

Integrating Research and Authentic Scientific Data into Undergraduate Courses



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Overview

- The value of integrating data and research into courses
- Ramping students up to independent research using inquiry-based activities
- Strategies and specific examples for integrating research into teaching
- Discussion

The Value of "Real" Data & Research

- As science educators, we are training future scientists and citizens who will need scientific knowledge and skills.
- Training students to *think* like scientists means giving them experience *doing* what scientists do:
 - Asking questions
 - Collecting data
 - Analyzing data
 - Drawing conclusions
- Connecting students with original research and authentic data can make science more meaningful and more fun.

Ramp Up Your Expectations



- Provide students with opportunities to build their knowledge and skills progressively over time.
 - Integrate data and/or research into a course not once but several times, increasing your expectations each time.
- One way to ramp students up to independent research is to change exercises from "cookbook" procedures to *inquiries* that address a research question.
 - This is termed "inquiry-based learning."

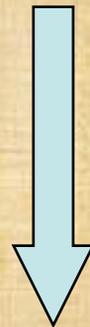
An Inquiry-based Approach

How much information do you give the student for an exercise?

It depends on the level of inquiry:

Level of Inquiry	Question	Methods	Solution	Type of Inquiry
1	X	X	X	(not!) Confirmation
2	X	X		Structured
3	X			Guided
4				Open

*less
challenging*



*more
challenging*

Strategies for Integrating Research into Teaching

- Talking about research
- **Analyzing data inside and outside of class**
- Doing library and web research
- Reading primary literature
- Writing research proposals
- **Doing research projects**
- Deliverables
- **Curriculum design**

bold = specific example discussed

Talking About Research

- Describe your own research experiences.
 - Students who have never done research do not know what it is like.
 - Your experiences may inspire them.



Analyzing Data

- Do exercises with real data in class.
 - This could include interpreting graphs, figures, etc., from scientific papers and/or your own research.
- Outside of class, have students interpret a real dataset either that you provide or that they have collected.
 - Build on their experience in class by asking for more in-depth analysis on their own.

Example: Tracing Mercury Contamination

- Draws on professor's own published research
- Involves students interpreting data maps to test hypotheses



Hygelund, Bretagne N., Ambers, Rebecca K. R., and Ambers, Clifford P. (2001) Tracing the source of mercury contamination in the Dorena Lake watershed, Western Oregon. *Environmental Geology*, v. 40, no. 7, p. 853-859.

Scenario

- An Oregon reservoir called Dorena Lake has high enough levels of mercury in its fish to warrant a *fish consumption advisory* urging people to limit the amount of fish they eat from the lake.
 - Lake managers want more information so they can deal more effectively with the problem.
- The source of the mercury is unknown, but it could be from:
 - atmospheric deposition
 - high background levels of Hg in watershed's volcanic bedrock
 - old gold mining district on rim of watershed where Hg was historically used for gold extraction

