Report of the
American Geophysical Union
Chapman Conference on

Scrutiny
of
Undergraduate Geoscience Education:
Is the Viability of the Geosciences in Jeopardy?

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Scrutiny of Undergraduate Geoscience Education:
Is the Viability of the Geosciences in Jeopardy?
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Introduction

The American Geophysical Union's (AGU) Chapman Conference on "Scrutiny of Undergraduate Geoscience Education" yielded a series of observations and recommendations that will help improve the education of professional geoscientists and the general public. Approximately 130 professors, teachers, university administrators, federal officials, and other interested geoscientists met in September 1994, at the new AGU headquarters in Washington, D. C., to begin a dialogue on the need for changes in undergraduate geoscience education.

Responding to the subtitle of the conference "Is the Viability of the Geosciences in Jeopardy?" Gordon P. Eaton, Director of the U.S. Geological Survey opened the conference by noting that the end of the Cold War and the development of the global economy are changing the geosciences. "We need, therefore, to address how geoscience fits into the realities of today and then what implications there may be here for redesign of the emphasis of our graduate and undergraduate curricula." (See Appendix III, Keynote Address.)

Should students be encouraged to prepare themselves for nontraditional careers? Eaton made some fundamentally important observations about the current state of the job market and how it relates to the educational mission of Earth sciences. The Earth science community has to decide how to best respond to his challenge, to what extent should change be facilitated, and for what reasons. The proceedings of this Chapman Conference have taken the initial steps to address these questions.

Conference participants discussed curriculum content, pedagogy, curriculum materials, institutional and faculty changes, partnerships and collaborations, "geosciences for everyone," and spreading the word to colleagues and to the public. This report by no means represents a consensus of the participants. On the contrary, a few recommendations are possibly conflicting, largely because different institutions of higher education understandably have different missions and perspectives. Selected observations and recommendations in this report should help geoscience departments and administrators in their efforts to reform what they teach and how they teach it. Copies of this report are being distributed to geoscience departments throughout the United States and Canada and to administrators to support their efforts to reform science education.

Curriculum Content

Curriculum development was discussed at length at the conference. Participants observed that geology as a discipline suffers from a reputation of being a "soft science" when compared with other physical and life sciences. Nevertheless, real opportunities are present in the Earth sciences for greater influence in public affairs, considering the central role the Earth sciences must play in solving pressing human problems such as natural hazards, environmental degradation, and exploitation of natural resources. Geoscience education has advantages over related disciplines (e.g., chemistry and physics) both in its emphasis on field studies, which are generally more accessible and interesting for general students in science classes, and in the integrative nature of the geosciences with respect to all other related disciplines. The geosciences are positioned to make significant contributions toward achieving scientific literacy for all citizens, a goal that has attained the status of national mandate. There is a need, however, to develop new models for courses. One strategy proposes collaboration among disciplines to build courses which emphasize problem solving.

The undergraduate geoscience curriculum serves the needs of diverse populations of students: preprofessional training in the geosciences, preservice education for future teachers (K-12), and general educa-
tion for nongeoscience majors. With respect to preprofessional training, Eaton noted that “Earth sciences are experiencing a new and different kind of evolution that should be requiring all of us to re- think the way we approach our missions.” The end of the Cold War and the development of the global economy put an end to many of the demands that kept national geological surveys in business, he said. “We need, therefore, to address how geoscience fits into the realities of today and then what implications there may be here for a redesign of the emphasis of our graduate and undergraduate curricula.” Universities are struggling, he said, because we “have for too long continued to train clones of ourselves.” The response of the geoscience curriculum to current and future job opportunities, particularly related to environmental issues, was one of the main topics discussed at the conference. John Snow, University of Oklahoma, predicted that by the year 2010, the M.S. will be the professional degree. Meanwhile, the traditional set of core geology courses does not prepare a student adequately for the job market and typically has a narrow research focus. “We are too tied to past traditions and there is a lack of diversity in undergraduate geology,” Snow said.

Geoscience education for nonmajors, and especially for preservice teachers, similarly presents numerous challenges and opportunities. Considerable debate at the conference revolved around whether geoscience courses should be taught differently for majors and nonmajors. Although this issue was left unresolved, a general conclusion was that all students should have a fundamental knowledge of Earth materials and processes.

There are several integral concepts in geoscience that transcend disciplinary boundaries: time, space, and scale and “Earth as a system.” These concepts should be emphasized in all science courses. There was a general consensus at the conference that undergraduates need a broader perspective of “how the world works” than they typically get in current undergraduate programs, and an integrated Earth systems approach to teaching in all courses was strongly advocated.

The search for an optimal core curriculum in the geosciences proved elusive for conference participants. A central concern was how to balance the knowledge base of traditional curricula (e.g., geology, mineralogy, petrology, sedimentology/stratigraphy, and structural geology) and new practical or socially relevant courses (e.g., hydrology and meteorology). There was general recognition that new curricular initiatives should be directed toward the following: the needs of the students and their communities, human and material resources at local institutions of learning, the local geographic setting (human and physical geography), and realistic job preparation.

Despite these concerns, the participants strongly believed that the job market should not drive the curriculum toward a perceived market-driven need because of the fluid nature of job opportunities in different employment sectors. Factors that contribute to a successful curriculum change require a dialogue among geoscience employers, alumni, and administrations with a commitment to development of appropriate curricular goals.

Awareness that a variety of career paths in the geosciences can help solve pressing human problems should be gained by all undergraduates. Students should be exposed to a variety of careers for which a geoscience background can be valuable, including not only traditional fields of geologic research (e.g., exploration and production of energy and mineral resources) but also fields such as K–12 teaching, law, land-use planning, agriculture, and environmental protection.

Research activities are integral to the responsibilities of most college level instructors, and enthusiasm for our research activities must be translated to our students. Research exercises can be designed and incorporated into all classes at some level. Ask questions of nature, create protocols, implement research methods, evaluate answers, and report results. Such
an approach should improve translation of knowledge, demonstrate the conduct of science, and engender excitement about the subject.

Introductory geoscience courses are best taught as “terminal” courses because most students will never take another science course. We may do a better job teaching if we focus on a few concepts and principles that we would hope all students would master, rather than providing an overview of entire disciplines that is directed toward a minority of students who may ultimately become majors. A significant number of conference participants advocated the elimination of survey-type courses and supported the concept of entry level classes that focus on Earth system science or special courses focused on topical issues (e.g., the environment) to serve better the needs of students and science education in general.

A special “break-out” session was initiated by Tanya Atwater. The session was attended by about 40 participants, who discussed specific concerns about the “core curriculum” in geology. Two central questions were addressed: (1) what can we do about the large introductory level geology courses to make them more appropriate to their main clientele (i.e., nonmajors) and (2) how can we reorganize the courses/content of our upper division courses to better reflect the role of geosciences in a rapidly changing world? Contraction of “core” sequences (e.g., mineralogy, optical mineralogy, and petrology; sedimentology and stratigraphy) into single course or yearlong sequence was one prevalent strategy to make room for new courses. This resulted in some hard decisions about traditional material that had to be deleted. One unexpected discovery has been that many students preferred the “long version.” The shorter version left them feeling insecure. Another solution is to offer one unit mini-courses to increase the number of topics offered without using a whole course slot. A few participants were not convinced of the need to change, citing short-term fluctuations in “hot” subjects and the job market. (See Appendix IV for a summary of the Atwater-led discussion.)

**Observations and Recommendations**

Curriculum needs to:
- be developed to communicate more effectively to diverse and multiple audiences.
- be revamped to meet contemporary needs.
- respond to the local environment, particularly the student clientele, with methods and pedagogical approaches developed to best accommodate the personality of the department.
- emphasize fundamental concepts of space, time, scale, Earth materials, and integrated Earth systems through problem solving rather than content in undergraduate geosciences courses.
- demonstrate the relationships among particular fields of science and their societal and economic impacts.
- increase quantitative exercises across the curriculum, both through required ancillary math courses and by application of those skills in geoscience courses. A “mathematical methods” course in the Earth sciences could be developed.
- emphasize fundamental principles of physics and chemistry and integrate these into curriculum. Geosciences courses can reinforce methods and concepts introduced in other disciplines.
- identify people and ideas in courses.
- connect student activities to the conduct of science and impacts on society; use guest lecturers from the ranks of professionals, alumni, and visiting scholars.
- emphasize “scientific habits of the mind” and “scientific practice.”
- encourage students to “reason from evidence.”
Connect student activities to the conduct of science...

- Integrate knowledge, materials, and methods among required courses.
- Knowledge is the ultimate goal of an undergraduate education in geoscience. Nevertheless, it is important to realize that
  - Most successful careers will be in applied fields rather than basic research.
  - Training in overspecialized fields will provide limited employment opportunities.
  - Pursuit of nontraditional geoscience careers is a viable option.
  - There is social responsibility inherent in the conduct of science.
  - There is a need to promote science to the public.
  - There is a related need to confront antiscience.
  - Students acquire and find knowledge through inquiry and discovery.

Alternative curricular activities and alternative means of assessment need to be developed, such as

- Activities which demonstrate mastery in a variety of ways, (e.g., writing exercises).
- Preparation of poster sessions.
- Participation in group activities that will expand students’ educational experience.
- Performance evaluations adapted to meet new educational goals (e.g., peer evaluations, self-evaluations, and portfolios).

Curriculum Materials

Owing to societal and economic pressures related to geo-hazards and geo-resources, opportunities and new career challenges have expanded in the geosciences. The development of computer-generated geoscience subject matter for instruction has lagged behind that in other science disciplines. Materials used in the classroom for teaching are largely focused on modern technology. Thus revision and modernization of today’s curriculum by faculty capable of using computers and other innovative tools are necessary to meet the challenge of preparing students in the computer age and attracting and retaining increasingly diverse student populations in the geosciences.

