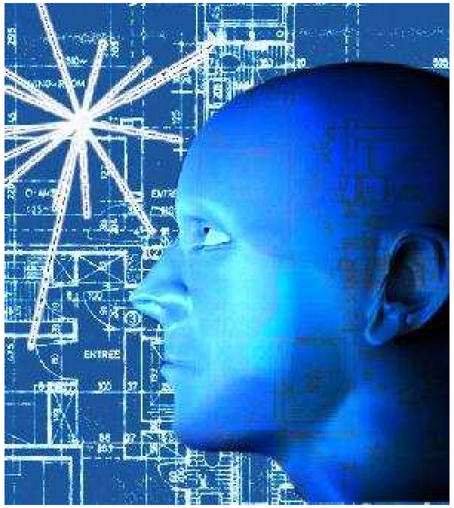


Survey Research

- Three basic questions format
  - Nominal – dichotomous
    - Respondent have to choose between two or more answers
      - Yes or no, True or False, Multiple choice
  - Likert-type
    - Most widely used scale in survey research
    - Respondents specify their level of agreement to a statement
      - Agree, Disagree, Undecided, strongly agree
  - Open-ended
    - Short answer or essay
    - Free to respond on their own

Survey Research

- Areas where survey are used
  - Human Computer Interaction
  - Pattern Recognition
  - Engineering Education
  - Usability



Survey Research

- Example
  - **Personal health information management system and its application in referral management**
    Maisie Wang; Lau, C.; Matsen, F.A., III; Yongmin Kim;
    IEEE Transactions on Information Technology in Biomedicine, Volume 8, Issue 3, Sept. 2004
    Page(s):287 - 297 .
- Web based personal health record

Survey Research

- Web based software system
- Collect and manage health information
  - Medical history
  - Past surgeries
  - Allergies, etc
- Includes messaging system
- 61 subjects but only 32 completed the survey
  - Usability

Survey Research

- Questions
  - Logging was easy
  - Account setup was easy
  - Filing in health record was easy
  - Filing in referral request was easy
  - View of health record was useful
  - Learned more about health
  - Response time acceptable

Survey Research

- Likert Scale in this case
  - strongly agree
  - agree,
  - somewhat agree,
  - somewhat disagree,
  - disagree,
  - strongly disagree

Survey Research

- Conclusions
  - "Results indicate that the system was well received by patients, clinic staff, and specialists. All parties involved found the system to be user friendly, convenient, and able to facilitate patient–provider communications."

Survey Research – Failing?

- If researchers do not know what they are looking for
  - Overwhelmed by data
- If questionnaire is constructed poorly
  - Questions demand knowledge respondent do not have
  - Questions hint answer – biased
  - Cause misinterpretation of questions
  - Researcher miscode answers.

Survey – Impt. to know

- Consent of IRB
  - **Institutional review board** (IRB)
    - AKA **independent ethics committee** (IEC) or **ethical review board** (ERB)
    - Committee that has been formally designated to approve, monitor, and review biomedical and behavioral research involving humans with the aim to protect the rights and welfare of the research subjects.

Survey

- Consent form
  - Explains purpose of research
  - Likely duration of participation
  - Potential harms and inconveniences
  - Potential benefits
  - Whether confidentiality will be protected and how
  - Participation is voluntary
    - Can withdraw at any moment.

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Case Study

- An in-depth, intensive investigation of an individual or small group of samples or population.
  - Emphasize detailed contextual analysis of a limited number of events or conditions and their relationships
- Real – life context
- Used in many different fields
  - Sociology
  - Engineering
  - Science

Case Study

- Pros
  - Success in carefully planned and crafted studies of real-life situations, issues, and problems
  - Many reports on many disciplines
- Cons
  - A small number of cases can offer no grounds for establishing reliability or generality of findings
  - Intense exposure to study of the case biases the findings

Case Study Steps

1. Determine and define the research questions
   - The researcher establishes the focus of the study by forming questions about the situation or problem to be studied and determining a purpose for the study.
2. Select the cases and determine data gathering and analysis techniques
   - Approaches to use in selecting single or multiple real-life cases to examine in depth and which instruments and data gathering approaches to use.
3. Prepare to collect the data
   - Systematic organization of the data
   - Prevent the researcher from becoming overwhelmed by the amount of data
   - Prevent the researcher from losing sight of the original research purpose and questions.

