Integrating Research into Courses

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As scientists we read the scientific literature critically to identify broad research trends in our discipline and specific approaches to research questions, observe and question phenomena around us, collect and analyze data, synthesize and present our results in a variety of settings. Although engaging in research is one of the more attractive aspects of education, students are often disconnected from original research and authentic data analysis. This is especially true of non-majors in general education classes, but it may also be true of upper class majors taking our advanced courses. In this session, we will explore strategies for integrating the different components of research and the use of authentic data into course curricula. We will consider examples that range from relatively simple 'add-ons' to extended in-class or lab-type exercises to more elaborate projects that can serve as the centerpiece of a course. We also will explore how to broaden the impact of our own research by building bridges between it and our teaching.

The examples below were selected to emphasize that there are many different ways to incorporate research into undergraduate courses. If you elect to integrate research and authentic scientific data in the courses you teach, then you will want to find the ways that fit best with your curriculum, teaching style, and research. Some classes might incorporate all the stages of research highlighted above; other classes might incorporate one or two aspects; or, a class project may be a small piece of a larger project or longitudinal study.

In addition, as you contemplate integrating research into courses, consider the resources of the department, institution and area. Are there field opportunities nearby? What analytical equipment does the department have? Do other departments or nearby institutions have facilities or equipment that you might use? What funding, if any, will be required? Might you apply to internal or external funding sources to support the class projects?

Categories and examples of integrating research and authentic scientific data in courses

Most examples given are either appended or can be accessed through the web links provided.

Early Exposure to Primary Literature

Students can be exposed to research literature even in introductory (general education courses) with success. By narrowing the focus of what the instructor wants students to gain from a research article students are encouraged and empowered to take the first step and dive into authentic research results. There are many ways of taking that first step, below are several examples.

While initially developed for high school audiences, the following can be easily adapted for general education undergraduates: In "**Citizen Scientists and Decision Making - A Case Study**" students can use the publicized results from an ocean drilling expedition to examine the relationship between science and the public media. Is the scientific information received from the media reliable? What do these scientific results mean in the context of my life? This activity presents a unique chance to learn how to understand science from personal and social perspectives - a skill very valuable in today's media frenzy of internet, newspaper, magazine and television sources. See: http://joilearning.org/classroom/citizen_scientists_312.html

We know the phrase “A picture is worth a thousand words” – consider using key diagrams from primary literature to introduce, through inquiry, key content concepts. For example, Mark Leckie and Kristen St. John use a summary figure on Cenozoic climate evolution to engage students in authentic research. See: http://csmres.jmu.edu/geollab/stjohn/GSCI115/CZclimatequestions.doc

Students must learn how to read scientific literature critically. Having students read the primary literature, write a critique, and then use their critiques as the basis of classroom discussion can help them to learn how to identify the key points in a paper, how to discern what parts of an argument are strong or weak, how to reconcile different aspects of the work with information from other sources, etc. Instructor comments on students’ written critiques will help students make rapid advances in their ability to read the literature. For more information on incorporating discussions into undergraduate classes see the ‘Reading from the Primary Literature’ by Cameron Davidson, ‘Writing and Revising Short Assignments’ by Jan Tullis, and “Using Written Critiques of Journal Articles to Foster Analytical Thinking by Steven Wojtal at: http://serc.carleton.edu/NAGTWorkshops/structure/presentations.html

Primary Literature can be integrated in short writing assignments as well. Student abstract writing of published (primary or secondary sourced e.g., *Scientific American*) scientific papers is used to aid students in identifying key components of a science paper, and clarify the purpose and content of an abstract. With instructor feedback, it can also improve student writing skills.
For information on abstract writing, in undergraduate classes see: http://serc.carleton.edu/introgeo/interactive/qotd/abstract.html

Scientific method

In introductory courses you may describe some version of the “scientific method” as the process by which scientists study the Earth. In fact, we believe that a description or discussion of the scientific method is an important component of any introductory course in earth sciences because the observation-inference methodology most Earth scientists use differs in significant ways from most students’ prior experiences or idealized notions of the scientific method. Rather than speaking hypothetically or using the examples given in the text book – use your own research as the example. In a general education course on climate change, Earth Systems, Cycles, and Human Impact, Kristen St. John uses her research in marine sedimentology as the basis for a discussion on the *how* scientists approach the study of past climate change. In this way the scientific method is personalized. From observation to data collection to data analysis and interpretation to proposing hypotheses and rejecting hypotheses, to theory development, and even to the necessary aspect of scientific publication – all of this can be explained with an example that you know the best – your own research.

