Integrating Research into Undergraduate Courses

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As scientists, we observe and question, collect and analyze data, write proposals, read scientific literature to identify broad trends in our discipline and specific approaches to research questions, and present our results in a variety of settings. Integrating research and authentic scientific data into the courses we teach can help bridge the gap between our teaching and our research – to the benefit of both the students and the faculty member. Integrating research into courses enables undergraduates to experience the nature of science; examining published scientific data or collecting, processing, and interpreting new data is skill building, empowering, and enables students to experience science as a *process* for exploring the natural world. Including research and authentic data analysis in courses is often challenging: published data sets may not seem accessible or in format useful for undergraduate education, equipment may malfunction, weather may not be cooperative, results cannot always be anticipated, analyses may take longer than a semester, etc. It is, however, usually rewarding: students can integrate scientific theory with scientific process, recognize the importance of multidisciplinary approaches to addressing scientific problems, make connections between different sub-disciplines in earth sciences, gain confidence in their abilities, and enjoy their discoveries, and even come to see their professors as multidimensional – not just their teacher but an active researcher. There are rewards for faculty too: as faculty and students work together they gain an appreciation and respect for each other, and in some cases publications may result.

Research and authentic data analysis have many facets, and there are a variety of ways to incorporate these into courses. We will consider examples that range from examples relatively simple ‘add-ons’ to extend class and laboratory exercises, to more elaborate projects that are the centerpiece of a course.

## Examples of integrating research into courses

*Most examples can be accessed through 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.

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 earn 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 we may describe some version of the “scientific method” as the process by which scientists study the Earth. Rather than speaking hypothetically or using the examples given in the text book, we can use our 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.

See: [http://csmres.jmu.edu/geollab/stjohn/NAGTworkshop/ScientificMethodKSK.ppt](http://csmres.jmu.edu/geollab/stjohn/NAGTworkshop/ScientificMethodKSK.ppt%20)

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 can be demonstrated with examples that we know the best – our 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, at the end of an exercise introducing the SEM, an assignment states: “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.” Depending on your course objectives, you may or may not have students follow through with testing their hypotheses. <http://serc.carleton.edu/introgeo/studentresearch/examples/SEMbeachsands.html>

### 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

Some faculty 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. The “Examples from geoscience faculty” link has an example by Lori Bettison-Varga on *Society for Creative Oceanography Proposal Request and Review (Bettison-Varga).*

# 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. The “Examples from geoscience faculty” link has examples of weekly assignments 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. Here are two examples, further described in “Examples from geoscience faculty.”

*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.

*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 a virtual field trip guide/report can be assigned in general education and introductory courses. This is a hefty capstone assignment and requires synthesis of content knowledge and original data, that goes 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 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 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 orogenies.

**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.

*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://www.joilearning.org/schoolofrock/Library.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](http://csmres.jmu.edu/geollab/stjohn/NAGTworkshop/ESP2%20stjohn.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.

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

*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. <http://serc.carleton.edu/introgeo/studentresearch/examples/PetrologyFieldLab.html>

## Further notes

The above examples 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.

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?

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##### References

Some examples of integrating research in undergraduate classes. Other examples may be found in meeting abstract volumes, serc.carleton.edu/NAGTWorkshops or www.dlese.org.

Amenta, R. V., Holyoke, C. W., Myers Krohn, T. G., Bonder, M. J., & Leopold, M. C. (1997). Undergraduate research in petrology approached through computer modeling of fabric evolution in igneous rocks. *Journal of Geoscience Education, 45*(3), 205-206.

Andersen, C. B. (2001). The problem of sample contamination in a fluvial geochemistry research experience for undergraduates. *Journal of Geoscience Education, 49*(4), 351-357.

Badger, R.L. (1995). Course integration through student research projects in geology. *Journal of Geological Education, 43, 477-479.*

Beane, R. J. (2004). Using the scanning electron microscope for discovery based learning in undergraduate courses. *Journal of Geoscience Education, 52*(3), 250-253.

Beane, R.J. and Urquhart, J. ( 2010). Providing Research Experiences to Non-Science Majors in an Introductory Science Course. *In* Boyd, M. and Wesemann, J., ed., Broadening Participation in Undergraduate Research: Fostering Excellence and Enhancing the Impact. *Council on Undergraduate Research* publication, p. 223-226.

Boundy, T. M., & Condit, C. (2004). Bringing the field into the classroom by using dynamic digital maps to engage undergraduate students in petrology research. *Journal of Geoscience Education, 52*(4), 313-319.

Carlson, C. A. (1999). Field research as a pedagogical tool for learning hydrogeochemistry and scientific-writing skills. *Journal of Geoscience Education, 47*(2), 150-157.

Ebert, J.R., 2006, Designing a sedimentary geology course around field-based class projects that yield publishable research: See the following which includes links to examples and a PowerPoint presentation that outlines the course and planning for class-based projects: <http://serc.carleton.edu/NAGTWorkshops/sedimentary/activities/13958.html>

Foos, A. M. (1997). Integration of a class research project into a traditional geochemistry lab course. *Journal of Geoscience Education, 45*(4), 322-325.

Fryer, K. (1991). Regional geological context for a course in petrology. *Journal of Geological Education, 39, 217-220.*

Hefferan, K. P., Heywood, N. C., & Ritter, M. E. (2002). Integrating field trips and classroom learning into a capstone undergraduate research experience. *Journal of Geography, 101*(5), 183-190.

Heins, W. A., & Walker, J. R. (1998). Using a campus waterway for undergraduate-course exercises and summer-research experiences. *Journal of Geoscience Education, 46*(1), 45-50.

Karabinos, Paul (1992). Attracting students to science through field exercises in introductory geology courses. *Journal of Geological Education, 40(4), 302-305.*

Keller, C. K., & Allen-King, R. M. (2000). A framework for integrating quantitative geologic problem solving into courses across the undergraduate geology curriculum. *Journal of Geoscience Education, 48*(4), 459-463.

Kyle, R.M. & Lesher, C.E. (2000). Teaching the scientific method using contemporary research topics as the basis for student-defined projects. *Journal of Geological Education, 48, 145-149.*

Locke, W. W. (1996). Teaching geomorphology through spreadsheet modeling; recent developments in quaternary geology; implications for geoscience education and research. *Geomorphology, 16*(3), 251-258.

Peck, W. H. (2004). Teaching metastability in petrology using a guided reading from the primary literature. *Journal of Geoscience Education, 52*(3), 284-288.

Peterson, C. D., Anderson, L. L., & Michtom, W. D. (1996). Applications of undergraduate research proposals in general-education earth-science courses. *Journal of Geoscience Education, 44*(2), 197-201.

Siegel, D. I., & McKenzie, J. M. (2004). Contamination in orangetown; a mock trial and site investigation exercise. *Journal of Geoscience Education, 52*(3), 266-273.

St. John, K., and Callahan, J., (2003). Making geology relevant to non-science majors through the

Environmental Site Assessment Project. *Journal of Geoscience Education* v. 51, no. 4.

Woltemade, C. J., & Blewett, W. L. (2002). Design, implementation, and assessment of an undergraduate interdisciplinary watershed research laboratory. *Journal of Geoscience Education, 50*(4), 372-379.