Excellent presentations of existing materials being developed in the geosciences were highlighted at the conference. Access to the new material is limited, however, by the lack of training in their use, poor distribution channels, and inadequate campus facilities. Training of faculty in the use of computer tools has not received adequate attention.

Mosaic, Internet, World Wide Web (WWW), and similar computer programs have much to offer teaching, learning, sharing of ideas, keeping current, and training and preparing students. Nevertheless, many people do not know how to access these programs. Central clearinghouses of information need to be made available. An expanded effort needs to be made to make courses more readily available and information more readily accessible.

Organizational meetings, short courses, and Chautauqua-type courses must devote more time to increasing opportunities in computer use. Societies such as AGU could serve as a clearinghouse on the Internet and in print to more widely distribute this information.

Observations and Recommendations

Faculty need to

- Find a local Internet expert.
- Learn the system(s) that will help them most.
- Attempt to act as a resource person for the rest of their department.
- Submit proposals to the National Science Foundation (NSF) Division of Undergraduate Education for improving undergraduate geoscience curriculum, instrumentation and laboratory improvement, faculty...
enhancement, teacher preparation, and advanced technological education.

Organizations and societies (AGI, AGU, AMS, CESE, GSA, NAGT, and NESTA) need to

- set up home pages and other clearinghouses to encourage and provide access to good materials for teaching.
- offer courses at meetings on hypermedia.

Publishers need to

- find less expensive ways to produce and market introductory materials for smaller audiences.

Computers can

- provide a tool for group project work including analyzing problems and testing solutions.
- increase the existing problem of inequality of access to technological equipment.
- provide access to a powerful host of programs including GEO-HELP, STELLA, Dynamic Digital Map, BLUESKIES, and ALERT, all of which have tremendous potential in improving existing introductory courses in Earth and space sciences.

Pedagogy

Much of the conference was devoted to ways of improving undergraduate geoscience education. It was generally agreed that thought processes rather than rote memorization should be emphasized—these skills contribute to lifelong learning. Developing a student's critical thinking skills was determined to be of central importance, supported by fundamentals of math, writing, and communication skills. In general, instructional methods that encourage exploration and discovery by the students were deemed most effective for long-term learning. In particular, field exercises with hands-on experience provide a meaningful way to engage this style of learning.

Problems related to teaching large sections and lower level introductory courses received special attention at the conference. Students in these classes have diverse abilities, learning styles, and background. Faculty frequently have too little contact with students. It is difficult to evaluate a student's performance. Consequently, students usually suffer because they do not get as involved in the subject matter and may end up with a negative attitude toward science. Letting teaching assistants run discussion sections, giving multiple choice exams, and grading on a curve have often been employed to cope with large classes. Alternate solutions include small group learning exercises, writing assignments, and cooperative learning activities such as peer-reviewed papers and projects.

Alternative modes of instruction were presented to address a variety of educational circumstances. Constructivist theory of learning was contrasted with positivist or traditional theory.

The positivist theory says that knowledge is obtained through observation. It is a part of an individual's previous ideas or beliefs. It is a set of universal truths. It can be transmitted. In a classroom, this method translates to a lecture type delivery, an emphasis on memorization, a focus on right and wrong answers, and the authoritative role of the instructor.

The constructivist theory says that knowledge is created by humans from their previous experiences. It does not exist independently from their perspective. It must be constructed by students for learning to occur. In the classroom, this means that active techniques dominate. There is an emphasis on comprehension.
Instructors and students are partners in learning. The instructor monitors the development of a student’s learning.

**Observations and Recommendations**

Emphasis in teaching should focus on

- thought processes rather than rote memorization, since these skills are the most valuable in future education or a career.
- class activities that develop critical thinking because they provide the most effective educational experiences.
- the significance of fundamental quantitative, problem-solving, interpersonal writing and communication skills.
- connecting bodies of knowledge within a given course to foster effective learning.
- field experiences (with their inherent aspects of observation, problem-solving, critical thinking, and testing) since they provide significant and effective forums for learning. These experiences promote relevance and personalization in connecting the learner with the Earth and Earth systems science.
- a format in which students take more responsibility for learning.
- developing alternative teaching and testing to meet the needs of and make the best use of talents of students from diverse cultural or ethnic backgrounds, including narrative or storytelling teaching style to relate complex concepts to students.
- integrating the strengths and perspectives of all students into classroom activities with outcomes and activities that help everyone feel more like a contributing scientist.
- examining students’ existing knowledge, perceptions, and experience, so that materials and approach can be adjusted to accommodate new understanding and the presentation of new concepts.
- de-emphasizing self-interested and specialized research in order to meet the needs of students.
- evaluating the process and not the product to encourage development of scientific habits of the mind.
- standards for personal and professional ethical behavior.
- preparing students for lifelong learning.
- evaluating performance based on student portfolios. These may include assignments such as writing letters to a public office, participation in a field exercise, reviewing an Earth science video, and participation in small group activities.

Goals for our students should include development of the ability to

- define complex problems.
- rely on self-education.
- think creatively and critically.
- work in teams.
- evaluate evidence.
- make judgments.
- communicate to a variety of audiences.

Societies and professional organizations should

- provide opportunities at national and local meetings to discuss teaching strategies.
- devote more space in journals to the enhancement of teaching.
- publish “benchmarks” for the content of undergraduate geoscience programs.

Areas in curriculum materials that need attention include

- changes in standardized tests (e.g., Graduate Record Exam) to accommodate changes in instruction methods which give less emphasis on content and more emphasis on critical thinking skills.
o student acquisition of computer and other technological skills.

o less control by external agencies of course content (presently done by Graduate Record Exam and professional licensing exams).

o reevaluation and development of textbooks based on learning theory that coordinate the best teaching methods with new formats.

o revision of texts to emphasize the "big" picture instead of small or abstract details.

Geoscience education has uncovered fertile ground in new scholarship indicating that

o new data are necessary to convince colleagues that problems exist in geoscience curricula and change is needed.

o new methods of evaluation of growth and development are needed to demonstrate and validate the initiative undertaken by science reform movements.

o there is a need to investigate how students actually learn so new teaching strategies can be used.

The research emphasis versus teaching emphasis needs to be minimized to

o avoid creating a false dichotomy that separates research and teaching.

o create undergraduate research experiences since they are an effective means of teaching.

o find sources for additional funding in the $2,000 to $20,000 range to support undergraduate research projects.

Institutional and Faculty Changes

The demands and requirements for institutions to prepare students have expanded. Institutions must be aware of their particular local, geographic, and employment needs for students; the need for scientific literacy for a diverse population of students; and the need to prepare students for life in a rapidly changing technological world, all within an environment in which resources are dwindling.

The job market in the geosciences has traditionally been "boom or bust" in response to jobs in metals, energy, and most recently water and the environment. Some important questions are

o to what extent should we allow current job markets to dictate curriculum, considering the changing nature of employment opportunities? Today's hydrologist may well be assigned an asbestos or radon problem tomorrow.

o how do we give our students cognitive "tools" to aid in retraining and in being lifelong learners? This, too, is independent of the contemporary job market.

o should we allow our curricula to devolve toward that of a "trade school"?

If specific curricula are ultimately dictated by current employers, there is once again the risk of over specialization (how many workers from the petroleum industry have had to retrain recently as hydrologists?). This type of imposed curriculum detracts significantly from the ability of specific departments and teachers to emphasize their local strengths (dictated by facilities, geography, or student and staff demographics).

Observations and Recommendations

Institutions, societies, and organizations need to

o recognize curriculum development, outreach, and informal science education projects as valid and valuable scholarly activities.

o foster programs that reward faculty for innovations in teaching, since many institutions penalize faculty for such endeavors.
To what extent should we allow current job markets to dictate curriculum...

- publicize examples of people and departments that reward good teaching and effective change, thereby providing other faculty with "ammunition" to take to their own departments and deans.
- facilitate the improvements in teaching, computing, and communicating by offering courses at meetings and supporting these efforts through funding grants.
- document and publicize examples of successes of new innovative programs, (e.g., Middlebury, Carleton, and Colorado School of Mines).
- help disseminate information and materials about existing programs and materials such as the NAGT Distinguished Speaker Program to help departments consider strategies for changes in pedagogy.
- place articles in the *Journal of Geological Education* and other periodicals that highlight teaching.

Faculty need to examine and assess their primary responsibilities as educators of undergraduate students. Students should

- have broad training to make them well-rounded Earth scientists.
- be prepared to assume nontraditional geoscience careers (e.g., double majors in education, business, law, and engineering).
- be capable of utilizing quantitative and communication skills.
- have a strong background in cognitive subjects such as math, physics, chemistry, and the social sciences (e.g., economics, and ethics).
- have a general knowledge of fundamental principles of the Earth sciences that transcends narrow disciplinary boundaries.

Faculty need to

- incorporate into introductory geoscience courses the ideas of Earth system science as a vehicle to introduce general principles for all students, majors and nonmajors alike.
- articulate to themselves, and then to the external community, the particular validity of Earth sciences in contemporary affairs.
- emphasize Earth systems science in our more limited disciplinary activities.
- offer courses that reach out to diverse populations. These should include topics related to the development of "citizen-scientists," "geology and people" such as those that demonstrate the relationship of geology and ethnic studies, relevant examples within an historical context, and integration of the geoscience curriculum into the traditional Native American culture.
- offer introductory courses as terminal courses rather than preprofessional since most students take only "one" Earth science course.
- become knowledgeable about "constructivist" teaching (see Pedagogy section) since it is particularly relevant for introductory and informal learning settings.
- make a concerted effort to find out how Earth sciences at the secondary education level are received by their admissions office. Is there an institutional bias against the Earth sciences in admissions policies?

