RESEARCH IN THE UNDERGRADUATE CLASSROOM: CREATING OPPORTUNITIES FOR INVOLVING STUDENTS IN SCIENCE

Shelby J. Boardman
Department of Geology
Carleton College
Northfield, MN 55057

Jeffrey B. Noblett
Department of Geology
Colorado College
Colorado Springs, CO 80903

Reinhard A. Wobus
Department of Geology
Williams College
Williamstown, MA 01267

At the CUR conference on undergraduate research (July, 1988) an official from the National Science Foundation suggested that some of the blame for the declining number of science majors should be attributed to poor teaching methodologies. This official was particularly concerned about the difference in numbers of high school seniors interested in becoming science majors and the numbers who actually complete such a major, especially at institutions which have traditionally prided themselves on their teaching reputation.

While we recognize that numerous factors contribute to this, we would like to suggest one way in which schools can respond. Many (most?) of us who have become scientists did so because of curiosity or a drive to discover how natural phenomena work, and all of us have responded to that curiosity by pursuing research projects. We suggest that the most propitious time to present a student with the initial opportunity to become involved in research may be when the student is deciding whether or not to select a career in the sciences. Rather than rehashing old labs, students could become involved in projects where neither they nor their faculty know the results ahead of time.

Typically, the only undergraduates who are involved in original research are those hand-picked seniors assisting a faculty member with a grant. In this article, we share some examples of ways in which students who are still sampling a science curriculum have been presented with original problems in the classroom and lab. They have been invited to join in the process of data gathering, the frustration of machine failures or anomalous results, and the glimmer of possible understanding as the data are discussed. The courses

described here generally have only introductory geology as a prerequisite and may be taken by non-majors as well as majors.

We intend for these examples to be just that; they are among those we presented as part of a poster session at the 1988 CUR Conference. The examples are, of course, drawn from geology curricula because that is what we teach. We hope that readers who have developed similar course projects in any science department will share their experiences with us. Are there significant problems facing other disciplines in their efforts to integrate student investigation into underclass courses and labs? What other methodologies have worked or failed to interest undergraduates in a science career?

CARLETON COLLEGE

Over the past two decades the Geology Department at Carleton College has implemented a curriculum that leads students through progressively more involved and sophisticated investigations and open-ended projects. The process starts at the introductory level and culminates with a senior research project done by each of our majors. Most senior theses are carried out independently, but some are done by pairs of students, each selecting a facet of a larger problem. Others represent collaborations with faculty members on problems that spin off larger and longer-term faculty research projects and a few result from working with other professional geologists, most commonly Carleton geology alumni. Many of these research projects have been presented at professional meetings such as the sectional meetings of the Geological Society of America.

Since the emphasis of this paper is on what happens to students early in their exploration of science as a possible career choice, I will discuss what we do in our introductory and second level courses to give students a taste of scientific investigation and discovery.

A freshman seminar on outdoor geology has attracted a disproportionate number of students to our department over the years. It is built around an inquiry approach to learning and at least 80 percent of the scheduled class time is spent in the field. The entire course is essentially an investigation of the geologic history of Minnesota, based on first-hand observation. Two full afternoons a week plus at least two long weekend trips are scheduled. The instructor serves as a facilitator for the students, guiding their questions, helping them translate observations into reasonable interpretations, and filling in with general information when necessary and appropriate. After each excursion to the field, students are required to write up their observations and draw whatever conclusions they can. Naturally, as the term progresses the sophistication with which they can deal with geological information concepts, processes and principles increases dramatically. At the end of the course each student writes a final report on the geology of Minnesota. The detail and complexity of many of these papers is startling, given the minimal background the students have.

The basic introductory geology course at Carleton is essentially a lecture-lab course that emphasizes physical geology. Through five field labs and an all-day field trip, students are introduced to many of the main elements of the geology of southeastern Minnesota. As in the freshman seminar, they are asked to compile and sift through this considerable amount of information on sedimentary geology, stratigraphy, geomorphology, glacial geology and even a little igneous petrology and tectonics (based on a field trip to the Mid-continent rift basalts exposed at Taylor's Falls) and prepare a final report on the geology and geologic history of this part of the state. They are not allowed to use any literature that is specific to the area, but are encouraged to refer to general references and texts for background information. Because of the limited amount of time available for field work, the instructor must provide more structure and guidance for students than in the freshman seminar, but the challenge of integrating all of the seemingly unrelated pieces into a coherent history is a real revelation for many students.

Another investigative lab done in the introductory courses is a groundwater experiment using a small well field that has been developed on campus. Students work in teams, and the entire group collaborates by sharing data, from eight observation wells placed around a pumping well. By working with discharge, drawdown and recovery data, students gain a real understanding of groundwater flow, porosity, permeability, cone of depression and other principles of hydrology. This lab also serves as an excellent illustration of dynamic, open system equilibrium processes as they operate in geology.