Question/hypothesis

Research methodology can be integrated into any laboratory exercise by posing questions or constructing hypotheses at the end of a laboratory or other exercise, thereby encouraging students to think further or explore other applications. The assignment may be formal or quite simple. For example Rachel Beane (Bowdoin College) makes the following assignment at the end of an exercise introducing the SEM: "We collected sand samples as part of our beach profiles. Ask a question, or construct a hypothesis, that can be tested using the sand samples and the SEM/EDS." See this exercises at: http://serc.carleton.edu/introgeo/studentresearch/examples/SEMbeachsands.html Depending on your course objectives, you may or may not have students follow through with testing their hypotheses.

At the other end of the spectrum, one can have a research project as the centerpiece of a course. In *Modern Geologic/Geographic Mapping & Analysis*, Steve Wojtal and his colleague Laura Moore ask students to pose a research question. After discussion with faculty, students write a research proposal, collect and analyze data, and present their results in a short oral presentation and in a short paper. The **appended** assignment outlines what they expect from students and includes an example of a grading rubric.

Proposal

One assignment that some of our colleagues have used to advantage is to assign students to write a short research proposal. Such an assignment may invite students to choose their own research topic, or ask students to write a proposal derived from the same selection of articles. See an **appended** example by Lori Bettison-Varga (College of Wooster) on Society for Creative Oceanography Proposal Request and Review. Such assignments invite students to write and review scientific proposals.

Background research

A background-research type of assignment is common for intermediate- or advanced-level courses. One variant has students find two or three papers on a particular topic, compare the approach taken by those papers, analyze the results of the different approaches, and conclude what is known on a particular topic. Leading a class discussion of one of these papers or other journal articles prior to assigning students to undertake the analysis on their own may help them to learn how to read and analyze scientific literature. **Appended** are examples of a weekly assignment and the final paper assignment on *Mountain Belts (Beane).* This class, taught in a tutorial format, emphasizes discussion of current research through reading primary literature and writing scientific essays. Articles are selected to emphasize geologic debates.

Experiment

The experimental or data collection portion of a research project may be one portion of a longer class project, or it may be an assignment on its own designed to help students learn how to use a particular piece of equipment. One approach we have found useful is to have the students compare their results with the results of earlier analyses that the instructor or previous years' classes have completed. This provides a larger database from which students may draw their conclusions, and it provides internal checks on their results. Below are two examples:

Regional trends in the petrology and hydrothermal alteration in the Proterozoic iron deposits of the Mid-Atlantic iron belt (Friehauf). Individual mines in the belt are used for student projects in mineralogy and petrology classes. This class research feeds into one of Friehauf's research projects involving a regional comparison of the petrologic characteristics of the host rocks, hydrothermal alteration, and ore mineralogy of these deposits (See **appended** assignment).

Mineralogy (Beane). In conference with the instructor, individual or pairs of students design a mini-project that can be accomplished with two weeks of laboratory work. One of the objectives of this assignment is to encourage students to become familiar with methods in mineralogy that are available at the college – including petrographic microscope, SEM with Energy Dispersive Spectrometer, and Electron Backscatter Diffractometer. Some students build on projects begun by students in previous classes or choose to continue their own projects as independent studies.

Field Synthesis

As a means of integrating classroom-based content knowledge with direct field-based observations and data collection, one can have students in general education and introductory courses prepare a virtual field trip guide/report. This is a hefty capstone assignment and requires synthesis of content knowledge and original data. Students will need to go beyond reporting on what was collected in the field to also explain the methods of data collection, interpreting what the data means, and (the synthesis) comparing their data to what they would expect if similar types of data were collected at unvisited field site. Kristen St. John has used this approach in her introductory Oceanography courses populated by general education students, education majors and geology majors. The entire class works as a team to collect data and digital images in the field, but each student writes their own virtual filed trip guide/report.