### Scrutiny of Issues in K–12 Earth Science Education

While the focus of the conference was on undergraduate education, the perception still prevails that the geosciences continue to be "soft science" and that geosciences are not recognized as an area of credible scholarship. Anecdotal evidence related that Earth science courses are not generally included in precollege high school programs. Evidence was presented that precollege Earth science course may not
count as a science credit for admission to
many universities and colleges. Many un-
dergraduate geoscience courses are taken
by many students, including preservice
teachers, as a path of least resistance to
meet university distribution requirements.

The current efforts to reform K–12
education presents the geoscience educa-
tion community with an opportunity to
shape the future of K–12 Earth science
education. Reform efforts by the National
Science Teachers Association (NSTA) and
the American Association for the Advance-
ment of Science (AAAS) plus the develop-
ment of national standards for K–12
science education by the National Re-
search Council will allow the geoscience
community to bring K–12 teacher educa-
tion into focus. The development of sci-
ence literacy in K–12 teachers is often in
the hands of undergraduate faculty.

**Observations and Recommendations**

K–12 Earth science education

- plays an important role in attracting
  students to the geosciences.
- provides future K–12 teachers with
  the tools to teach Earth science.

Reform efforts should include

- preservice teachers doing projects
  that parallel the activities of scientists
  in order to learn how science is con-
ducted.
- geoscience departments taking a
  more active role in the preparation
  of teachers.
- an interdisciplinary geoscience/
  mathematics course as a method of
  reaching preservice teachers.

Current programs that currently enhance
the quality of K–12 education include

- PRISM (Project to Improve Science
  Models), a 3-year NSF-funded project
  for elementary and middle school
  preservice teachers that is designed
to de-emphasize the lecture format
and to promote modeling in the
classroom.

- Project Atmosphere that develops
  master teachers as resource agents
  for peer training and curriculum
development.

**Partnerships and Collaborations**

Partnerships and collaborations were
shown to provide a mechanism for mak-
ing effective use of a variety of resources
to improve curricula, to increase students' opportunities in pursuing research, and
to initiate departmental and institutional change in undergraduate geoscience
education.

Presentations illustrated ways to enhance
the teaching of geoscience through expansion of technological resources and in-
creased research collaboration. Successful
and effective collaborations and partners-
ships included (see Appendix VI, Abstracts
for individual programs)

- those in which a computer center
  was organized and arranged to expedi-
te and accelerate the interdiscipli-
nary collaboration.
- student-faculty collaborative research.
- instructional partnerships involving
  collaborative teaching of engineering
  geology and those that incorporate
  several degree programs into one
  department with a multidisciplinary
  faculty team.
- multi-institutional partnerships that
target the increased participation of
underrepresented ethnic minorities
in geoscience through a dual-degree
program.
- industry and institutional collabora-
tion that provide innovative modern
learning environments for students
by utilizing hypermedia technology.
- the development of Earth systems
  science curricula by a partnership
  between government agencies and
  academia.
Partnerships should be developed among all levels of Earth science educators...

Observations and Recommendations

- The cooperative support of geoscience education among professional societies through the Coalition for Earth Science Education. CESE provides a communication linkage among multidisciplinary organizations representing atmospheric, oceanographic, space, and solid Earth sciences.

- There is a need to maintain systematic and periodic surveys of employment and professional activity in the geosciences. This is especially important considering recent dynamic shifts in workforce demands. These surveys should require specifics that would help to establish the necessary educational preparation for geoscience professionals. Surveys, such as those on the enrollment and degrees of students, should continue annually and should continue to include data on women and minorities. Current geoscience career data in a variety of formats should be made available to the students, teachers, professors, and counselors.

- Professional geoscience societies should coordinate their efforts in geoscience education reform by playing a more proactive role in outlining the significance of universal geoscience education and by overcoming the problems posed by institutional obstacles in improving undergraduate education.

- The multidisciplinary nature of our world necessitates that students should be educated in a multidisciplinary setting. Geoscience faculty need to cooperate with other science disciplines and mathematics departments to modify the curriculum and develop materials to meet these needs. This endeavor requires the support and collaboration of academia, industry, government, and professional societies including those outside of traditional "geosciences."

- A clearinghouse should be developed to improve the dissemination of information on undergraduate geoscience education. Improving communication through regional networks on such topics as K–12 educational preparation, introductory/terminal geoscience courses, issues relevant to departments, and funding available for educational software development could lead to partnerships that would help to encourage and support change.

Geoscience for Everyone

The geosciences are ideally situated to promote science education to the general public. Opportunities exist to increase public awareness about the connections between Earth, its materials, and its processes and the conduct of our personal and collective lives. Two areas where we can have a great impact are in (1) introductory geoscience courses and (2) informal learning and outreach activities.

Geoscience education must meet society's needs for (1) citizens educated in the understanding of science and the fundamental concepts about Earth resources and hazards that affect their everyday lives, (2) training of Earth scientists to serve the needs of society, (3) scientifi-
cally literate professionals who rely on information about the Earth (e.g., lawyers, engineers, public officials), and (4) K–12 educators.

Multicultural geoscience materials that are accessible to people from diverse cultural heritages must be developed.

Everyone in the Earth science community has the opportunity to promote our disciplines to the public through topical forums, publications in non-science journals and the local media, and serving on advisory boards or community action groups. These activities may respond to local, national, or global imperatives and can be acted upon by individuals, state and federal agencies, and professional societies. The Earth sciences have much to offer in the discourse on public affairs.

In general, there is a need to reach out to wider audiences to reaffirm the importance of the Earth sciences in our society. We need to find more creative ways to de-mystify science for the general public. There is a need for all Earth scientists to serve our communities in some meaningful way through demonstrating the relevance of our scientific contributions.

Geoscientists in academic positions should make a concerted effort to find out how the Earth sciences at the secondary education level are received by their admissions office. Is there an institutional bias against the Earth sciences in admissions policies?

Scientists should develop direct contact with young students. Students should recognize that a career in the sciences can be creative and rewarding and that scientists are real people.

Scientists should work as partners with K–12 teachers in the development of educational materials to make sure that both the content and pedagogy are appropriate for the level of instruction.

Scientists should initiate programs to attract talented students into geosciences. Special emphasis should also be given to attracting the best and brightest precollege students among underrepresented groups (women and minorities). These programs could include mentorships, career information, workshops, and field programs.

Also, it should be demonstrated to the community (particularly K–12 teachers) that the geosciences are the overarching sciences that provide relevance and application to the study of chemistry, physics, and biology.

Observations and Recommendations

Majors, nonmajors, and preservice teachers all have the same initial needs with respect to learning about Earth and science in general. Keep these constituencies together; all have something to offer, all have something to gain.

General education courses should

- include the idea of Earth system science as a vehicle to introduce general principles for all students, majors and nonmajors alike.
- respond to the needs of students who will apply science in the future (doctors, lawyers, engineers, and other professionals) and to those who will use Earth resources (home-owners and parents) by responding with challenging and relevant materials.
- consist of programs that relate scientific content to relevant societal issues.
- contain a thematic or topical approach to geosciences, rather than a broad survey of the discipline.

Looking Toward the Future: Where Do We Go From Here?

The AGU Chapman Conference on “Scrutiny of Undergraduate Geoscience Education” generated excitement among the participants. Insights into the changing nature of undergraduate geoscience education and a series of recommendations to improve undergraduate geoscience education were presented and discussed in detail.
The question that now faces the geoscience education community is “where do we go from here?” Conference participants have suggested several possible areas of effort, including but not limited to:

- developing a new, integrative, undergraduate geoscience curriculum.
- collecting and disseminating information on effective undergraduate geoscience teaching and assessment strategies and curriculum materials.
- developing workshops to improve undergraduate teaching.
- designing an introductory Earth systems science course that would meet the needs of both nonscience and geoscience majors.
- integrating more geoscience research and multimedia technologies into undergraduate courses.
- convening a second conference on undergraduate geoscience education in 1996.

In response to Gordon Eaton’s comments, it is worth considering, “to what extent should our curriculum be responsive to the immediate job market?” If we are to reform our curriculum, it should be done as a matter of principle rather than expedience. Should not our primary responsibility as educators be directed toward the broadest training of well-rounded Earth scientists, capable of using quantitative and communication skills; with a strong background in cognitive subjects such as math, physics, chemistry, and social sciences (e.g., economics and ethics); and with a general knowledge of fundamental principles of the Earth sciences that transcend narrow disciplinary boundaries?

At what level is there “intrinsic” value of specific, traditional scientific knowledge or methods? It is hard to place a specific market value on the development of higher-order thinking skills that are developed through practical applications of traditional subject matter (e.g., cross sections and phase dia-

grams). The job market in the geosciences has traditionally been boom or bust in response to jobs in metals, energy, and, most recently, water and the environment.

To what extent should we allow current job markets to dictate curriculum, considering the changing nature of employment opportunities? Today’s hydrologist may well be assigned to an asbestos or radon problem tomorrow. How can we give our students cognitive “tools” to become lifelong learners? This, too, is independent of the contemporary job market.

Should we allow our curricula to devolve toward that of a “trade school”? If specific curricula are ultimately dictated by current employers, do not we run the risk, once again, of over specialization (how many workers from the petroleum industry have had to recently retrain as hydrologists)? And does not this type of imposed curriculum detract significantly from the ability of specific departments and teachers to emphasize their local strengths (dictated by facilities, geography, or student and staff demographics)?