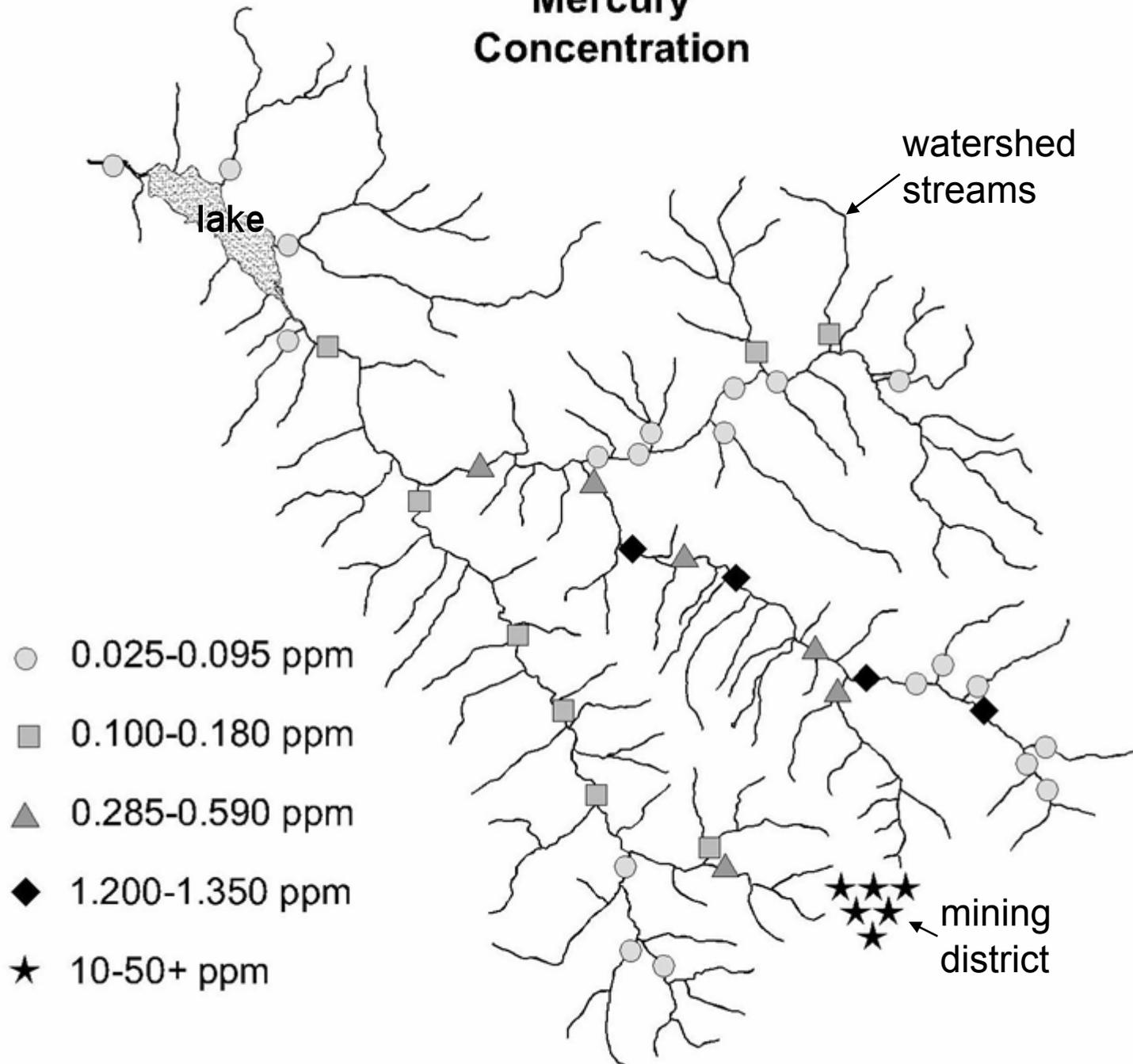
Methods

- Collection and chemical analysis of:
 - fine-grained stream sediment at locations all around the watershed
 - sediment/soil and tailings deposits in the historic gold mining district



What pattern of mercury distribution around the watershed would you expect for each possible source?

Mercury Concentration



How is Hg distributed around the watershed?

Where is the Hg coming from? How does it get to the lake?

Which hypothesis is supported?

How To Make It More Challenging

- Have students generate the list of hypotheses instead of handing it to them.
- Provide some other data figures from the paper for additional practice with data interpretation.
- Ask for higher level interpretation:
 - Is Hg associated with any other elements?
 - If so, in what form might it be traveling?
 - How could you find out for certain?
 - What other analyses would be necessary to completely rule out the other hypotheses?
- Give students the first part of the paper (intro, methods, results) and have them write, or just outline, their own discussion and conclusion sections.

Would this work for you?

- Can you think of an example of data from your own research that you could use in one of your classes?

Doing Library & Web Research

- Have students do background research on a topic such as:
 - exploring the geology of their home region
 - evaluating natural hazards in a region
 - comparing the perspectives in different journal articles



Reading Primary Literature

- Use primary literature for readings, discussion, and writing assignments.
 - It takes practice for students to become proficient at reading and understanding primary literature.
 - Give guidance by asking students orally or in writing:
 - What was the purpose of the research?
 - What question(s) did the author(s) ask?
 - What methods were used?
 - What are the main results and conclusions?
 - Are the authors justified in their conclusions?



Writing Research Proposals

- Have students write a short research proposal on a question of their own choosing or one related to a collection of articles they have read.
 - This could be an activity unto itself regardless of whether the students actually do the research project.



