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# Introduction to Research in Computing

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# How do you know things?

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- ◆ You know
  - The world is round.
  - It is cold on the dark side of the moon.
  - Vitamin C prevents colds.
- ◆ How do you know things?
  - At some point everybody knew that the world was “flat”.

# Example



# Example



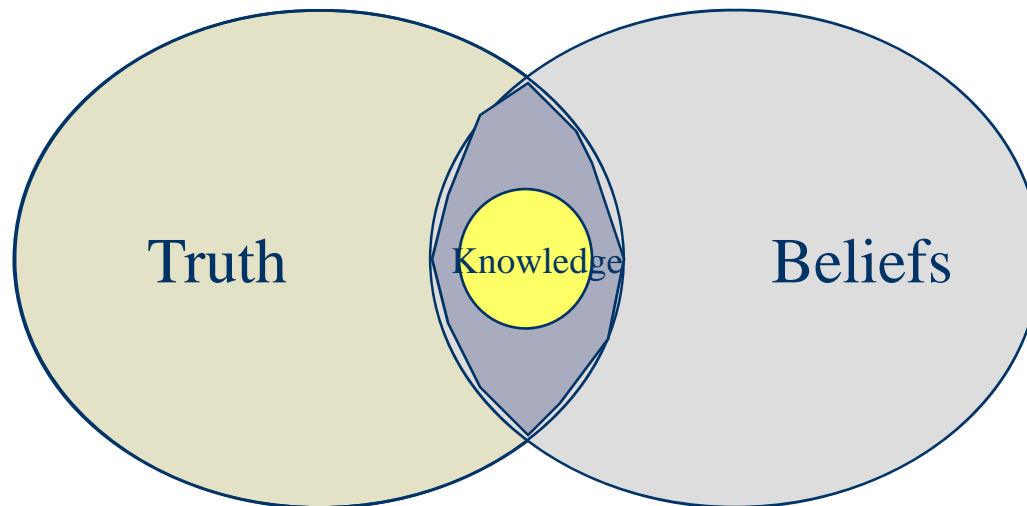
**Maguery worm: are two varieties of edible caterpillars that infest maguery and Agave tequilana plants. .... They are also considered delicious deep fried or braised, seasoned with a spicy sauce and served in a tortilla.**



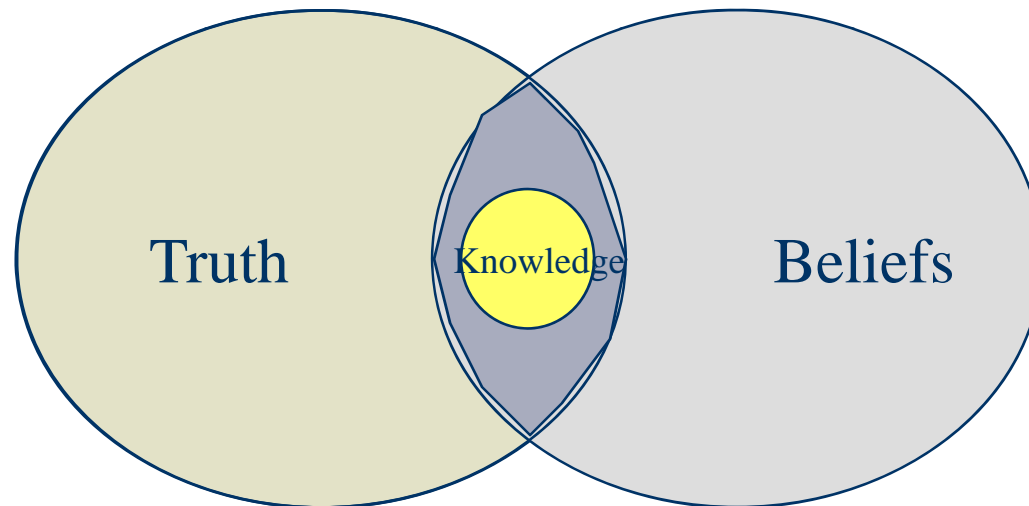
# Questions

- ◆ Are worms “really” good or bad to eat?
  - How do you know what is really true?
- ◆ Looking for reality
  - Tricky business
  - **Epistemology** or **theory of knowledge** is the branch of philosophy that studies the nature, methods, limitations, and validity of knowledge and belief.