Should we encourage our students to prepare themselves for nontraditional geoscience careers, (e.g., double majors in education, business, law, and engineering).

Eaton has made some fundamentally important observations about the current state of the job market and how it may relate to our educational mission. It is up to us to decide how to best respond to his challenge and to what extent we should facilitate change and for what reasons. It is hoped that the proceedings of this Chapman Conference have taken the initial steps to address these questions.

Whether the task is general or specific, communication and cooperation will be essential as an attempt is made to improve undergraduate geoscience education. We must also keep in mind that while enthusiasm is great, resources and time are limited. To make significant progress on improving undergraduate geoscience education will necessitate a focusing of our energies and prioritizing our goals.

Please join us in this effort.
Appendix I, Final Agenda

Wednesday, September 7, 1994

5:00 p.m.  Meeting Registration and Opening Reception

Thursday, September 8, 1994

8:00 a.m.  Session 1: Geoscience Opportunities in a Changing World

           Jon Price, National Research Council

8:10 a.m.  Geosciences Education for the Coming Century

Keynote Address by Gordon Eaton, Director, USGS

8:40 a.m.  Focus Papers

W. H. Beasley  Are the Geosciences Getting Their Share of the
              Best and the Brightest? If Not, Why Not, and
              What Can We Do About It?

R. H. Macdonald  Developing Student Career Choices in Geoscience

9:20 a.m.  Each of the following 10 authors will be given 2 to 3 minutes
           to highlight the main points of the presentations and discussions
           that will follow the break.

J. T. Snow  Future Opportunities for Geoscience Undergraduates

D. A. McManus  Some Overlooked Matters of Geoscience Education

U. Aswathanarayana  How to Refocus the Geoscience Education in Eastern
                    and Southern Africa to Address the Urgent Needs of
                    Food, Water, Energy and Habitation of the People

P. R. Romig  Geo Engineering: Inventing a New Discipline

C. K. Skokan  Multidisciplinary Senior Design Program at the
               Colorado School of Mines

P. Croft,  The Excitement of Meteorology! An Interactive
A. Williams  Study in the Geosciences

M. S. Binkley  Educating Non-Traditional Students in
               Meteorology

M. S. Smith,  The Conflict Between Legislative Fiscal Responsi-
R. A. Laws  bility and the Modern Geoscience Undergraduate:
             A Case Study for North Carolina

R. Frodeman  Redefining the Earth Sciences: Geology as the
              Paradigm Science for the 21st Century

J. G Windsor  Maintaining a High Quality, Undergraduate
              Oceanography Program at a Private University

9:55 a.m.  Coffee Break and Poster Setup

10:15 a.m.  Concurrent Interactive Poster Presentations and Discussions

11:30 a.m.  Plenary Session—Group Discussion

12:00 p.m.  Break for Lunch
1:15 p.m.  Session II: Undergraduate Curriculum

Presiding:  Ed Geary, Geological Society of America
           Dorothy Stout, Cypress College

1:30 p.m.  Focus Papers

E. Buchwald  Undergraduate Geology Education-The Carleton
             College Experience
A. H. Barabas  Designing Viable Undergraduate Geology
               Curricula—A View From the California Trenches
R. L. Miller,  Engineering Practices Introductory Course
C. K. Skokan  Sequence at the Colorado School of Mines

2:15 p.m.  Charge to Breakout Groups for Discussion

Group A:
A. H. Barabas  Designing Viable Undergraduate Geology
               Curricula—A View From the California Trenches
M. E. Grismer  Education in the Geoscience—Hydrologic Science

Group B:
P. Mathisen  Integrating Hydrologic Models Into the
            Undergraduate Curriculum
K. L. Prestegaard  Hydrology Curriculum for Geoscience Majors
                  and Non-majors

Group C:
J. T. Snow  The Role of Earth System Science Education in
            Geoscience Undergraduate Programs
E. Buchwald  Undergraduate Geology Education—The Carleton
             College Experience

Group D:
J. E. Hubbard,  Undergraduate Geosciences Education:
    R. S. Weinbeck,  SUNY Brockport Experience
    G. P. Byrd,
    J. A. Maliekal

Group E:
D. W. Fiesinger  Diversification of the Geology Curriculum: A
                 Remedy for the Early 1980's or Vanguard for
                 Geoscience Programs in the 21st Century?
R. L. Miller,
C. K. Skokan  Engineering Practices Introductory Course
              Sequence at the Colorado School of Mines

3:15 p.m.  Coffee Break

3:30 p.m.  Breakout Groups Continue—Develop Group Recommendations

4:30 p.m.  Plenary Session—Group Reports and Discussion

5:30 p.m.  Adjourn

6:30 p.m.  Conference Dinner—Washington Hilton
Friday, September 9, 1994

8:00 a.m.  Session III: Improving the Teaching of Geoscience

Presiding: Marilyn Suiter, American Geological Institute
           Dorothy Stout, Cypress College

8:15 a.m.  Focus Papers

W.A. Prothero Issues and Challenges in Teaching the Large
           Lower Division Science Class
J. Schweitzer, The Role of Constructivism and the Learning Cycle
B. Tapp In the Reform of Geoscience Courses at the
           Collegiate Level

8:45 a.m.  Each of the following 10 authors will be given 2 to 3 minutes
to highlight the main points of the presentations and discussions
that will follow the break.

D. L. Woodrow Change in Geoscience Undergraduate Education:
                   The View From a Liberal Arts College
D. L. Stout What Is the Role of the Community College in
           Geoscience Education?
P. M. Whelan Undergraduate Education in the Geosciences:
                   Some Reflections on Teaching and Learning
D. Perkins Turning Undergraduate Education on Its Ear
L. Srogi, C. G. Wiswall, Cooperative Learning, Writing, and Research
R. M. Busch Activities in the Geology Curriculum
R. E. Lopez Using a Constructivist, Cooperative Learning
                   Approach in a Historically Based Introductory
                   Undergraduate Space Physics Course
J. A. Knox Tell Me a Story: Interdisciplinary Justification for
           Narrative Teaching. With Application to the
           Atmospheric Sciences
R. H. Macdonald Promoting Active Learning in Large Introductory
                   Courses
E. E. Geary Faculty Metamorphosis: An Examination of the
           Changing Roles of Geoscience Faculty and
           Geoscience Departments
A. L. Pierson, Undergraduate College Faculty Workshops in
J. W. Farrington Oceanography and Oceari Engineering, 1987-
                   1992

9:30 a.m.  Coffee Break and Poster Setup

9:55 a.m.  Groups Discussions

Group A  Woodrow and Stout
Group B  Whelan and Perkins
Group C  Srogi and Lopez
Group D  Knox and Macdonald
Group E  Geary and Peirson

11:00 a.m. Plenary Session and Group Discussion

11:45 a.m. Break for Lunch
1:00 p.m.  Session IV: Undergraduate Curriculum Materials

Presiding:  David Mogk, Montana State University
            Dorothy Stout, Cypress College

1:10 p.m.  The Role of NSF in Geoscience Education
            Susan Hixson, National Science Foundation

1:35 p.m.  Focus Papers
            Doug Crawford  Visualization Technologies in Environmental Curricula (VTEC)
            P. Sandberg  Enrichment of Introductory Geology Courses by Use of Electronic Networks and Computer-Assisted Learning

2:15 p.m.  Each of the following seven authors will be given 2 to 3 minutes to highlight the main points of the presentations and discussions that will follow the break.

            C. D. Condit  Stand-Alone Hypermedia Programs Designed for Geologic Education and Geologic Map/Image/Data Dissemination
            A. Moore    Simple Systems Modeling: A Step Toward Critical Thinking
            R. W. Ridky  Access and Utilization of Scientific Data Sets in Undergraduate Geologic Instruction
            R. S. Stanley  A System Dynamics Approach in Teaching Geology
            R. Wilhelmson, M. Ramamurthy  Atmospheric Science Education Using Multimedia, Mosaic, Current and Historical Weather Data, and the Internet
            M. D. Licker  Mathematica in Undergraduate Education

2:45 p.m.  Coffee Break and Poster Setup

3:00 p.m.  Concurrent Interactive Poster Session and Discussions

4:00 p.m.  Plenary Session—Group Discussion

5:00 p.m.  Beyond Mosaic: Interactive Graphics on the Internet
            P. Samson, A. Steremberg, D. Price, C. Schwerzler, and M. Kamprath

6:00 p.m.  Adjourn
Saturday, September 10, 1994

8:30 a.m.  Session V: Collaborations and Other Mechanisms

  Presiding:  Eugene Bierly, American Geophysical Union
             John Snow, University of Oklahoma

8:40 a.m.  Focus Papers

  D. J. Wilson, P. R. Romig
  E. Frost, E. Ambos, L. Esprit, D. Kerven,
  M. Mijic, E. Ng, M. Martin, I. Woerner

  Infrastructure as a Mechanism for Driving Change
  Project ALERT (Augmented Learning Environment
  and Renewable Teaching): A Collaborative
  California State University (CSU), Historically
  Black Colleges and Universities (HBCU), and Jet
  Propulsion Laboratory (JPL) Program for Earth
  and Space Science Instruction Using Hypermedia and Internet Science

9:20 a.m.  Each of the following 10 authors will be given 2 to 3 minutes to
           highlight the main points of the presentations and discussions that
           will follow the break.

