Building Scientific Understanding:
beyond the inquiry cycle

Observations

Question

"Inquiry Cycle"

Reflection
- Conclusions
- Applications
- Further questions

Actions
- Hypotheses
- Study design
- Research
- Data analysis

Building Scientific Understanding:
beyond the inquiry cycle

Building scientific understanding BEGINS with the INQUIRY CYCLE

Observation → Question → Hypotheses → Testing Hypotheses → Conclusions

- Drawn here in a linear fashion for simplicity
- Also known as the "Discovery Phase" of building scientific understanding

Building Scientific Understanding:
beyond the inquiry cycle

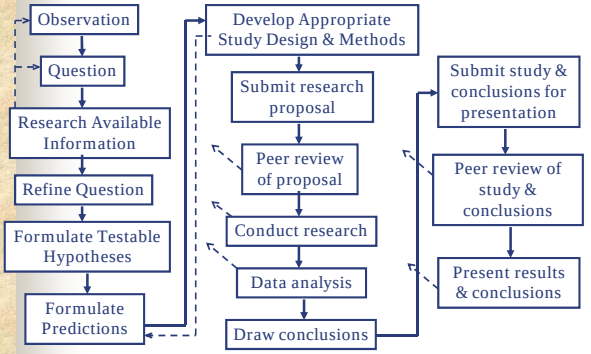
Discovery Phase	*Verification Phase*
Observation	Peer review of proposal
Question	Peer review of results & conclusions
Hypotheses	Verification by further study
Testing Hypotheses	Reconciliation with known theory
Conclusions	Standing the test of time

Building Scientific Understanding:
beyond the inquiry cycle

The "RESEARCH PROCESS"

Discovery Phase	*Verification Phase*
Observation	Peer review of proposal
Question	Peer review of results & conclusions
Hypotheses	Verification by further study
Testing Hypotheses	Reconciliation with known theory
Conclusions	Standing the test of time

The Research Process *in more detail*



Field Observations: Pattern & Process

Patterns occur in nature

- Scientists assume these patterns have some understandable basis; that the world is not governed by chance.
- Exploring the link between pattern and underlying process will reveal something about how nature works.

Field Observations: Pattern & Process

Pattern:

Isolated patches of biotic development in a barren polar desert landscape

Process:

The Art of Making Observations

I. Spatial considerations

A. Scale

The Art of Making Observations

I. Spatial considerations

A. Scale

B. Perspective

The Art of Making Observations

II. Time considerations

Pollination

Succession

The Art of Making Observations

Going Beyond Your Eyes

Listen

Smell

Taste

The Art of Making Observations

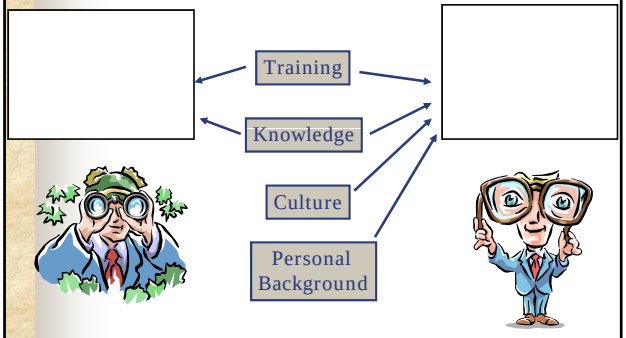
Going Beyond Your Eyes

Examine Data

Quantitative analysis is often used to elucidate patterns not readily observable with human senses

The Art of Making Observations

Recognize bias in your observations



The Art of Making Observations

Recording your observations

3 Rules scientific observation

1.

2.

3.

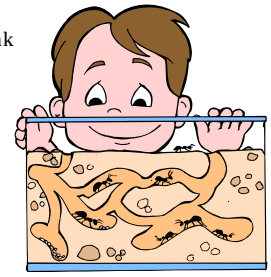
- **The elements of an excellent lab / field notebook vary among disciplines & situations**
- **You will learn this skill in lab courses at UWB**

Asking Questions

Turning observations in questions: The art of wonder

Asking good questions is harder than you might think

But it IS a skill we all started out with



Asking Questions

Turning observations in questions:

Example 1

Observation: Shrub A occurs more frequently toward the bottom of the hillslope.

Question: Why does Shrub A increase in density lower on the slope?

Example 2

Observation: Clutch size in birds increases with greater latitude.

Question: Why does clutch size increase with latitude?

Asking Questions

Is it a good question for the natural sciences?

Observation: North Creek is filled with garbage.