Case Study Steps

4. Collect data in the field
   - Collect and store multiple sources of evidence comprehensively and systematically
   - Patterns can be uncovered
5. Evaluate and analyze the data
   - Interpretations in order to find linkages between the research object and the outcomes with reference to the original research questions.
6. Report results
   - Convey to the reader evidence that all avenues have been explored
   - Establish boundaries

Case Study Example

- **VHDL-based digital circuit synthesis: a case study**,Viana, F.L.; Damiani, F.; Proceedings of the 2000 Third IEEE International Caracas Conference on Devices, Circuits and Systems, 2000. 15-17 March 2000 Page(s):C47/1 - C47/6
- Electronics

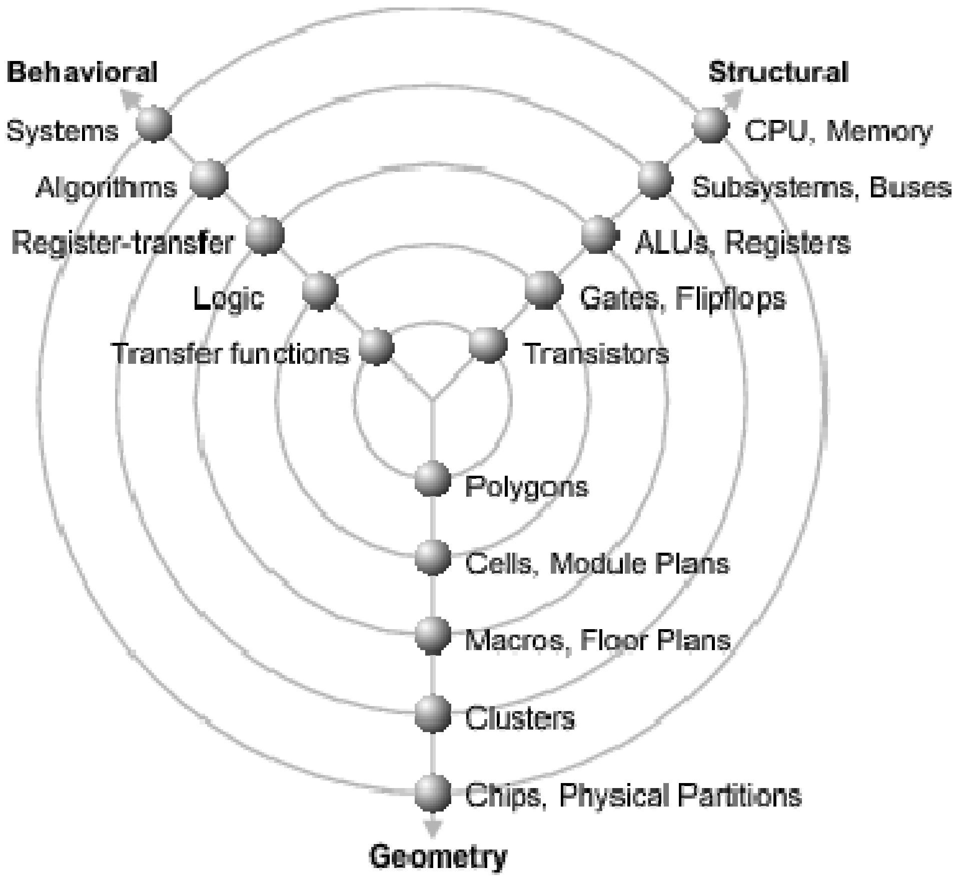
Case Study Example

- A case study of the Description-and-Synthesis methodology for digital circuit design
  - High Level Solution to the problem
- Previous Capture and Simulation methodology is compared
  - Specification →Requirements →Block Diagram →Functional Structures →Logical Circuit

Case Study Example

Gajski-Kuhn Y-chart

Visualize design views as well as design hierarchies



Case Study Example

- Synthesis
  - Transformation from specification to physical implementation of the circuit.
- Case study
  - Fixed Point Adder (fundamental in ALU)
  - VHDL
  - Comparison in area and timing results
  - Two EDA environments

Case Study Result

- Conclusions
  - Advantages of Description-And-Synthesis Methodology
    - Ensures design reuse
    - Evaluation of quality of specification and guide synthesis
  - Results vary according to synthesis software algorithms.