Doing Research Projects

- Integrate short- and/or long-term research projects into courses.
 - These can even be the centerpiece of the course.
 - Projects can be individual or group efforts.
 - You can design the research question or students can.
 - Often the most compelling projects are those which have significance for the local community, e.g., soil or water quality, natural hazards, geologic resources, etc.



Deliverables

- Give students practice presenting project results through:
 - writing assignments
 - oral presentations
 - poster presentations



Example: Winogradsky Column Project

- **Audience:** Nonscience majors taking a course for core science requirement.
 - *Life on Earth and the changes that our Earth has undergone and will experience:* part of a program at UMd. (<http://www.marqueecourses.umd.edu/courses.html#geol124>)
- **Aim:** To provide experience with the scientific method, evaluation of science, hypotheses, and uncertainty.
- **Rationale:** These students will be faced with science in their future, and this perspective will be valuable for them as nonscientists in society.

Winogradsky Column Project

- **Theme:** How the activity of life (metabolism) responds to and shapes the environment in which organisms live.
- **Technique:** Construction and observation of a Winogradsky column.
 - This is a way of culturing a range of microorganisms using water and/or mud in a container.

Winogradsky Column Project

- **Project design:**
 - Group project with 4-5 students per group.
 - Groups each decide on a hypothesis to test and design their own Winogradsky columns to test it.
 - Groups have the option to modify experiments after a few weeks.
 - Weekly observations are made of the columns.
 - Weekly discussion includes elements of science in the project (nature of hypotheses, levels certainty, tests, controls, flaws).
 - The goal of the project is not to make the best Winogradsky column but to do a thorough job of using the scientific process.
- **Assignments include:**
 - A proposal including a 5-minute oral presentation
 - A paper
 - A poster and oral presentation

Creating Small-scale Original Research Projects in Upper-level Classes

*An example (and slides) from
Gregory Hancock
Surface Processes
College of William & Mary*