# Preposition



# Proposition



Knowledge = justified true belief



# The four canons of science

- ◆ **Determinism**
  - The universe is orderly
  - All events have meaningful, systematic causes
- ◆ **Empiricism**
  - The best way to find out how the world works is to make observations.
- ◆ **Parsimony**
  - Facing with two competing theories that do an equally good job of handling a set of empirical observations, we should prefer the simpler one.
- ◆ **Testability**
  - Theories can be tested.
    - Confirmable or disconfirmable using current available research techniques.



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# Knowing about the world

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- ◆ Authority
- ◆ Intuition
- ◆ Logic
- ◆ Observation

How would you know if eating worms is good for you?



# How do we find out?

## ◆ Scientific Discovery

### ■ Law

- Universal statement of the nature of things that allows reliable predictions of future events

### ■ Theories

- General statement about the relation of two or more variables

### ■ Hypotheses

- Predictions about specific events that are derived from one or more theories.

# Hypotheses

- ◆ A prediction, stemming from a theory, stated in a way that allows it to be tested.
  - Help to test the validity of theories
  - Question
    - What is the best way to study for a test?
      - ◆ Cramming the night before the exam
      - ◆ Study over several nights
  - How are questions answered?
    - Research





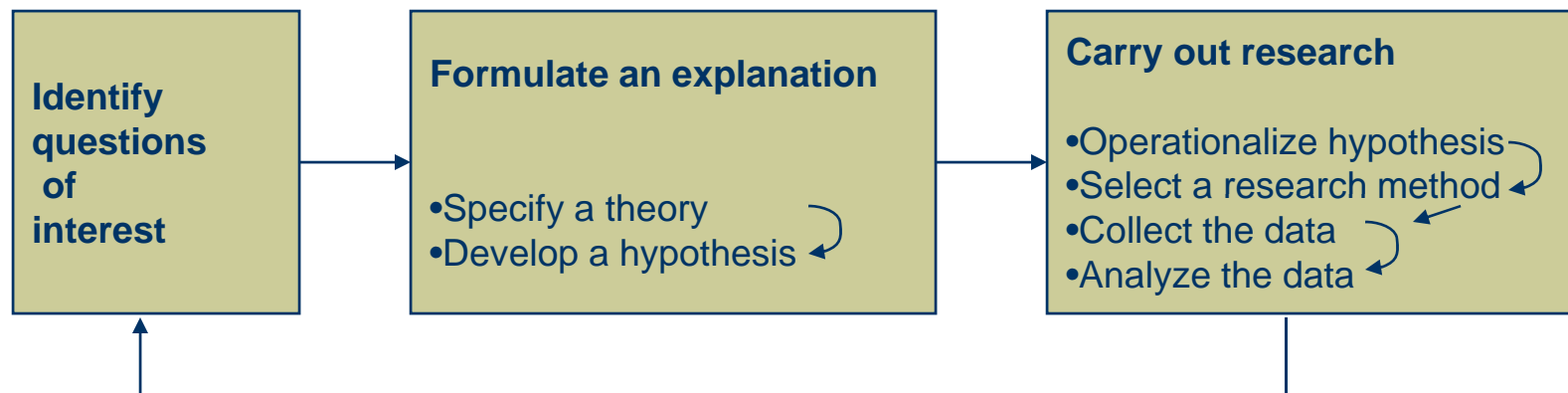
# Research



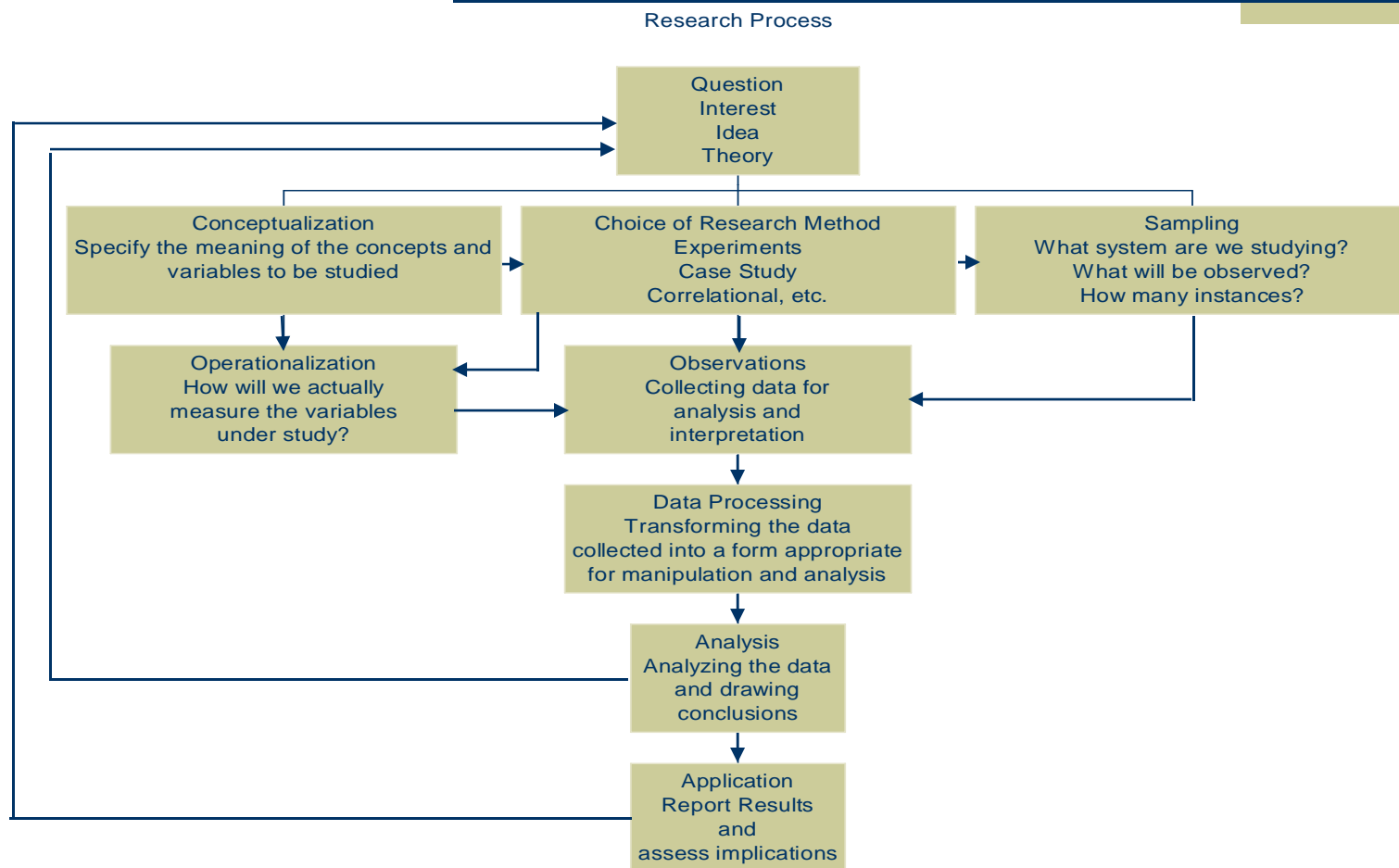