  T. M. Boyd
  L. K. Fox, W. F. Kane
  M. E. Dowse, C. W. Harper, I. J. Crumbly
  E. E. Geary
  D. R. Johnson, M. W. Kalb
  S. E. Kruse
  F. W. McCoy, S. D. Maynard
  W. I. Rose, S. Beske-Diehl, A. Mayer
  S. D. Scott, R. T. McAndrew, G. R. Brown
  M. H. Wallace

  Summer Field Courses: An Opportunity for
  Inter-University Cooperation
  Enriching the Geoscience Curriculum Through
  Collaborative Teaching: Engineering Geology
  at the University of the Pacific
  The Cooperative Developmental Energy Program:
  An Innovative Partnership to Increase Minority
  Participation in the Geosciences
  How the Coalition for Earth Science Education
  Supports Undergraduate Geoscience Education
  A NASA Funded University-Based Effort to
  Develop Earth System Science Curricula and
  Infrastructure Within Universities
  Student Collaborations and Faculty Connections:
  Geophysics Research and Education at a Liberal
  Arts College
  The University of Hawaii Marine Option
  Program
  Geological Education Must Get Broader and
  Deeper to Survive
  A Divisional System for Teaching Undergraduate
  Geological Engineering at the University of
  Toronto: Flexibility at Low Cost
  Undergraduate Research Experiences and the
  Research Methods Course

9:40 a.m.  Coffee Break and Poster Setup

10:00 a.m. Concurrent Interactive Poster Sessions and Discussions

10:45 a.m. Plenary Session and Group Discussion
12:00 a.m.  "Geology goes Hollywood"  Dorothy Stout

12:30 p.m.  Session VI: Issues in K–12 Education

Presiding:  M. Frank Watt Irerion, American Geophysical Union
            Marilyn Suyier, American Geological Institute

12:15 p.m.  M. F. W. Irerion  A Snapshot of K–12 Earth Science Education

12:45 p.m.  E. Buchwald  How Should Preservice Elementary Teachers
            Learn Science?

1:00 p.m.  K. G. Havholm,  Modeling Appropriate Pedagogy in a Geoscience
            R. Hooper,  Course: Project PRISM at the University of
            R. E. Hollon  Wisconsin, Eau Claire

1:15 p.m.  B. T. Lynds  The Teaching of Geosciences for Future Middle-
            School Teachers

1:45 p.m.  L.W. Geer,  Project Atmosphere: The Precollege Educational
            D. R. Smith  Initiative of the American Meteorological Society

2:00 p.m.  Group Discussion

2:15 p.m.  Coffee Break

2:30 p.m.  Session VII: Geoscience Education for Everyone

Presiding:  M. Frank Watt Irerion, American Geophysical Union
            David Mogk, Montana State University

2:35 p.m.  Focus Papers

A. M. Thompson  Knowing Science vs. Being Scientific: What
                Approach to Geoscience Education for Non-
                Scientists?

G. McKenzie,  Understanding the Earth: Earth Systems Science
E. Moseley-Thompson  for Non-Major Students in the Geosciences

3:10 p.m.  Each of the following 13 authors will be given 2 to 3 minutes to
            highlight the main points of the presentations and discussions that
            will follow the break.

P. M. Astwood,  An Issues-Based Environmental Geology Course
J. R. Carpenter  for Non-Science Majors
L.W. Braile  Experiences With an Introductory, Non-Science
            Majors Geoscience Course
L. J. Graumlich  Approaches for Increasing Participation of Under-
                represented Groups in Earth System Science
                Education by Linking Global Processes to Local
                Issues Through Active Learning
S. B. Harper  Thematic and Awareness Goals for Teaching Non-Majors in the Geosciences
K. M. Kemp  Do You Teach Geoscience Differently to Non-majors?
D. W. Mogk  Towards Training a New Generation of “Citizen-Scientists”
P. Samson, G. Meadows, L. Olsen  Geosciences as the Catalyst for Education Reform
S. C. Semken  Ho’zho’ and Hutton Together: Toward Autochthonous Geoscience Education for Navajo Students
B. J. Tewksbury  Strategies for Teaching Introductory Geology to Both Majors and Non-Majors: Connecting the Geology of Africa With Pre-Historic, Historical, Political, Cultural, and Economic Evolution
K. L. Verosub  The Need for New Paradigms for Introductory Geoscience Courses for Non-Science Majors
J. P. Boysen, D. N. Yarger  Using Computer-Based Applications to Actively Engage Students in the Learning Process

3:50 p.m.  Coffee Break and Poster Setup
4:05 p.m.  Concurrent Interactive Poster Presentations
5:00 p.m.  Plenary Session and Group Discussion
5:30 p.m.  Adjourn

**Sunday, September 11, 1994**

9:00 a.m.  **Session VIII: Conference Wrap-up**

**Presiding:**
Dorothy Stout, Cypress College
John Snow, University of Oklahoma
Eugene W. Bierly, American Geophysical Union

9:00 a.m.  Opening Remarks by Conference Conveners
9:20 a.m.  Task Groups Assignment and Work
10:20 a.m.  Coffee Break
10:30 a.m.  Reconvene in Plenary Session and Discussion of Tasks
11:35 a.m.  Conference Evaluation
12:00 p.m.  Conference Adjourns
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Appendix III, Keynote Address

Remarks by Gordon P. Eaton
Director, U.S. Geological Survey

Education and Employment Trends for Earth Scientists

I'm pleased to have the opportunity to share my views on employment and education trends in the Earth sciences. I believe them to be among the most pressing topics that our community has before it today.

I come at this topic from two different perspectives. First, as Director of the USGS, I represent what has traditionally been one of the largest employers of Earth science professionals anywhere. Second, I bring the perspective of more than two decades of work in the academic community over a period of 40 years. It is this community that produces the Earth scientists that we and others hire. I have been impressed over the last few months by the parallel concerns that face both producers and consumers of Earth science expertise.

The Earth sciences are experiencing a new and different kind of revolution that should be requiring all of us to rethink the way we approach our missions, not all of us, particularly some of our universities, appear to be responding. We have entered a post-industrial period, a post-romantic (or heroic) period (the lone, ruggedly independent, field geologist alone on the remote mountainside with Brunton and hammer, surrounded by stunning scenery, his/her heavy pack on his/her back), and, as George Klein has put it recently, a “post-golden age of academic science” period. I don’t need to belabor the point that it is also a post-plate tectonic revolution period. That party is largely over.

In one sense, the Earth sciences in our country first came into their own, as something significantly more than just an intellectual interest in natural science, with the advent of the Industrial Revolution. The British Geological Survey was created in 1835. Its concerns were focused on coal and bedrock geologic mapping. Suddenly, information on the energy and mineral resources of nations became an economic and strategic necessity. The world’s federal geological surveys were all born sometime during this prolonged industrial era. Close on the heels of the Industrial Revolution we experienced a pair of World Wars, the Korean Conflict, Vietnam, and the so-called “Cold War” with the former Soviet Union and other communist bloc countries. All of these events served to keep the Earth sciences, particularly the study of energy and metallic mineral resources, very high on the national agenda. However the end of the “Cold War,” the advent of the post-industrial society, deep concern for the environment, and the development of a global economy based on the interdependence of nations spelled an end to many of the explicit demands that kept both national geological surveys and the domestic geological arms of our major U.S. resource industries in business.

On the minerals end of the equation, we’ve also had to confront the fact that we’ve done much of our job and we’ve done it quite well. We were asked to find strategic and critical minerals supplies, and we did just that. This February, one of the speakers at our annual McKelvey Forum reported that “contrary to predictions from the 1950s to the 1980s, persistent widespread shortages of non-fuel minerals have never occurred, partly because exploration has been remarkably successful. Despite increased rates of consumption, present estimates suggest that world mineral supplies are adequate for the foreseeable future.” In addition to this, advanced, highly developed nations such as Japan and Germany have demonstrated that it is possible to flourish in the absence of direct national ownership of significant geologic resources.

However what has this to do with employment trends and undergraduate education? A great deal. This is where most of our students found employment in the past, and we designed and geared curricula to this fact. This happened well before any one
of us in this room became professional Earth scientists. Our own academic training prepared most of us for the extractive industries whether we chose that career path or not and whether or not we attended private liberal arts colleges or public technical universities.

Not so very long ago, the extractive industries in the United States hired two thirds of all of our students. Today, the domestic activity of those industries is very greatly diminished. In their international activities they are increasingly hiring foreign nationals. Given that fact, where should we focus our curricular efforts now? In keeping with that, let us ask how well our research universities are doing?

I worry that part of the research university community shows evidence of continuing to believe that what they are and what they do and what they are interested in is exactly what the country needs. We have for far too long now continued to train unlimited numbers of Ph.D. clones of ourselves.

I believe that all this reveals a picture of why geological surveys and classic geoscience enrollments of domestic students are today struggling. There is no foreseeable external change anywhere in sight to modify this picture by returning us to the past. It is an issue that faces not only this country but also countries around the world.

In addition, the funding of science simply for science's sake is starting to fade as a public interest for the first time since World War II. Pure, curiosity-driven research without strategic focus is poised to begin to diminish as a proportion of federally funded research. We need therefore to address how geoscience fits into the realities of today and then ask what implications there may be here for a redesign of the emphases of our educational curricula.

Reds Wolman, of Johns Hopkins and the National Research Council saw it clearly, saying, "The health of our science is inextricably mixed up with the notion of whether or not it is perceived to be useful to society. Social and political issues are a paramount concern.”

Today's environmental job responsibilities require a much better understanding of the complex interrelationships among components of the biosphere, the atmosphere, the hydrosphere, human activities, and the land around us. We must carry out the necessary academic training and fundamental research and develop appropriate technologies to anticipate, detect, and correct environmental problems, to manage natural resources in an environmentally sound way, and to sustain the environment. The levels of population, economic, and industrial growth suggested by current trends and patterns of development point to an urgent need to improve industrial processes and products and to provide food, energy, and natural resources with greatly reduced environmental impact. Understanding both biological and physical processes and their interdependencies is vital to maintaining biodiversity and health ecosystems.