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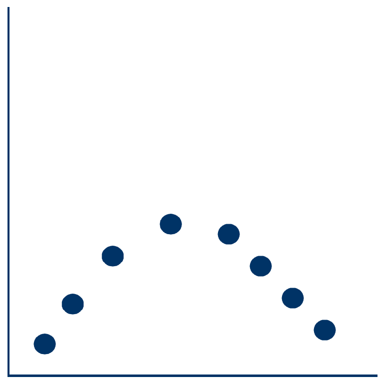
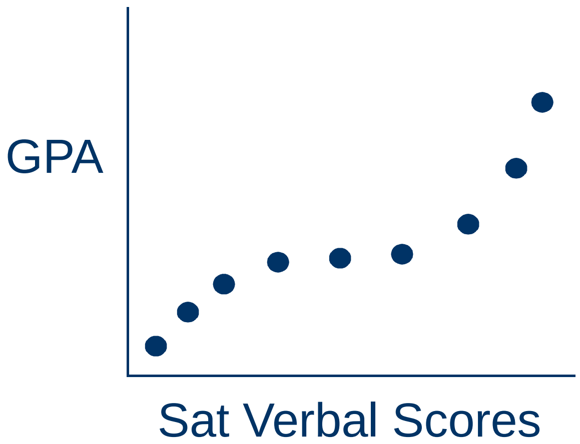
Correlational Research

- Variable: A measurable factor, characteristic, or attribute of an individual or a system.
- Research that examines the relationship between two sets of variables to determine whether they are associated or "correlated"
  - Linear relationship

Correlational Research

- Careful!!!





- Low correlation
- Non linear relationships

Correlational Research

- Non causal
  - More study time ⟶ Good grades
  - Highly correlated
  - Cause?
    - Interest in the subject → More study time?
  - Correlational studies
    - Strength of relation between two variables
    - Does not demonstrate cause-and-effect

Correlational Research Example

- **Numerical and experimental analysis of enzymatic reaction in electrochemical sensors: electrochemical enzymatic analysis**
  Barak-Shinar, D.; Rosenfeld, M.; Rishpon, J.; Neufeld, T.; Abboud, S.; Sensors Journal, IEEE Volume 6, Issue 1, Feb. 2006 Page(s):151 – 159
- Sensors and materials

Correlational Research Example

- Amperometric electrochemical flow biosensors for enzyme activity detection
  - To observe the activity of a specific enzyme
  - Enzyme – Biomolecules that catalyze chemical reactions
    - Proteins
- Results:

Correlational Research Example

- Results
  - The correlation coefficient was 0.98.
  - A linear relationship was obtained between the inlet substrate concentration and the steady-state electric current for both the numerical and the experimental results.

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Experimental Research

- Experiment: The investigation of the relationship between two or more variables by deliberately producing a change in one variable in a situation and observing the effects of that change on other aspect of the situation.
- Cause-and-effect

Experimental Research

- Experimental manipulation: Change that an experimenter deliberately produces in a situation
- Treatment: the manipulation implemented by experimenter
- Experimental group: any group receiving a treatment in an experiment

Experimental Research

- In an *observational study*, measurements of variables of interest are observed and recorded, without controlling any factor that might influence their values.
  - Political Poll
- An *experiment*, on the other hand, deliberately imposes some treatment on individuals in order to observe their responses.
  - In principle, only experiments can give good evidence for causation.

Experiment example

- *New* communication protocol improves throughput in the network.
- To assess the effect, researchers measure network latency over a period of a week.
- They randomly select the day when the protocol will be used comparing the new versus the old one.
- The same machines will be used in both.
- Same size files will be sent over the network.