- ◆ Systematic inquiry aimed at the discovery of new knowledge.
  - Operationalization
    - The process of translating a hypothesis into specific testable procedures that can be measured and observed.

# Scientific Method

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



# The Research Process





# Conceptualization

- ◆ A **concept** is an abstract idea or a mental symbol, typically associated with a corresponding representation in and language or symbology, that denotes all of the objects in a given category or class of entities, interactions, phenomena, or relationships between them.
- ◆ Conceptualization – the process of coming to an agreement of the meaning of a term
- ◆ Creating a conceptual order
  - Cognitive map



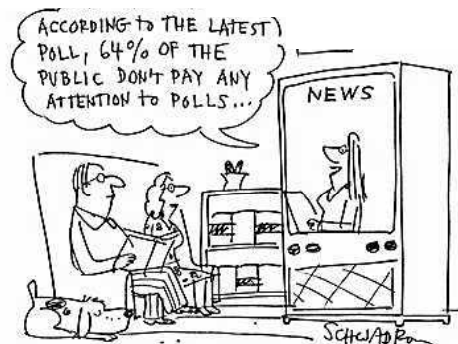


# Research Methods in Engineering and Science

- ◆ Survey
- ◆ Case Study
- ◆ Correlational Research
- ◆ Experimental Research

# 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





# 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
  - 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

- ◆ 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.
- ◆ 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.
- ◆ 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.
- ◆ Collect data in the field
  - Collect and store multiple sources of evidence comprehensively and systematically
  - Patterns can be uncovered
- ◆ 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.
- ◆ Report results
  - Convey to the reader evidence that all avenues have been explored
  - Establish boundaries