The growing importance of environmental responsibilities is clearly reflected in the job market in the Earth sciences. Demand for relevant Earth science expertise now lies more frequently in the area of low-temperature aqueous geochemistry than in igneous petrology; in resources such as water, sand and gravel, and crushed aggregates rather than in metallic minerals; and in coastal and estuarine processes rather than in those fascinating ocean spreading centers. Increasingly, more professional emphasis appears to be required in understanding the processes and history of the youngest part of the geological time scale and in the shallowest levels of the Earth's crust.

Part of the demand is in curricular areas we have traditionally under emphasized in the past. The list includes coastal and estuarial geologic processes, engineering geology, environmental geology, geomorphology, geopedology, hydrogeology, neotectonics, and surficial geology. The mapping of glacial deposits, for example, requires a rather different set of skills and approaches than bedrock mapping, whether in consolidated sedimentsary rock, igneous rock, or metamorphic rock terranes.
The challenge of undergraduate Earth science education is to produce technically well-rounded individuals capable of meeting new and changing demands. Unfortunately, at many schools it appears that we are not yet ready to meet that challenge.

Since 1983, an unusually high watermark year, the number of undergraduates in Earth sciences has dropped by more than half, followed by a breathtakingly overwhelming uptick. Graduate programs have been more stable, however obvious declines among American graduate students have been clearly seen and more can be expected. Many of the students in our graduate programs are not U.S. citizens, and therefore a substantial number of them will be returning to their homelands.

The Administration wants the National Information Infrastructure to play a central role in our educational efforts. They are concerned that we educate our children for the workplace of the twenty-first century in a twenty-first century setting.

In the process of defining relevance and flexibility we must not lose sight of the critical need for technological training. Technology must be imbedded at all levels of education.

Partnerships are also key to the reforms we need to see in science education. The White House is firmly convinced that the nation must involve teachers with practicing researchers to bring the excitement of research and its discoveries into the classroom.

These challenges relate not only to undergraduates studying Earth science but also to the broad general public as well. A recent report noted that "the lifelong responsibilities of citizenship increasingly rely on scientific and technological literacy for informed choices. Our scientific community must contribute more strongly to broad public understanding and appreciation of science." In other words, we need to ensure that our students, be they Earth science majors or not, have the scientific underpinnings that will be necessary to create a more sustainable future for the planet.

I believe that the university community must examine how and for what purpose it is training Earth science students today. It has, for too long, been on an inertial curricular path tied to the past. Today's curriculum, developed and externally modified very little during a century-long era in which more than two thirds of all employment opportunities lay in the extractive industries, is now in need of very serious critical review, with an eye toward today's and tomorrow's real professional opportunities. It is time to stop looking backward at yesterday's professional opportunities as though they are still the only ones.

We need to look at the broader range of careers that can benefit from a foundation in the study of geoscience and other fields in a broadened and altered form. Also we must look at more broadly based studies that help our science majors meet the challenge of a changing emphasis toward multidisciplinary studies and work.

We must also expand our perspective to include education of a scientifically literate society and the training of teachers at the secondary and elementary level in order to build the framework and to generate enthusiasm in future generations.

Issues such as hazardous and toxic waste isolation require a strong foundation in other sciences, such as physical chemistry and hydrodynamics, as well as other fields of knowledge such as computer science. Environmental issues require knowledge of biology, organic chemistry, statistics, and the so-called "soft sciences" of economics and public policy, not just more geology courses.

Today's curricula must be redesigned to provide students with both the fundamental knowledge and the intellectual flexibility to meet changing societal needs and the shifting demands of the professions.

We are looking forward to a period that will require us to rethink and reshape a system that has now supported us a full century. The kind of systemic change that is necessary and that we face will not be easy.
Through our universities, we need to produce women and men who can effectively work in teams that bring the necessary collection of skills to the table to attack the complex problems we need to address.

Today's professional responsibilities mandate flexibility, not only in the areas we research through our careers, but also flexibility of mind and value that allows us to see and understand the importance, connections, and linkages of many different disciplines in studying Earth systems, some of them clearly not science. They are of no lesser value and meaning for that fact.
Appendix IV, Core Curriculum Summary

Scrubtiney of Undergraduate Education
Friday Evening Meeting About
Curricular Nitty-Gritty
Summary by Tanya Atwater

A group of 35-44 participants (representing about 25% institutions) met on the pool verandah from 8 to 10 PM to discuss curricular matters. We began by going around the group and having each person introduce her/himself and tell (1-2 minutes) what problems each hoped to hear discussed. From this reporting, two issues emerged loud and clear:

1. What to do about the large introduction-level geology courses to make them more appropriate to their main clientele, namely non-majors and nonscientists. (And, flip-side: Can such a course simultaneously serve as a first course for majors?)

2. How to reorganize the courses/content required of our upper division students (i.e., the “core curriculum”) to better reflect the role of geosciences in the present and future world.

We agreed that we would focus on the second problem and defer the first until Saturday evening, same time, same place.

The core curriculum problem: For many participants the problem is approximately as follows.

Their department has a well-worn, entrenched core curriculum list of required courses for their geology majors that hasn’t been substantially changed in decades. They recognize that the world is changing, both in the near future geo-job market and in the longer term needs of society. These changes (and the clamoring of the students’ voices) suggest that the core should be expanded to include courses in hydrology and/or environmental geology and/or other “useful” (AKA applied) courses. The classical core curriculum constitutes a very full load of course work, already, so that the addition of courses without contraction of some of the existing required work is not an option. What should be cut?

(It was recognized that this problem is most clear for a standard geology major, that other majors, e.g., earth systems science, have other problems.)

We first heard from participants whose departments had already attempted a solution.

The most commonly reported contraction was a compression of mineralogy, optical mineralogy, igneous and metamorphic petrology into a one year course sequence (with one lab per week). Deleted subjects included aspects of crystallography and petrogenesis and many subtleties of optical mineralogy. Some reported that they had “repackaged” these into new courses called “earth materials” and suggested that a repackaging was less painful to many faculty than mandated excision of pieces of an existing course. The acceptance of the mineralogy/petrology contraction was mixed: one participant reported that her department queried students from before and after making the change and the students clearly preferred the long version; the shorter version left them feeling insecure.

Another common contraction was to collapse various soft rock offerings (e.g., sedimentology and stratigraphy) into a one semester course. Another was to delete their computer programming course. One solution was to offer some topics as one unit mini-courses, so that a number of topics can be offered without each using a whole course slot. Some participants reported overemphasis on structure (year long course) as a bone of contention in their departments.

A few participants and their departments were not convinced of the need to change, citing relatively short term fluctuations in “hot” subjects and/or reluctance to let the present job market drive the curriculum. (It was noted by others that the students, by their elective choices, tend to drive it that way anyway.)

A few participants reported having their curricula at least somewhat determined by
their students' needs to meet requirements for professional certification.

A few participants reported that their curricula had very few requirements, rendering our discussion moot for them.

It was noted that departmental curricular discussions seemed to be quite different at small vs. large departments. Participants from small departments were generally surprised at the curricular furor reported from many large departments.

To satisfy our curiosity, we made a crude show-of-hands survey to see what subjects were on the present required lists for a B.S. in geology for our various institutions, with the following approximate results.

Mineralogy/hard rock petrology: at least half require 1 year, many require more, many reported additional optical in sediments courses

Sedimentology/stratigraphy: most require 1 semester

Structure: most require 1 semester, some require 1 year

Field methods: about half require 1 semester plus summer, many require either 1 semester or summer, many report additional field work in other classes

Geomorphology: about one-third require 1 semester

Senior thesis and/or capstone: most require 1 or both

For lower division preparation, most reported one year each of chemistry, physics, and calculus, though about one-quarter reported an additional semester of math and a few have in-house versions of some of chemistry and/or physics.

Some reported abolishment of their Historical Geology course and one described a repackaging of it with parts of other courses (historical, paleontology, stratigraphy, geochronology) to form a new "geological time" course.

We wound down with a discussion of our introductory geology courses and their functions within the major. Most departments still require their students to begin with introduction to physical and historical geology courses. Some require only physical geology and 1 participant reported a simple requirement of any beginning course in earth science, whatsoever. This led to a general discussion of the role of the beginning classes, and we found ourselves debating and wondering about the importance/irrelevance of the content covered at this first step.

Many participants remarked that they had found it quite useful to hear what other departments require and how they are coping with changes. We agreed that it would be useful to start an e-mail group to exchange nitty-gritty curricular information. Saturday morning, an e-mail steering committee volunteered itself to help set up this group (T. Atwater, G. Smith, M. Neilson, and B. Tapp). This group will set up an e-home and some guidelines then will extend an e-invitation to everyone on the Scrutiny meeting e-mail list or paper mail list and to any other geological curricular groups that come to our attention.
Appendix V, Participants Goals

Curriculum Content

"Refocus goals of lower-division courses and work with colleagues."

"I will modify, evaluate, and report on the modification of course large lecture sections."

"Contribute an article on need for curricular reform and success of curricular reform."

"Institute curricular reform in my own courses and in my department."

"Explore/summarize options for Earth system science curriculum in geosciences."

"Prepare an upper level Earth systems course (that includes Bretherton & Social Process diagrams) for all students and promote/publicize it as an option for one component of an Earth systems program."

"Synthesize and summarize main features, advantages, and benefits of reform movement in calculus. Calculus in Context from the Five Cadge Consortium. This movement provides a possible model for geosciences."

"I will incorporate some of the pedagogical techniques in my courses."