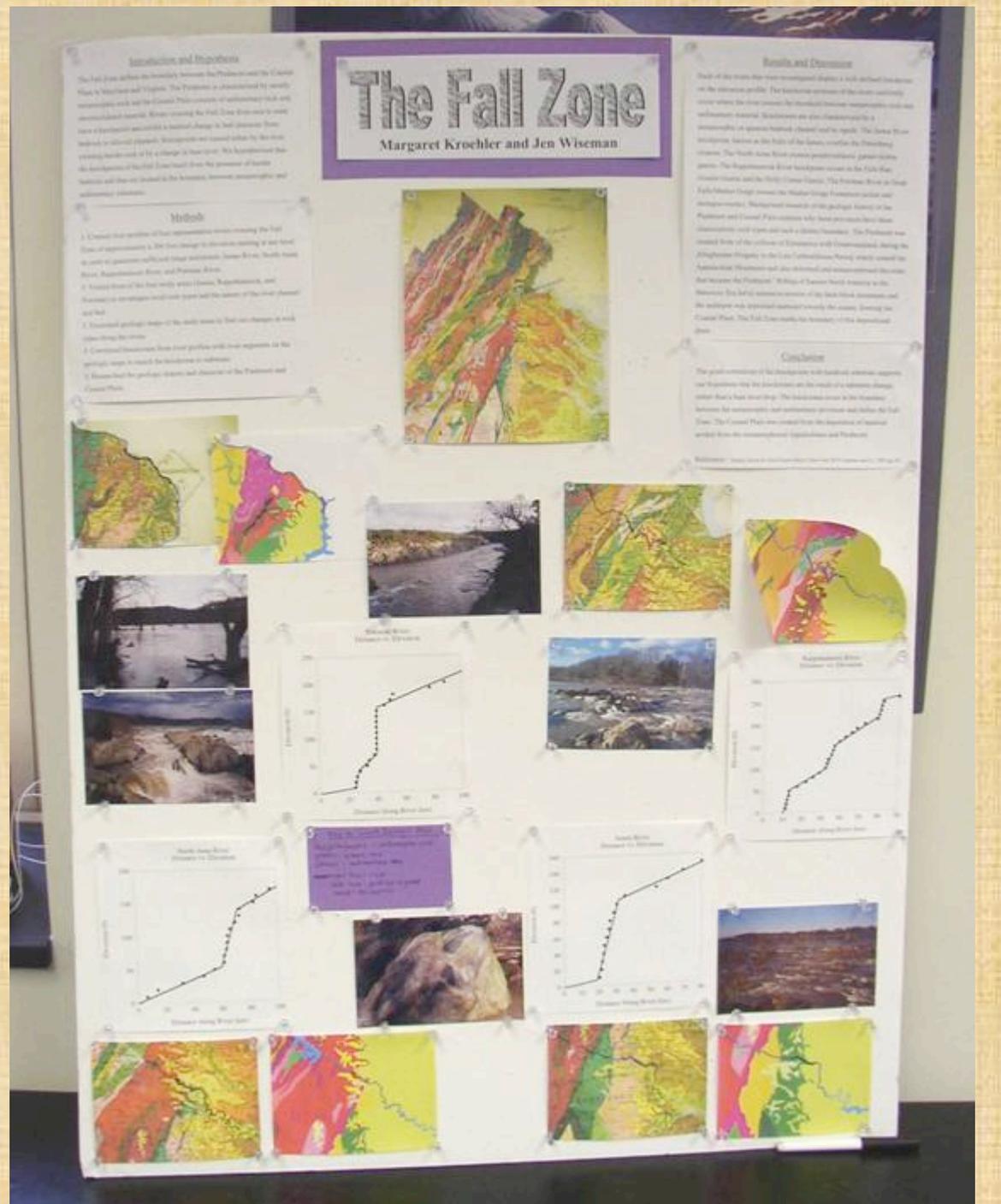
Project Goals

- Provide an opportunity for students to “do” science
- Allow students to take charge of a project
- Keep your time commitment to a minimum
- Explore new avenues of research, particularly local research

