A Modular Earth-Science Curriculum

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ABSTRACT
The Earth Systems Science (ESS) BS Program at George Mason University offers students a broad background in science and earth science and the opportunity to concentrate on one of several specialty tracks or modules: geology, geoarchaeology, geographic analysis, and earth-science education. The ESS Program evolved from the Geology BS Program and has become the mechanism by which our department has made the transition from geology to a broader approach to earth science. The ESS curriculum can serve as a model which other universities may find useful in planning future development of earth-science programs.

Keywords: Earth science – teaching and curriculum; education – geoscience, education – undergraduate, geology – teaching and curriculum.

Introduction
The geosciences are in the middle of a transition. Geology has long been the premier earth science at most universities. Today, at many universities, environmental science is assuming that role. Geological surveys are downsizing locally, nationally (Harrington, 1996), and internationally. The job market for geologists has diminished. Yet the environmental-science field is flourishing. Geology is not losing its purpose but may be losing its identity. During this transition, geology must effectively define its role in the fields of earth science and environmental science. The program described in this paper is our attempt to define geology as one of the earth sciences and to recognize that the earth sciences are integrally related to environmental science.

For the sake of discussion, I need to define some terms. I will use the term “earth science” for the several fields which deal primarily with the materials and processes of the various non-living earth systems and “geology” as a branch of earth science that deals with the solid earth. Atmospheric science, oceanography, and hydrology are other earth sciences. “Geoscience” is used specifically to refer to the geological sciences: the various branches of geology including geochemistry, geophysics, geohydrology, and others. “Environmental science” will herein refer to the geographical analysis, and earth-science education. The ESS Program evolved from the Geology BS Program and has become the mechanism by which our department has made the transition from geology to a broader approach to earth science. The ESS curriculum can serve as a model which other universities may find useful in planning future development of earth-science programs.

The other challenge facing academic geology programs is the threat of downsizing or elimination. Given the trends mentioned above, scaling-down of geology programs may be justified in some cases, but...
if we want to preserve geology’s role in earth and environmental sciences, we must adapt. Strategies will vary with the nature of each institution. At George Mason University, having been faced with the threat of elimination of geology, our strategy has been to shift from a geology program to a more diversified earth-science program which includes geology as one of several areas of specialization. We identify earth science as separate from environmental science but foster much interaction and cooperation with the Environmental Science graduate program, which is administered by the Biology Department.

The Geology faculty at George Mason developed the Earth Systems Science (ESS) Program to meet three objectives: 1) to define earth science as a discipline that is separate from, but related to, environmental science; 2) to provide broad training in the earth sciences as well as specific training in an aspect of earth science; and 3) to recognize geology as one of the earth sciences. The ESS Program has successfully defined and preserved the role of geology at GMU without watering-down the geology curriculum. In addition, the program provides our students with an earth-science background and skills that help them adapt more readily to the geoscience and environmental-science careers that await them.

Other departments, particularly geology departments that are developing strategies for survival and/ or future development, may find our strategy useful. Some larger geoscience departments have been employing these ideas for years. Our model may not work at every university, but it certainly has improved the growth potential of geology and earth science at George Mason University.

The Curriculum
Because of institutional pressure to discontinue the Geology BS Program, the ESS Program was developed as a means of preserving geology within a larger earth-science program. The ESS Program is the result of discussions with other science faculty on campus and was approved only because of their support. The program is a compromise between a general (earth) science degree and a degree which provides some depth in an earth-science-related field. Compared to the BS in geology, the geology track in the ESS BS degree requires more courses in biology and the other earth sciences and fewer geology electives and general electives. The heavy biology requirements in the ESS Program are presently under review.

Our modular Earth Systems Science BS degree program is designed to provide a broad background in math, science, and earth science, specific training in geology for those so inclined, and additional areas of specialization for those interested in other areas of earth science. Requirements for the ESS degree (Table 1) include 24 credits of general-education courses, 52 credits of core science and math, and 23 to 27 credits in a specialization track or module, and 17 to 21 credits of general electives. The core science and math courses required of all ESS majors include two semesters each of calculus, physics, chemistry, biology, and geology, plus one semester each of oceanography, meteorology/climatology, ecology, and a generic field mapping course. In terms of the number of required courses, ESS is probably the most demanding science BS degree at our university.