"Restructured paleontology course. Move away from three lectures and one lab per week to one lecture, one workshop, and one lab. The workshop will emphasize active rather than passive lecture learning. Workshops will be flexible, interactive among students and professor, and include: discussions of readings; problem solving in groups; activities on the Internet including engaging in geoscience discussion groups; and developing poster sessions resulting from mini-research projects."

"Develop quantitative geoscience course with three faculty members from different disciplines. Emphasis will be on converting conceptual problems and questions into a quantitative format, recognizing the generic nature of mathematical models, and statistical methods. Faculty will rotate through the course, bringing new perspective to students and other participating faculty, and developing and solidifying collegiality among faculty. I tried this as an experimental course in the spring 1994 and it was a blast."

"Initiate the development of a course mathematical methods in the Earth Sciences at the sophomore/junior level."

"I will de-emphasize lecture where possible."

"I will change my introductory course by not always lecturing, have some time for students to break up into small problem-solving groups, therefore facilitating active learning."

"I'm going to do work toward establishing a systemic state-wide initiative for incorporating earth system science in the State Educational Department's curriculum."

"I'm going to do work toward developing a course in Earth science that can be cross-listed with ethnic studies."

"Attempt to employ constructivist approach to our introductory courses by teaching an honors course in “Earth systems science.”

Curriculum Materials

"I will extend to my institution my recommendations to adjust the curriculum revisions we just developed, and outline a process for setting up a partnership with feeder institutions to diversify student body."

"Use Winnie the Pooh to illustrate process of science in my class in the spring."

"Continue my present efforts at developing and disseminating course materials."

"Will develop K–12 curriculum materials in climatology/meteorology."

"Throw out currently used lab manual in physical geology class. Develop new, interactive, constructivist assignments."

"Integrate lecture and lab components of course."
Pedagogy

"We are hosting the Fall '95 NAGT-FWS meeting and I will try to plan a workshop to deal with one of these ideas that came from the conference—maybe introductory courses or curriculum or innovative pedagogy."

"I will publish a paper on the success of the portfolio grading system which I have introduced in my environmental geology course."

"Try to push for pedagogy workshops for our faculty—have them open up to concept of not just force-feeding facts."

"Make changes in the way I teach, incorporating information and ideas from the conference."

Institutional/Faculty Changes

"Try to establish links with other science departments at my institution to develop a introductory Earth systems science course for majors, non-majors, and preservice teachers."

"Work to hire a new chair who will be supportive and pro-active as regards undergraduate education."

"I will work with geology and meteorology faculty to develop computer based applications which can focus on discipline commonalities."

"I will work with other geoscience faculty on Internet to disseminate these applications."

"I am going to set up a bulletin board with methodological tips such as techniques and bibliography to sensitize geoscience faculty."

"To develop a general one credit course on the general affects of research with emphasis in geosciences for undergraduate students."

"I will work harder at motivating my department faculty to see the need for change in curriculum by selling it's benefits such as gaining flexibility in interdisciplinary research."

"Push for development of culturally based course in Earth sciences with Hawaiian focus similar to Native American program."

"Stimulate faculty interest in conceptual process."

Geosciences for Everyone

"Improve, expand, and disseminate Navajo cultural geoscience materials by appropriate means."

"Resolve to bring other 2 year college geoscience faculty, especially those at minority/majority schools into the process of curriculum scrutiny and evaluation."

"Produce a new Earth science resource book for teachers at all levels."

Partnerships & Collaborations

"Work with other geology faculty who are interested in educational outreach."

"Liaison with AAPG to try to focus through Academic Liaison committee concerns/interest of professional petroleum geologists in curriculum."

"Continue with collaboration with some members I met."

Spreading the Word to Colleagues & Public

"I'll introduce my faculty to what was discussed here."

"Get access to Mosaic, try to find appropriate course materials and disseminate within the department and neighboring departments."

"Attempt to organize a LISTSERV discussion group for people interested in curricular reform."

"To start up a partnership program like SAGE that will partner geoscientists with local science museums to review and expand educational programs and exhibits in the geosciences."

"Produce some how to sheets on urban environment for dissemination to this group."

"Share some K–12 materials that work in DC or the marine community."

"Pass our conference report to the university self study reform group."

"Write more about what works."

"Will continue to talk about CDEP. Be available to help others in thinking about establishing similar collaborative programs."
"I am active with my state Earth science teachers association. I will more aggressively seek to involve my departmental colleagues."

"Report to faculty of OU School of Meteorology on the deliberations of this conference."

"I will assemble faculty to discuss curricular reform, possibly in a retreat format."

"Will communicate these ideas to our home department."

"Summarize main points of conference to my faculty."

"I will make an informal report on the conference to all interested faculty and students at a lunch time seminar this Wednesday. I will make a more formal report, including specific recommendations at an upcoming faculty meeting."

"Convey our ideas to our undergraduate committee first and then work with them to approach the faculty as a whole."

"In next year, write and publish two articles—one in JGE and one in JCST—based on my presentation here, which will disseminate some broadly applicable ideas in geoscience teaching."

"In next month, write two short articles which describe my experiences here to my department and colleagues at Wisconsin and also to Wisconsin meteorology alumni to help them get acclimated to the idea that Ph.D. training can include experience in teaching."

"Push for change to Journal of Geoscience Education & National Association of Geoscience Teachers."

"Excerpt of conference proceedings in JGE."

"I would be very interested in being involved in any future conferences and would gladly help with organization."

"I would be willing to serve on a task force on "Earth Systems" curricular for undergraduates or a task force on models of integrating teaching and research with undergraduates."

"We publishers are interested in forming alliances with NSF (project DUE) projects to develop and market educational products that are forward thinking and reaching. We at Freeman are interested in taking a longer, developmental approach to eventually providing quality materials that will work for real geoscience educational reform. We also advocate process in product development, not an end product."

"Learn to use MOSAIC."

"Incorporate more under graduates in my research."

"Recommend portfolio for faculty evaluation."

"Find out if grad students are fully networked."

"Pull together annotated bibliography."

"Publish on some successful strategies on the learning cycle and learning stations."

"Work with the developing State of Missouri professional licensing board in developing standards for Professional Geologist registration."

"Work on multi-disciplinary initiatives, hopefully through NSF proposal."

"Promote less is more concept."

"Become more Internet literate, and teach Internet literacy to students at all levels."

"Establish an informal e-mail network of friends/collaborators who attended here and expressed interest in the improvement of geoscience teaching."
Appendix VI, Abstracts

Thursday, September 8, 1994

Morning
Session I: Geoscience Opportunities in a Changing World

Are the Geosciences Getting Their Share of the Best and the Brightest? If Not, Why Not, and What Can We Do About It?

William H. Beasley (School of Meteorology, University of Oklahoma, Norman, OK 73019; 405-325-6561; e-mail: wbeasley@okstate.edu)

A quick survey of the rather successful National Merit Scholars recruitment program at the University of Oklahoma suggests that something is amiss. For example, out of a total of 192 national scholars entering in Fall, 1994 (160 National Merit Scholars, 18 National Achievement Scholars, and 14 National Hispanic Scholars), only ONE (1) is entering the College of Geosciences, despite the fact that the School of Geology and Geophysics enjoys an international reputation as one of the founding and still leading programs in exploration geophysics and the fact that the School of Meteorology is one of the strongest and largest atmospheric science programs (in terms of numbers of students, faculty research funding, and faculty reputation) in the U.S.

Why is this so? My hypothesis is that high-school students, and their advisors and counselors as well, do not know what the geosciences or any of the specialties within geosciences really are all about or what their practitioners do. Indeed, it may be even worse. They may think they know, but actually could be misinformed.

What can we do about it? I propose a National Geosciences Program for high-school students that would combine some features of the Westinghouse Science Talent Search, NSF Research Experiences for Undergraduates, and the Geosciences Summer Academies at the University of Oklahoma. Outstanding junior students from each state and major territory would spend several weeks of the summer before their senior year in a research program at a university. Exposure to research, through one of the disciplines of the geosciences, would serve not only to entice a few of the best and brightest into the field but also to expose many students who would go on to other fields, such as medicine, law, business, even politics, to science in general, and geosciences in particular, with the hope that this would make them better informed leaders and decision makers in the future, no matter what they do. The program could be funded and administered in a variety of ways. I would like to see the AGU take the lead among numerous more specialized professional organizations to make it happen.

Developing Student Career Choices in Geoscience

R. Heather Maccold (Department of Geology, College of William and Mary, Williamsburg, VA 23187-8795; 804-221-2469; rhmaccd@mail.wm.edu)

Just as geoscience departments provide opportunities for students to develop their geoscientific knowledge, skills and understanding, we should also provide opportunities for students to explore careers in the geosciences and should make explicit the value of a geoscience background in a variety of careers.

In addition to serving as role models and providing students with stimulating experiences in and out of the classroom, faculty can help students, both majors and nonmajors, make career decisions by employing the following strategies, arranged in approximate chronological order beginning at the level of an introductory course.

1) When showing slides or photographs in class, name the person and briefly describe his or her work.
2) Give interested students a career brochure developed by one of the geoscience organizations.
3) Have students conduct informational interviews with professionals, a valuable experience whether or not they continue in the geosciences.
4) When guest speakers come to classes and departmental lecture programs, ask them to include a brief description of their job and/or career path and give students time to meet with the speakers.
5) Collect information on summer jobs and internships and encourage students to apply for these positions.
6) Encourage students to network with alumni by inviting a panel of alumni to talk about their careers and publishing a department newsletter with information on what graduates are doing.
7) Hold an information session on selecting and applying for graduate schools and/or jobs and offer to review applications and/or resumes.
8) Require students to do a research project that culminates in a written report; the report can be used as a writing sample, as evidence of ability to complete a project, and might result in a paper or a presentation at a professional meeting.