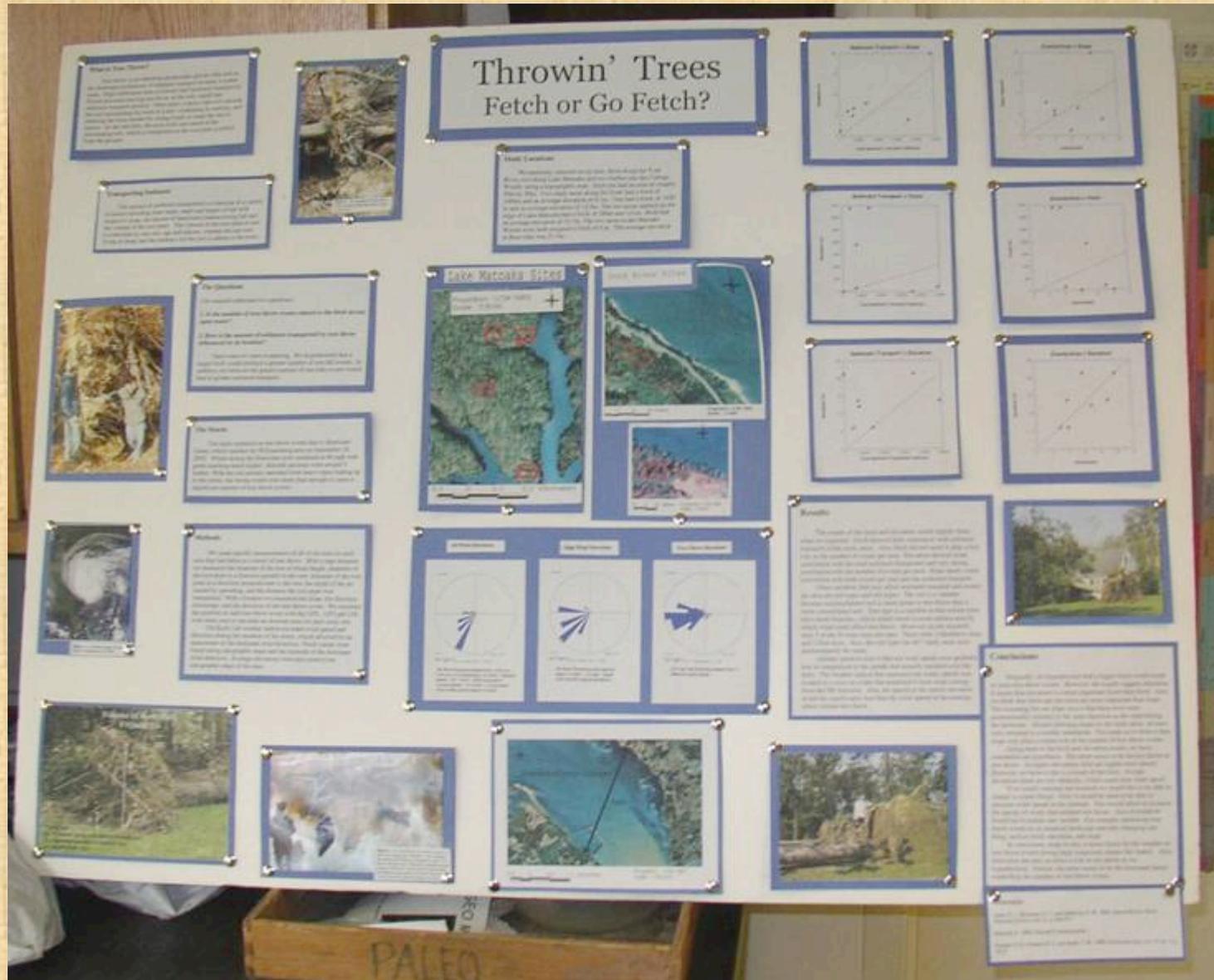
Project nuts and bolts

- Hand out assignment and topic list in first two weeks
- Students select projects and are paired
- Prepare initial proposal with question and methods
- Prepare a short bibliography (~5 papers)
- Evaluate progress during a lab session ~1 month before assignment is due
- Present research in poster form at end of semester

Example 2: Are falls at the Fall Zone related to harder lithology?



Example 3: Did wind fetch affect local sediment transport by tree throw events during Isabel?



PALEO

First step:

What methods/techniques could I expect students to use?

- What do they already know how to do?
- What am I going to teach in the class?
- Should I add a technique to class?
- What can I show them quickly outside of class?

Second step:

What projects could I have them do?

Some possible guidelines for selection:

- I must have interest in the topic
- I must frame it as a research question or hypothesis
- The materials must be readily available
- The students must know the techniques
- The topic must be discussed in lecture or lab

Would this work for you?

- What are some projects you might suggest for your students?

Curriculum Design



If or when you become involved in this process:

- If possible, work with department colleagues to build practice with data analysis and research into courses at all levels.
- Build from the ground up:
 - Try to increase students' preparation and teachers' expectations with each successive course in the major.
 - Ramp students up to more open-ended research by their senior year.
 - A senior capstone course involving a research project is a great way to culminate this process.

A Project-Based Course

- Advanced Lab course required for environmental science majors during fall of senior year.
 - Course focuses on one major research project that requires students to apply knowledge and skills from all prerequisite courses (chemistry, ecology, geoscience, GIS, etc.).
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- A photograph showing two students in a field of bare trees. One student, wearing a blue long-sleeved shirt and blue pants, is standing and looking down at something in the hands of another student. The second student, wearing a green long-sleeved shirt and blue pants, is kneeling on the ground, focused on a task. The ground is covered with dry leaves and sparse green grass. The background consists of many thin, bare tree branches.
- Students work on the project as a team with an emphasis on positive and equitable collaboration.

The Research Question

- The research question is usually defined by the instructor.
 - In some years, students have been given a choice of research questions.
- The student team must:
 - work out the project design
 - collect and analyze data
 - present their findings both orally and in writing at the end of the term
- The question generally involves an environmental issue of local importance that is academically significant.



Examples of Past Projects

- Effects of a small dam on a lower order stream
 - Comparison of the geomorphology and ecology of two campus streams, one dammed and one not dammed
- Evaluation of the ecological health and safety of the college lake
 - Included recommendations given to the college's Board of Trustees regarding lake management
- Lingering effects of a former Superfund site on streams and soil
 - Investigation of pH and metal contamination problems surrounding an old titanium mine
- Evaluation of potential hazards of biosolids application on agricultural fields
 - Analysis of biosolids and soils for heavy metals and bacteria during local controversy over the issue

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