The general structure of introductory environmental geology is similar to that of the introductory geology course, with both lectures and labs, but the principles of physical geology are presented within the context of environmental problems and issues. Toward the end of the term students spend about two or three weeks working on a land use assessment for an area on the edge of Northfield that is currently

undergoing development. They consider the effects of several factors, including slope, bedrock depth, soil type, runoff potential, the spatial relationship between the development and the surrounding areas, to devise their own plan, which they must justify. The results are presented in a report, along with supporting figures and maps.

Landform Analysis is the second course most students take in our geology curriculum, and many are still assessing whether or not to major in geology. Most of the labs are actually field investigations of some of the interesting glacial and fluvial geomorphology of the area. For example, the Cannon River flows through the campus. Several labs at the beginning of the term are spent gathering data on the river: mapping its course, surveying cross-sectional area in several places, recording velocity, calculating discharge, measuring sediment size and distribution and noting the character of erosional and depositional features. The data are used in conjunction with data gathered in previous years to evaluate the behavior of the river through time.

Two themes can be found in all of these examples. The first is that we believe it is better for students to be actively engaged in working in a natural setting on real questions and problems than staying indoors assimilating a prescribed body of knowledge. The second is that we are committed to stressing the learning process rather than the amount of factual information presented to students. With the style of teaching we engage in, there is no way we can present as broad or comprehensive a survey of a subject as in a traditional lecture/lab course. We believe the most important concerns, especially at this point in the lives of prospective science majors, are the quality of the thinking and reasoning the students do and excitement they feel during their involvement in these lower level geology courses.

COLORADO COLLEGE

Several courses at Colorado College have successfully incorporated original investigations within their curriculum; this approach is still being tested in other geology classes. A key aspect of our ability to pursue these projects is a curricular calendar (The Block Plan) under which students take only one course at a time with each course (block) lasting for three and one-half weeks. This enables us to apportion time as necessary to meet the class objectives. Many courses contain extended field trips (from one to more than twenty days). Field trips range from local day trips to backpacking trips in the mountains to taking classes anywhere from Michigan to Craters of the Moon to Death Valley to Hawaii. Thus, a second aspect of these projects is administrative and operational support of the field program in terms of owning and maintaining vehicles that enable us to get to study areas. A third aspect is the class size; all classes are limited to twenty-five students, and many non-introductory classes have half that many students. The two areas which have most successfully included research projects as a teaching device are geomorphology-related classes and geophysics.

The geomorphology and glacial geology courses both involve students in data collection and interpretation. Such involvement has included backpacking to 12,000 feet, as well as day trips. The projects have focussed on reconstructing Pleistocene glaciation and paleofloods. Interpretation of maps and aerial photos provides the foundation for selecting interesting sites. Several classes have worked on a continuing project, establishing a grid system and measuring annual movement of a rock glacier. Another class investigated boulders along the Arkansas River to constrain paleoflood limits. Others have used a variety of techniques to model glacial advances in mountain valleys. Three students continued the research as senior theses or honors dissertations, with two of them presenting their results at an annual Geological Society of America meeting.

Acquisition of several items of geophysical equipment through an NSF-CSIP grant has enabled the geophysics course to undertake a similar line of research. Investigations of Laramide faulting along both eastern and western boundaries of the Front Range and of the purported caldera structure near Guffey, Colorado are underway. These projects emphasize having each class acquire new lines of data and model their results, then review data and models from past classes for clarification. Again, several senior theses have evolved from this work.

Other classes are exploring ways to add a research component. Upper level igneous petrology, metamorphic petrology, volcanology, field and structural geology are all in the process of establishing field mapping projects with research potential. Sedimentary petrology and stratigraphy classes are defining interpretive projects in the local basin. Unfortunately, the curricular structure which permits us to get to these sites also makes it difficult to prepare thin sections or perform chemical analyses in order to complete an entire project within one block. Nonetheless, our goal is to adapt as many of our classes as possible to include a significant original laboratory or field project. The entire department benefits from having students who were exposed to doing original work early in their education.

WILLIAMS COLLEGE

At Williams, geology students first participate in original research during independent lab projects in geomorphology, the first non-introductory course taken by students - usually sophomores - who are considering a major in geology. These projects are chosen after individual consultation with the instructor and are run concurrently with lab exercises during the last third of the semester-long course. Utilizing the resources of the local area, including the Hoosic River drainage basin and the college's 2500-acre Hopkins Experimental Forest, students in geomorphology have worked on projects involving stream flow and channel morphology, water quality, soil chemistry, and landfill siting, among others. One student project dealing with siltation rates in a pond on campus has received the continuing interest and support of the Town Conservation Commission (as well as the local press). In another project currently underway, two students are using a grid system and a fiberglass pole to make a bathymetric map of a peat bog in nearby Vermont to determine the shape and origin of the basin and the thickness of peat within it.