Design of Experiments

- Experimental units: individuals on which the experiment is done, also called subjects when the units are human beings.
  - The network
- Treatment: the specific experimental condition applied to the units.
  - protocol
- Factors: the explanatory variables, which often have levels.
  - Old vs new

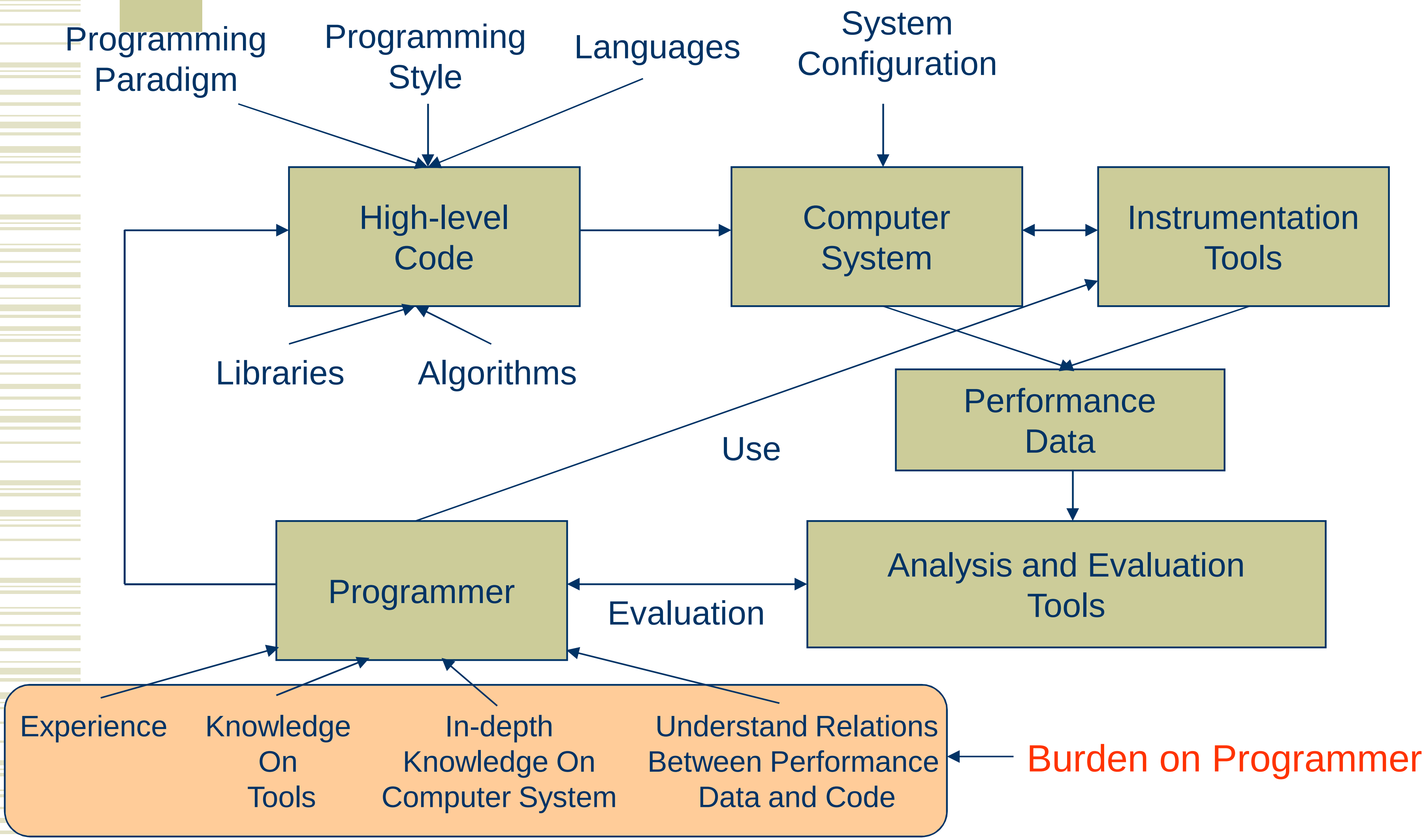
Principles of Experimental Design

- Control
  - Researcher decides which subjects are assigned to the treatment group
- Randomization
  - Impartial and objective
- Replication
  - Reduces chance variation in the results and can help achieve statistical significance

