Design and Analysis of Experiments for an Interdisciplinary Undergraduate Research Experience

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"Tell me and I forget. Teach me and I remember. Involve me and I learn."-Benjamin Franklin

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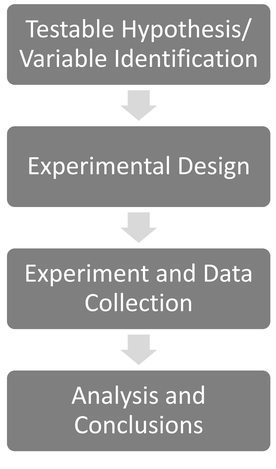
Abstract

Course Based Undergraduate Research Experiences (CUREs) are a model for undergraduate science education promoting "a deeper understanding of science for all students." (AAAS, 2011, pg. 29) We present comprehensive materials and activities developed for interdisciplinary CUREs (iCUREs) emphasizing statistical thinking, experimental design, and the evaluation of evidence. In ASU-West CURE courses, interdisciplinary student teams produce **authentic research** primarily in the natural sciences (biology, environmental science, forensics). Students generate hypotheses, develop protocols, conduct experiments to generate the data, evaluate evidence, and present the outcome. Hence, an emphasis on statistical thinking, proper experimental design and statistical analysis of the student developed research questions is critical. The materials include discussions and activities that guide the students and the instructor through all phases of the experiment through a statistical lens. Topics include the development of a Testable Hypothesis/Variable Identification, Experimental Design, Data Visualization, and the Evaluation of Evidence. The complete materials are available on project website.



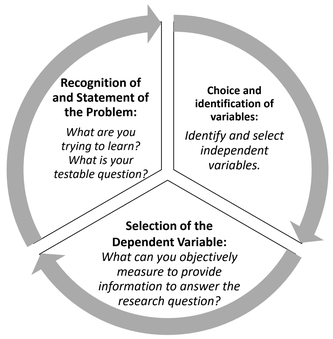
Additional Support Materials

Common Course Outline – Details the full CURE including:

- ❑ How to read/write a scientific paper
- ❑ How to conduct a literature review
- ❑ How write research protocols
- ❑ How to Design a Scientific Poster
- ❑ How to design a presentation

Workshop for interested teams ~ Summer 2020

Pre-Experimental Planning and Hypothesis Formation



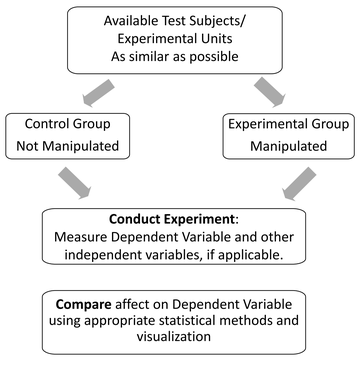
Overview of the Planning Process

"About 80 percent of your success in conducting a designed experiment results directly from how well you do the pre-experimental planning" - Doug Montgomery

In this phase students will:

- ❑ Think critically and statistically about their research.
- ❑ Understand the importance of proper planning.
- ❑ Identify through a series of activities:
  - what factor or independent variable they are interested in?
  - what factors influence their research question and dependent variable?
  - what other factors will affect their experiment?

Experimental Design



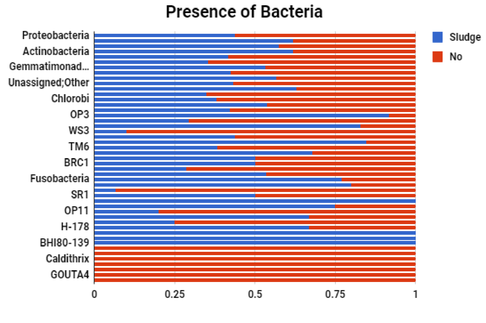
"All experiments are designed experiments; some of them are designed well, and some of them are designed really badly. The badly designed ones often tell you nothing." – Doug Montgomery

Students build upon the Planning Phase and Design their Experiment; Emphasis in this phase is placed on basic design principles: *Randomization: Replication*, and *Comparison*.

In this phase students will:

- ❑ Understand and follow basic design principles.
- ❑ Identify key aspects in the Planning Process that affect the design.
- ❑ Identify and ultimately sketch out their experimental design.
- ❑ Understand how and why to control for nuisance factors.

Data Visualization and Analysis to Support Conclusions



Example Student Visualization: Proportion of Bacteria Found in Sludge vs. No Sludge Samples For Key OTUs

Students build upon ALL previous phases and utilize data visualizations and statistical methodologies to appropriately support conclusions.

In this phase students will:

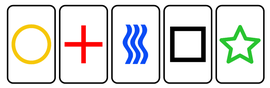
- ❑ Describe which graphics are best used for a variety of data types and identify characteristics of good/bad visualizations.
- ❑ Appropriately visualize data (see Draw your Hypothesis activity);
- ❑ Recognize the need for statistics (see Role of Statistics activity)
- ❑ Select an appropriate statistical "test" or methodology necessary to test the research question.
- ❑ Evaluate results and communicate appropriate conclusions.

Activity: Draw Your Hypothesis

This activity should be performed after students have developed their hypotheses and design. Students have started their experiments and have familiarity with the literature. They should be thinking about what their experiments are testing and what they **might** show.

1. Students discuss their hypotheses and experimental design.
2. Students then are asked to "draw their hypothesis." That is, what would the data look like graphically if their hypothesis is not disproven by experimentation?
3. Students or groups swap drawings and describe their drawings to each other.

Activity: Role of Statistics



Suppose you are trying to prove/disprove the existence of extrasensory perception (ESP). In order to test the existence of ESP or a "6th sense," a psychologist in the early 1900's developed a set of 25 cards that consisted of 5 shapes shown in figure above. The test subject is presented the card with the shape side down and states what shape is on the card.

Activity: motivates the need for statistics to justify the conclusions of their research, beyond visualizations. Understand the role of statistics to provide evidence beyond that of "chance."

References

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