A new interdisciplinary environmental science course will be offered for the first time in the spring semester of 1990. Limited to a small number of freshman and sophomores and partly funded by a grant from the Ford Foundation, the course will be taught by professors from geology, chemistry, and biology. Labs will involve original field studies of various ecosystems and environmental problems of the local area, utilizing the facilities of the college's Environmental Analysis Laboratory.

Other geology courses taken by sophomores or juniors also involve original data gathering and interpretation as components of lab projects or field problems that continue from year to year. Students in igneous and metamorphic petrology are building a significant data base of model analyses of plutons of the New Hampshire and White Mountain magma series. Sampling and field description take place during field trips to central New Hampshire each year, followed by the preparation of stained slabs for point-counting and of thin section study of the same rock units. In the sedimentation course, students work at Plum Island, Massachusetts, each year, where they measure longshore sediment transport, study grain-size distribution across a barrier island, and interpret sedimentary structures in tidal inlets.

Because Williams still employs the 4-1-4 calendar, the 3 1/2 week Winter Study Period in January can provide a sustained amount of time for students to devote to a single project. Seniors doing theses always spend that month on their work, but juniors and even sophomores have occasionally become involved in research as well. Their work has usually been off-campus and has been directed by a full-time research scientist (often a Williams alumnus). Some students, for example, have worked in labs at the Lamont-Doherty Geological Observatory in New York. There is no question that this sort of experience - however brief - has been highly stimulating to those involved and has further motivated them toward a career in science.

CONCLUSIONS

Involving sophomores and juniors who are still considering a variety of majors in a science research project is an excellent means of attracting students into science. Too many of our courses get bogged down in data/vocabulary transmission or in reworking old laboratory problems where answers have been recorded by generations of students. Designing original problems for a class of students with mixed talents and mixed interests is not always viable or simple. Certainly, it is much more difficult to get grant support for projects which can be tackled by non-majors and which can be brought to some level of completion within the course framework. If we are to respond to the declining levels of interest in the sciences, we need to re-examine our teaching principles. How can we support faculty who make the effort to create original investigations appropriate to the teaching of undergraduate science? Do these projects succeed in interesting students to seek an understanding of calculus, statistics, chemistry, physics and other frequently terrifying hurdles for undecided science majors? Should we avidly pursue ties with industry and government scientists for assistance in selecting projects of mutual interest (in return, perhaps, for machine time or the opportunity for our students to judge career options in an everyday setting)? What interdisciplinary projects might best be pursued jointly by classes in different departments? The possibilites for creating research projects in the undergraduate curriculum are numerous.

"DEAR DR. DONNELLEY . . ."

R. Bruce Partridge
Department of Physics and Astronomy
Haverford College
Haverford, Pennsylvania

I still find letters addressed to Dr. Donnelley stuck in my mailbox, most of them requests for reprints of a 1986 paper.* What the writers don't know is that the "senior" author of that paper was in fact a college junior.

Undergraduates can do research - and can do it seriously enough and well enough so that their results deserve publication in standard journals. We all recognize both the importance and the possibility of undergraduate involvement in research, so there is no need to stress either here. Instead, I'd like to take this opportunity to describe some policies at Haverford which I believe encourage student research, then to say a bit about undergraduate involvement in off-campus research (e.g., at national observatories), and finally to practice what I preach by including the views of some undergraduates in this article.

From the beginning, we tell students at Haverford that they will have a chance to join us in research. I suspect that notion means little to a freshman, let alone a prospective college student. But it is a seed worth planting. If a student shows an interest in research, we try to get him or her involved in at least a preliminary way by early in the junior year. That way there is a reasonable chance some publishable results will come along by the end of senior year. When we have NSF or other funds available, we try to hire students as research associates during the summer, especially the one between the junior and senior years. Given how busy we keep undergraduates during the school year, an early start in research is crucial. (Could it be that graduate students seem more productive as much because they are around longer as because they are "older and wiser"?) Starting early like this, of course, has a drawback - students are less sophisticated and have fewer courses under their belts. That puts more burden on us, their mentors. I've found that it helps to carve out a small part of a project first, a part which is limited enough so a student can do most of it on his or her own, and thus feel "in charge". That builds confidence.

*Donnelley, R.H., Partridge, R.B., and Windhorst, R.A. 1987, *Astrophys. Journal 321*, 94 .