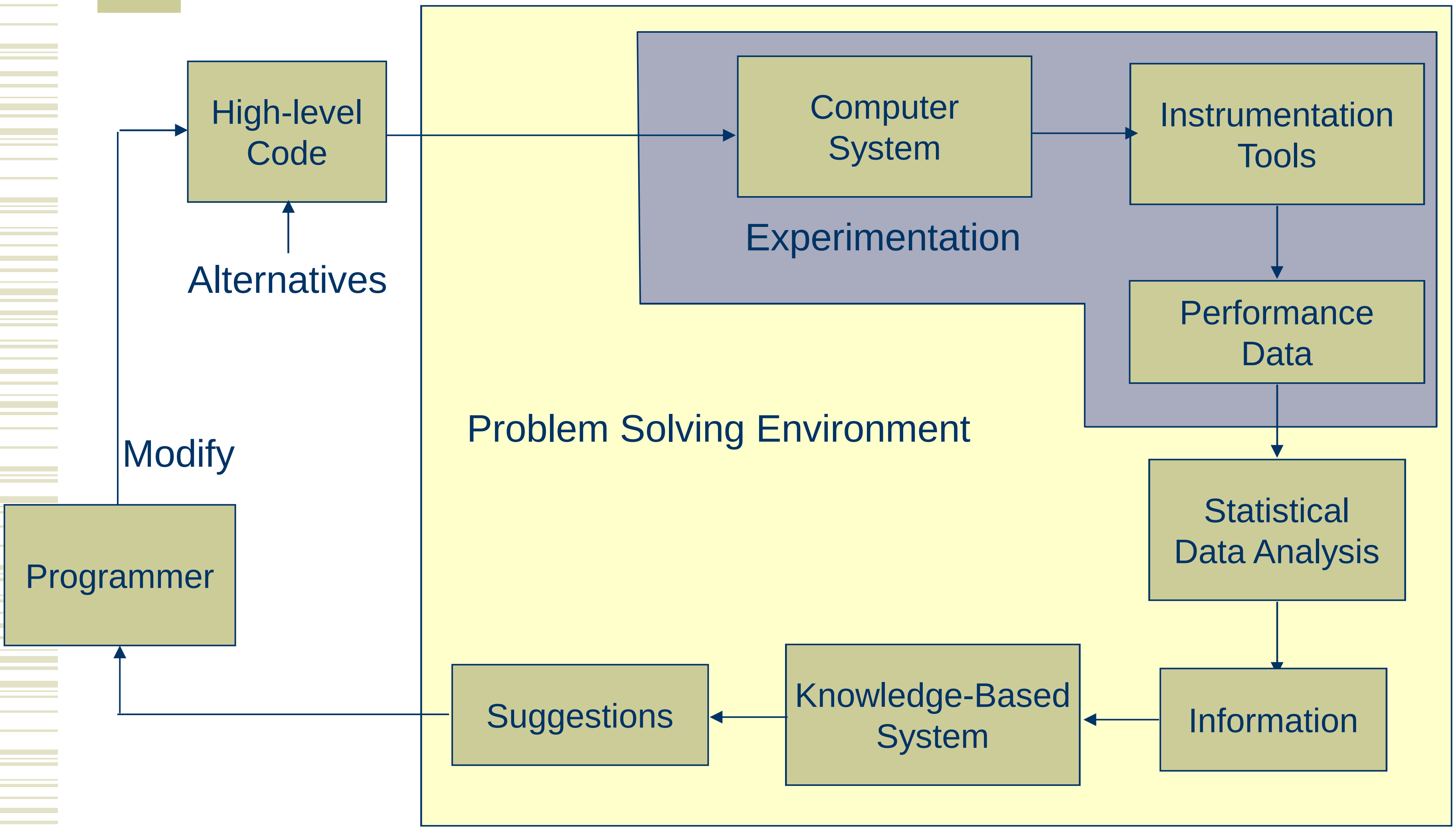
Experimental Design Example

- Nayda G. Santiago, Diane T. Rover, Domingo Rodríguez: A Statistical Approach for the Analysis of the Relation Between Low-Level Performance Information, the Code, and the Environment. ICPP Workshops 2002: 282-289
- Computer Performance Area