Question: Why do people put their trash in North Creek?

Is it a good question for scientific study?

Observation: Some campus trees have orange ribbons tied on them.

Question: Why do some campus trees have orange ribbons?

Asking Questions

More considerations about questions

1. Is it interesting?
2. Is it testable?
3. Is it broadly applicable?

Researching Available Information

1. Talk to the experts.
2. Read _____ printed material.
3. Listen / watch recorded media.
4. Examine electronic media (e.g., WWW).

Refine your question or Make further observations

Forming hypotheses & predictions

Example

Observation: Douglas-fir saplings are plentiful in the open fields of Puget prairies but not in the nearby forest understory.

Question: Why do Douglas-fir saplings only occur in open prairies?

Hypothesis 1: Low light intensities in the forest understory cause seedling mortality in Douglas-fir.

Prediction 1-1: Douglas-fir saplings should exist in gaps within the forest where light is higher.

Prediction 1-2: Douglas-fir seedlings in the prairie will die when artificially shaded.

Forming hypotheses & predictions

Example *continued*

Observation: Douglas-fir saplings are plentiful in the open fields of Puget prairies but not in the nearby forest understory.

Question: Why do Douglas-fir saplings only occur in open prairies?

Hypothesis 2: Douglas-fir seedlings in the forest understory experience mortality because they are exposed to a root fungus transmitted from parent trees.

Prediction 2-1: Percent infection of root tissue by fungal pathogens will be greater in seedlings from the forest understory than the prairie .

Developing Appropriate Study Design & Methods: *some considerations*

1. **How have similar questions been approached?**
   Talk to the experts / search for information
2. **Consider statistical validity** ***a priori***
3. **Be sure the methods match the hypothesis**
   Simple questions may not require sophisticated approaches
4. **Be realistic & resource effective**
   Match methods to time & resources ($ and labor)
5. **Sometimes technology & new methods can drive questions & hypotheses**

Preparing & Submitting a Research Proposal

1. **Proposals must demonstrate clarity in the above steps**
2. **What is in a proposal?**
   - Introduction – context
   - Literature review
   - Specific observations
   - Hypotheses / Predictions
   - Expt. Design / Methods / Analysis
   - Contingencies
   - Equipment / Timetable
   - Credentials
3. **Peer review is a crucial first step –quality control**

What is Peer Review ?

Peer review is usually (but not always) done anonymously

Preparing & Submitting a Research Proposal

1. **Proposals must demonstrate clarity in the above steps**
2. **What is in a proposal?**
3. **Peer review is a crucial first step – quality control**
4. **However, peer review can be a double-edged sword**
   - Many excellent proposals do not get funded (edgy work; limited $)
   - ↑ time spent proposing → ↓ researching
5. **Pre-proposal research can be critical**
   - Preliminary data to support your ideas
   - Proof that you can actually do what you propose

Conducting the Research, Analyzing the Results & Drawing Conclusions

1. **Conducting the research**
   - The tedious, exacting reality
   - Specific to question & discipline – you will learn some techniques at UWB
2. **Analyzing the data and drawing conclusions**
   - Analysis approach should have been predetermined
   - Computers, statistics, more computers, more statistics, modeling
   - Review literature and discuss with colleagues for perspectives to help in analysis & drawing conclusions

Presenting Your Research

1. **Creating an impression & sparking discourse**
   - Oral presentations
   - Poster presentations

Presenting Your Research

2. The real detail: peer-reviewed papers

- The structure of an original research paper– *details later*
- Submission & peer review
  - ✓ The long & winding road
  - ✓ An imperfect but crucial process of quality control
    - ❖ Personal preconceptions (good & bad)
    - ❖ Reviews done on a volunteer basis
    - ❖ Limited number of reviewers

Peer Review: *Its role in building scientific understanding*

- Peer review is the crucial step that places individual work within the broader framework of human scientific knowledge & understanding.
- Science without peer review is GREATLY diminished in effectiveness & reliability
- Science and peer review have become globalized – thus peer review provides a cross cultural check on scientific understanding.
- It is critical that you select sources that are peer-reviewed (or traceable to the peer review system) as the basis of your scientific information

Presenting Your Research

2. The real detail: peer-reviewed papers

- The structure of an original research paper– *details later*
- Submission & peer review
- Why publish?
  - ✓ Building a body of knowledge & understanding with regard to the subject and methodology
  - ✓ Allows work to be independently verified
  - ✓ Fame & fortune / funding agencies expect it / moral obligation

The Research Process *in more detail*