In addition to the core science and math requirement, ESS majors must select a concentration or track. The specialization tracks or modules are summarized in Table 1. Existing tracks include Geology, Geophysical Archaeology, Geographic Analysis, and Earth Science Education. The Geology track requires coursework in the areas traditionally required for the geology degree at most universities, including a geological field course or field camp.

The track in Geographical Analysis provides coursework in surficial materials and geographical methods of analysis (remote sensing, cartography, quantitative analysis, GIS). It builds on our strengths as an academic department that houses both geographers and
geologists. This new track has become very popular with our majors.

The Geoarchaeology track was developed in coordination with the Department of Sociology and Anthropology. This track combines coursework in geology (mineralogy, geomorphology, sedimentary geology) with some basics of anthropology and an archaeological field school.

The Earth Science Education track is specifically oriented toward potential secondary-school earth-science teachers and provides the scientific content required of high-school earth-science teachers in the Commonwealth of Virginia. This track includes education courses in the undergraduate curriculum and provides a five-year degree option that will allow students to obtain teaching licensure and/or a Master of Education after completing the BS.

**Effect on Enrollment Trends**

Figures 3a and 3b show the enrollment and graduation trends in our Geology BS, Geology BA, and ESS BS degree programs. ESS has effectively replaced
Geology as our primary BS Program, but this is a result of the programmatic change and not necessarily the choice of the students. Our total number of majors or graduates in these degrees has not changed substantially since the inception of the ESS Program; however, there is some indication that these numbers are leveling-off at a higher level than before the ESS Program existed. This increase does reflect national trends in the geological sciences as indicated in Figure 1.

Field Courses
The basic skills of taking accurate field measurements are a necessary capability for almost all fields of earth science. On the other hand, different subdisciplines of earth science require different specialized field skills. Why teach geological mapping to an atmospheric scientist? With this in mind, we employ a modular approach to our field requirements. ESS students are required to take Field Mapping Techniques, a basic course in field measurements, and if appropriate, a field class in their area of specialization.

Field Mapping Techniques covers the use of various field instruments including the compass, transit, plane table, alidade, and global positioning systems, and the ability to locate features on topographic maps and aerial photos. Emphasis is placed on determining the accuracy and precision of each technique. Many of the skills taught in this basic field course are not covered in traditional geological field camps or field mapping courses. One advantage of the Field Mapping Techniques course is that this broad exposure to various field methods provides students the skills necessary to handle a wide array of field situations which they may encounter in various geoscience and environmental careers. Students that have taken this course can later apply their mapping skills to more specialized and sophisticated field tasks, such as geological mapping or archaeological techniques. Therefore, in addition to the basic field course, our geology majors (ESS with a specialization in geology) are required to take a geological field-techniques course or a geology field camp. Geoarchaeology majors (ESS with a specialization in Geoarchaeology) are required to take an archaeology field school.

Future Program Development
The modular nature of the ESS curriculum facilitates future program modifications. Instead of developing entirely different degree programs, development of a new specialty track could allow students a significantly different earth-science degree option. In the best of all worlds, the ESS degree program would be much more complete if tracks in marine science or atmospheric science could be added. Since submittal of this manuscript, the geoarchaeology track in the Earth Systems Science Program has been canceled due to lack of student majors.

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FIGURE CAPTIONS


Figure 2. Federal research funding to colleges and universities, 1976 to 1994. Data is reported by the U. S. Department of Education (annual data reports, 1984 to 1996) under the category of Environmental Sciences.

Table 1. Schematic diagram of the 120 hour Earth Systems Science BS program emphasizing its modular organization.

Figure 3. Enrollment trends in Geology and Earth Systems Science degree programs at George Mason University. Note that prior to 1990, the B.S. in Geology was the only degree offered.