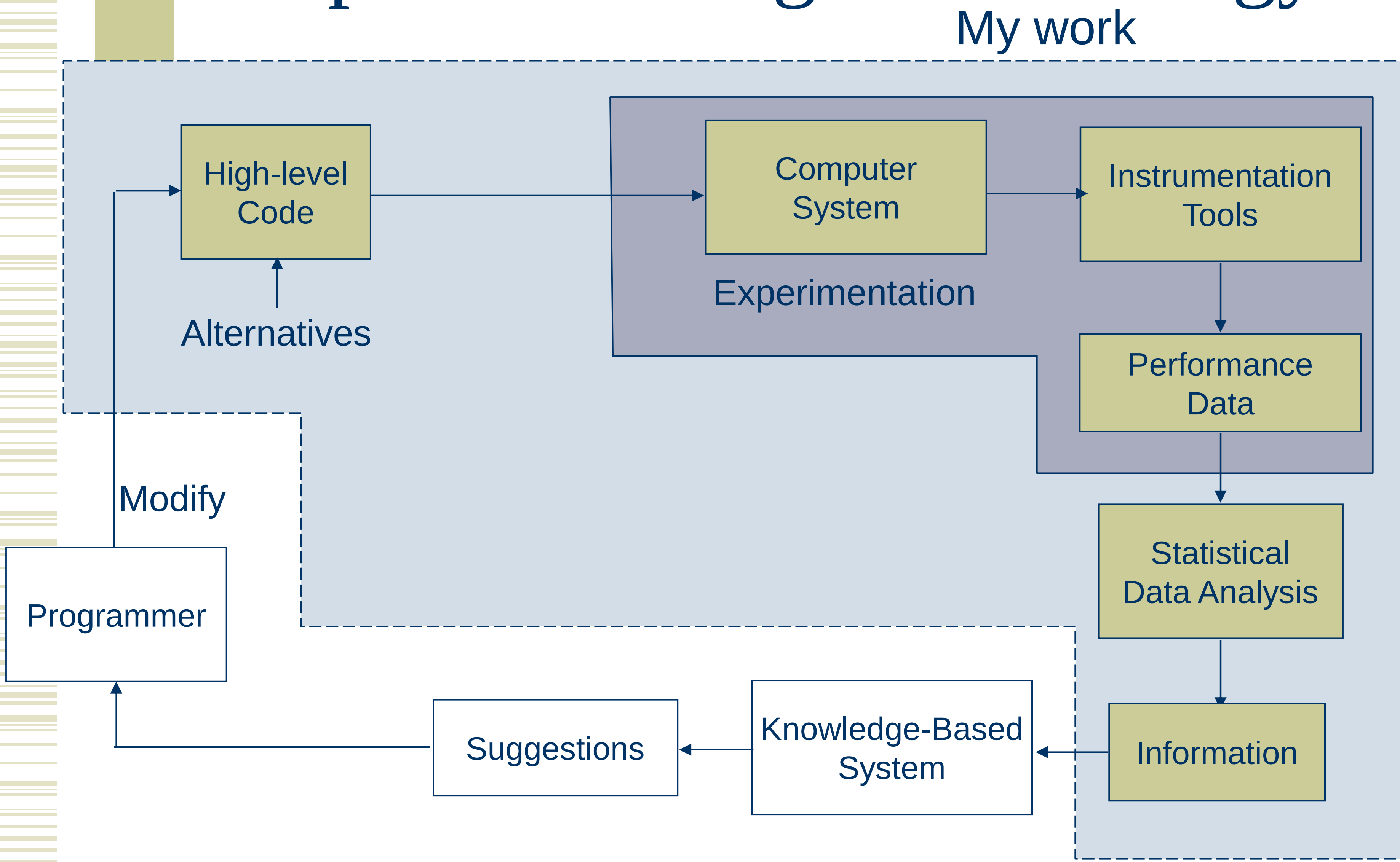
Current Tuning Methodology



Proposed Tuning Methodology



Proposed Tuning Methodology



Factors

- Compiler options
- User workload
- Sampling time
- Number of processors
- Problem size
- Algorithms
- Iterative solvers
- Hardware configuration