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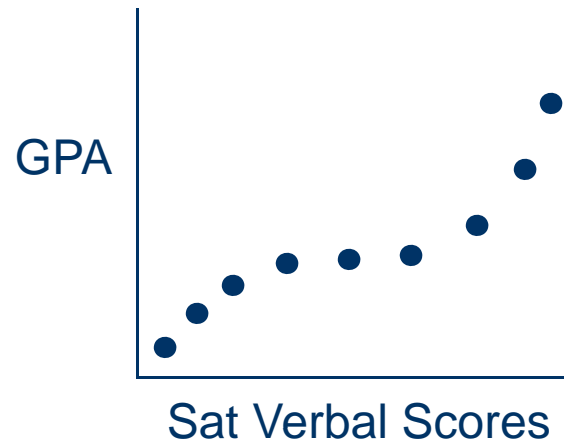
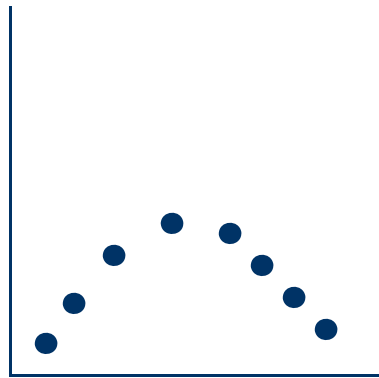
# Correlational Research

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- ◆ 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



# 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



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# Principles of Experimental Design

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- ◆ 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

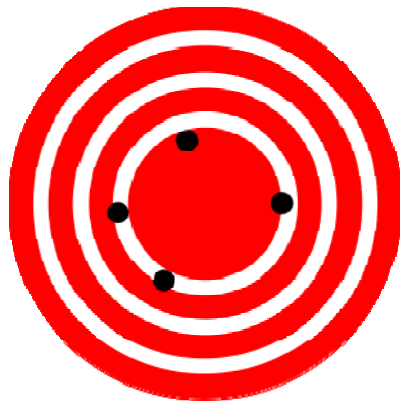


# Validity

- ◆ 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.



# Literature Review

- ◆ A systematic search of formal and informal publications in order to find items relevant to your area of interest. These include books, journals, conferences papers and theses or other types of academic publications
- ◆ A literature review is a necessity.
  - Without this step, you won't know if your problem has been solved or what related research is already underway.
  - Why
    - Necessary to acquire an understanding of your topic, with its key issues.
    - Awareness of relevant research that has already been conducted.
    - Prevent you from duplicating work already done.
    - Helps you choose/design your own methodology.





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## Literature Review (cont.)

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- ◆ When performing the review:
  - Start searching professional journals.
  - Begin with the most recent articles you can find.
  - Keep track of relevant articles in a bibliography.
  - Don't be discouraged if work on the topic is already underway.



# Literature Review Pitfalls

- ◆ Be very careful to check your sources when doing your literature review.
- ◆ Many trade magazines are not peer reviewed.
  - Professional conferences and journals often have each article reviewed by multiple people before it is even recommended for publication.
  - The IEEE and ACM digital libraries are good places to start looking for legitimate research.



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# Literature Review Pitfalls (cont.)

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- ◆ The Internet can be a good source of information. It is also full of pseudo-science and poor research.
- ◆ Make sure you verify the claims of any documentation that has not been peer reviewed by other professionals in the computing industry.



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# How to conduct a literature search

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- ◆ Define topics – Identify the problems
  - Clarify the meaning of the topic and/or particular words.
  - Identify the words and phrases that best describe your subject and how to link them together.



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# Decide on scope or boundary

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- ◆ May need to choose a specific aspect if the area/topic is too broad.
- ◆ Depending on the topic searched, you may find too many or too little information.



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# Define topics in terms of keywords

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- ◆ Think of words that may be used as an alternative for your topic.
- ◆ Combine your words: this may help retrieve only the meaning you want.
- ◆ Think of possible changes in terminology when looking for older material.
- ◆ Set limitations for your search: publication date, language, etc.



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## Draw up a list of sources/databases

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- ◆ These include the library or the internet (online catalogues).



# Conduct your searches



- ◆ Search through each source/database. Start with the most recent publication and work your way back.
- ◆ Keep a record of your searches. These should include the publication year of every document.
- ◆ Record all useful references. This will enable you to provide an accurate bibliography at the end of the project.





# Read Them

- ◆ Requires assessment, discrimination and judgment.
- ◆ Leave time between readings for thoughts and note taking
- ◆ Increase the understanding of the data you are collecting.



# Evaluate Sources

- ◆ Is the article written by a professional and published by a respectable organization?
- ◆ What are the credentials of the author?
- ◆ Is the article published in a “refereed journal”?
- ◆ Webs
  - What is the domain of the site (.com, .org, .edu,etc.)?
  - Why was the web created?
  - Who created the web page? Is he an expert on the subject?
  - When was the page last updated?

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