See the syllabus describing the assignment:

http://csmres.jmu.edu/geollab/stjohn/NAGTworkshop/Ocean_syl06.doc

See an example of a student generated virtual field trip guide/report:

http://csmres.jmu.edu/geollab/stjohn/GEOL211/JCfieldtriprpt/

A different assignment example is from Kristen St. John's Earth Science for Teachers course, in which students investigate the geologic resource and hazard issues for their own home. This requires a mix of on-site field observations, data gathering via phone interviews and/or internet searches, and integration of content knowledge from the course.

See the syllabus describing the assignment:

http://csmres.jmu.edu/geollab/stjohn/Geol301/GEOL301syllabus_Sp_07.doc

A slight modification of this approach will work in upper level courses, where one can ask students to combine information from lectures, readings, discussions, and laboratory exercises to address a broad problem. In Steven Wojtal's Structural Geology course, the capstone exercise (**appended**) asks students to compile the results of previous laboratory exercises and written critiques with their understanding of material covered in lectures and demonstrations to examine the tectonics of the central Appalachians in the context of mechanical models of orogenis.

Data analysis/modeling

Data sets or samples collected by faculty, by previous classes, or available in the scientific literature or on the web are frequently incorporated into projects that emphasize data analysis or modeling. Two examples are:

School of Rock Expedition (St. John and Leckie). This includes a suite of datasets from scientific ocean drilling (DSDP, ODP, IODP) that have been translated into exercises on biostratigraphy, magnetostratigraphy, climate change, plate tectonics and other topics. See: http://joilearning.org/classroom/audience_index.html

Past Climate Change in the Irminger Basin (St. John). This is an example of how you can take your own research data - methodology and materials – and create an exercise for introductory students and teachers.
See: http://csmres.jmu.edu/geollab/stjohn/NAGTworkshop/ESP2 stjohn.ppt

Presentation

Whatever their future careers, students are likely to need to make oral, written or poster presentations. Having students present research proposals, analyses of background research, experimental methodologies, data analyses, or modeling will prove useful to them. Using a grading rubric distributed prior to their presentation may help to guide them. Two examples are:

Field Studies Report (Wilson). Students write a report describing the taxa and geologic setting of invertebrate fossils they collect on a field trip. Assignment is **appended**.

Peaks Island Project (Beane). This introductory class project involved a weekend field study, followed by three weeks when groups of students conducted original studies to contributing to different aspects of the project. Students presented their results as abstracts and oral slide presentations. The appended project also gives an example of a grading scheme used for the presentation portion of the project. This class project was part of a multi-year project designed to integrate research into all levels of courses and was partially funded by an NSF-Course, Curriculum and Laboratory Improvement grant. See:
http://serc.carleton.edu/introgeo/studentresearch/examples/PetrologyFieldLab.html

Interdisciplinary Courses

Interdisciplinary courses are fraught with student pitfalls from retention to synthesis, yet research trends suggest that multidisciplinary/interdisciplinary research endeavors are needed to deconvolute complexity of many scientific questions prompting us to begin training our students early to take on these challenges. Project-based courses are one way to successfully combine skillsets from many fields, without extensive prior training. This approach focuses students on a common interdisciplinary hypothesis that then integrates both primary knowledge and skills with the more transcendent skills of scientific inquiry.

Thinking about the process of scientific inquiry: An experiment-based course in Geomicrobiology (Roberts). This is an example of an interdisciplinary course taught

using an experimental research project. The goals were to teach the basics of geomicrobiology, but also initiate motivated upper-division undergraduates and first-year graduate students into the culture of scientific research. This course includes many of the components mentioned above. See:
http://www.cte.ku.edu/gallery/visibleknowledge/roberts/print.shtml

Graduate Courses

Most examples here are for undergraduate course and training but it is important to note that many of our incoming graduate students have *not* had the benefit of such training prior to arriving in a graduate program. All of the approaches can be used to great advantage in graduate courses and ideally, are integrated into a few courses aimed at first-year graduate students.

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