Design of Experiment

Problem Size
Compiler Options
Mat-Vect Mult Algorithm

→ **Design of Experiment** →

Split-Split
Plot Designs

Validation

Problem Size
Compiler Options
Algorithm
Data Structure

→ **Design of Experiment** →

Full
Factorial
Fully
Randomized

Design of Experiment

- Results
  - The appropriate randomization scheme, number of replications, and treatment order for the experimental runs.
- Contributions
  - Innovative use of DOE for establishing causal relations for application tuning
  - The appropriate design of experiment should be selected according to the performance analysis problem
- Significance
  - The use of DOE and ANOVA will determine the cause of the performance differences in the results

ANOVA

- Analysis of Variance
  - Null Hypothesis
    - No effect of any variable
    - All variations in results are caused by random nature of data
    - Null hypothesis – assumed true until proven wrong
  - False – there is enough evidence to prove a factor alters results.

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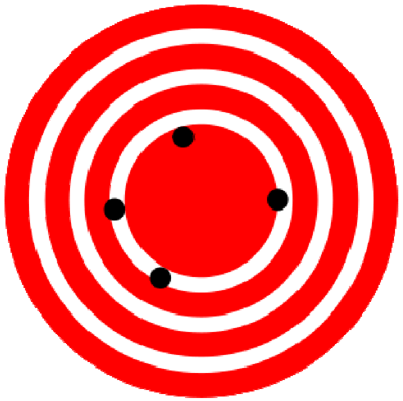
Validity

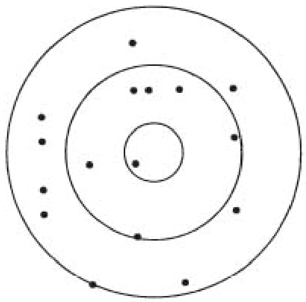
- The relative accuracy or correctness of the statements.
- Internal validity
  - Extent to which a set of research findings provides compelling information about causality
- External validity
  - Extent to which a set of research findings provides an accurate description of what typically happens in the real world.
  - Generalizability
- Conceptual validity
  - How well a specific research hypothesis maps onto the broader theory that it was designed to test.

Precision and Accuracy

- Precision
  - Consistency or repeatability of a measure or observation.
- Accuracy
  - Degree of conformity of a measured quantity to its actual value.

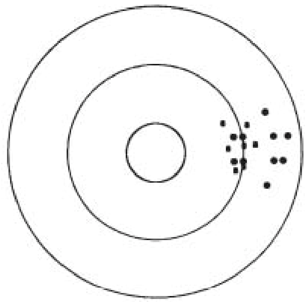


Validity and Reliability



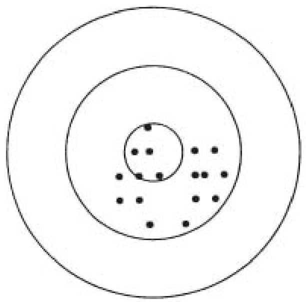
Neither valid nor reliable

The research methods do not hit the heart of the research aim (not 'valid') and repeated attempts are unfocussed



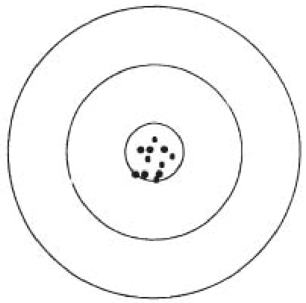
Reliable but not valid

The research methods do not hit the heart of the research aim, but repeated attempts get almost the same (but wrong) results



Fairly valid but not very reliable

The research methods hit the aim of the study fairly closely, but repeated attempts have very scattered results (not reliable)



Valid and reliable

The research methods hit the heart of the research aim, and repeated attempts all hit in the heart (similar results)

References

- Brett W. Pelham and Hart Blanton, Conducting Research in Psychology: Measuring the Weight of Smoke, 2nd edition, Wadsworth Publishing, 2002
- David J. Lilja, Measuring Computer Performance : A Practitioner's Guide, Cambridge University Press, 2000
- Research Concepts by Chris Jones and Xiaoping Jia, presentation
- Earl Babble, The Practice of Social Research, 8th Edition, ITP, 1998.
- Mark L. Mitchell and Janina M. Jolley. Research Design Explained, Fifth Edition, Thomson Wadsworth, 2004.

Questions?

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