Perhaps the most important strategy is to take a personal interest in students and encourage them as they develop professionally. Whether or not they select a geoscience career, students will benefit if we more consciously help them explore career options.

FUTURE OPPORTUNITIES FOR GEOSCIENCE UNDERGRADUATES

J.T. Snow (The College of Geosciences, The University of Oklahoma, Norman, OK 73019-0628; 405-325-3101; e-mail jsnow@okstate.edu)

Many of the disciplines in the Geosciences have established career paths for students completing the Bachelor's degree. Students entering the work force with a degree in geology/geophysics have been focused on industries discovering and extracting mineral and energy resources. Similarly, since the late 1940's, it has been assumed that meteorology graduates would enter federal service as weather forecasters. In future years, while some Bachelor's graduates will always pursue such careers, the fraction will become continually smaller as traditional employers shrink, restructure, or move operations overseas. Potential new employers (and restructured traditional ones) are demanding much more of new employees in terms of professional skills and technical adaptability. Unfortunately, most undergraduate programs continue to prepare students for only two options -- the traditional career paths or graduate study implicitly structured to prepare for an academic career.

I suggest that undergraduate programs in the Geosciences need to be restructured in response to long trends in the employment market. A few areas where many current programs need adjustment include:

- More internationalization (language skills, global geographic skills, cultural understandings) to prepare students to work overseas;
- Increased hands-on experience with modern data collection systems and the numerical tools to analyze the resulting massive data streams;
- Greater emphasis on low temperature chemistry in both air, water and earth, to prepare students for work in the "environmental quality" industry; and
- Increased use (as opposed to development) of numerical models and simulations to explore events in the Earth System.

Obviously, incorporating new courses, laboratories and field work must come at the expense of things currently included in undergraduate programs. I suggest the Geoscience community needs to make the undergraduate degree a five-year program, or
establish it as a preprofessional degree. In the latter case the Master's degree would become the professional degree, but this would require decreasing the emphasis on research at the Master level that has occurred in recent years.

Some Overlooked Matters of Geoscience Education

Dean A McManus (School of Oceanography, University of Washington, Seattle, WA 98195; 206-543-0587; e-mail: mcmanus@u.washington.edu)

Conversations with faculty and students this year in geoscience departments at eight universities in the U.S. and two in Australia lead me to propose that we geoscience faculty consider the following statements as part of our responsibilities for better educating our undergraduate students and fostering our science.

We should: 1) encourage our students to value knowledge over grades, the reverse of today; this cannot be accomplished by preaching but only by letting them discover the value of knowledge through its use; 2) assist them to pass through the now common Post-Baccalaurate Break before graduate school; we cannot risk losing outstanding students during this break; 3) inform them better about careers in applied geoscience and in non-traditional fields, while introducing them to basic research; more of them want to apply their geoscience than before, but many faculty do not know industry or government career requirements; and although many students say they do not want to do basic research, they have not yet done any, to know what it is; 4) prepare them better to explain a geoscientist's social responsibility to the public; the demand for this explanation is coming from the public; however we define "social responsibility," we are silent at our own risk; 5) prepare them better to talk to the public about geoscience; if the public cannot understand what geoscientists are doing, why should they care—or fund the research? and 6) prepare those who can to respond to antiscience attacks; the attacks are ignored by most of us, but for how long will our students' careers be respected by society if the attacks go unanswered?

How to Reform the Geoscience Education in Eastern and Southern Africa to Address the Urgent Needs of Food, Water, Energy and Habitation of the People

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The undergraduate curricula in geology in the universities in Eastern and Southern Africa are patterned after the then-existing systems of education of the colonial powers (Portuguese in the case of Mozambique and Angola, and British for the rest). The route for upward mobility in the formal sector came to be identified with the passing of examinations based on this style of academic education, which happens to be irrelevant to the urgent needs, namely, food, water, energy and habitation. If the earth science has to discharge its social and intellectual responsibilities to the community, it must necessarily address these life-and-death issues. This cannot be accomplished if the earth science is taught, as is done now, as pieces of compartmentalised pure science, represented by the traditional branches, such as petrology - mineralogy, stratigraphy, etc. Is it indeed possible to design a system of geological education which addresses the urgent needs of the people, which is scientifically sound, and which is linked with cognate subjects like Agriculture and Land-use. Through the instrumentality of soil and water management, geological knowledge and skills can be put to use to grow crops with better nutrient content, provide water for drinking and other purposes, and provide renewable energy and habitation to the people - and all these in ways which will bring about ecologically and economically viable development.

Land-use planning

Geoscience

Agriculture & Meteorology

Geo Engineering: Inventing a New Discipline

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Because the full impact of new curricula are not felt for ten to twenty years, academic planning must be based on fundamental, long-term forces rather than current trends or fads. Those forces driving earth-science education will be determined by the need to feed, clothe and house a burgeoning global population with a limited resource base and without destroying the environment in the process.

As more people compete for a limited resource base, exploration just for the sake of knowledge no longer will be practical. The need to solve increasingly-complex problems subject to limitations of time and money will force us to invent the discipline of Geo Engineering, which will be characterized by two fundamental changes: 1) Information will have limited value unless it is nearly 100% complete and accurate. We must develop tools that will allow us to see inside the earth with an order-of-magnitude better resolution and completeness. 2) We must learn to practice our profession as engineers in the philosophical sense of the word. This includes four key elements that currently are missing in most earth-science education: a) Problem-oriented priorities - Students must learn to identify and focus on the key elements in broad, open-ended problems. b) Engineering Design - Project design must be based on quantitative analyses using modeling and simulation. c) Structured Decision-making - Thought processes and decisions must be thoroughly codified and documented. d) Multi-disciplinary collaboration - Collaborative leadership in multi-disciplinary teams must replace hierarchical structures.

This will require a fundamental re-structuring of our educational philosophies, and we will succeed only if industry, government, academe and professional societies participate as equal partners.

Multidisciplinary Senior Design Program at the University of Colorado's School of Mines

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Increasingly, industry managers and engineers tell us they are concerned about the narrow technical confines in which seniors are currently taught. More and more "real world" problems require engineers and scientists who are capable of working with people from other disciplines to achieve a satisfactory solution. At the Colorado School of Mines, a two-semester course sequence addresses this concern by
using multidisciplinary teams of students working with faculty to solve complex, open-ended problems with both technical and non-technical constraints. One example of a such senior design project was an environmental study. Five students from geophysics, geology, civil engineering, and chemical engineering worked on site characterization and clean-up effectiveness on a small area near Denver. Their studies included location of the water table by use of geophysics, modelling of groundwater flow, and chemical analyses of both soil and water. The students conducted independent research as well as applied knowledge gained in previous courses. They also enhanced their oral and written technical communication skills.

The Excitement of Meteorology! An Interactive Study in the Geosciences

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(Sponsor: University of South Alabama)

In order to enhance scientific literacy, and encourage students to pursue science in higher education, a summer course intended to make students aware of the interdisciplinary nature of meteorology and the career opportunities available has been developed. The course will consist of a series of lectures, laboratory exercises, field trips, and a research project during a one month period.

The goals and objectives of the project are to develop high school students' basic science skills through the study of meteorology, make them aware of the interdisciplinary nature of meteorology, provide opportunities for them to see and hear the meteorologist as a researcher, teacher, and communicator; provide the necessary information and incentive for students to choose a career in meteorology or the sciences, make students aware of the various employment opportunities in the field, and show the moral and ethical responsibilities and importance of atmospheric science to society.

The project has been structured to focus on basic meteorological principles the first week, the practical application of these principles during the second week (including the educational training required), the study of special topics and completion of student projects the third week, and student presentations and evaluations the fourth week. Field trips will allow students to see professional meteorologists in the workplace whereas their project will provide them with research experience.

Students will also prepare a "weather perceptions" study during the project in order to assess their own and the public's level of weather knowledge and identify misperceptions that exist. Follow-up studies and projects will be completed by each student during the school year immediately following the summer course. The "weather perceptions" study will not only provide information on general deficiencies in meteorological education and awareness, but also importantly it will help to identify problems in the communication of scientific information by meteorologists and to the public.

Educatiny Non-Traditional Students in Meteorology

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Given today's lifestyle, the media, and especially television, is probably the greatest potential source of education for most individuals. Unfortunately, many of today's television weathercasters have little or no background in meteorology to go with their college degrees in communication. This situation will probably not improve in the future, as news directors would prefer a communicator who can learn some meteorology rather than a meteorologist who must learn the art of broadcasting.

The Broadcast Meteorology Program (BMP) at MSU seeks to provide one solution to this problem. The BMP combines an on-campus curriculum (undergraduate and graduate level) with an off-campus program of study designed especially for television weathercasters.

The on-campus program currently serves over twenty undergraduate and eighteen graduate students. The students take some of the "normal" meteorology courses (synoptic, thermodynamic, ...) along with courses in severe weather, radar and satellite meteorology and others. In addition to these courses, the students take four semesters of weather analysis and forecasting and four semesters of practicum in broadcast meteorology. The weather analysis and forecasting courses put the students in front of the classroom giving fifteen minute weather briefings. The practicum classes allow the students to learn operational meteorology. The students provide over forty-five radio shows and fifteen television weathercasts each week using state-of-the-art equipment (WSL, MapTools, Marta, COMET, ...). Since the students are learning both the art of broadcasting and the science of meteorology, we have a 100% placement rating of our graduates.

The off-campus program currently has 175 students enrolled. These students are from 43 states, Canada and the Bahamas. They enroll in thirteen courses and can earn thirty-nine hours of credit. The off-campus courses are offered on the semester system, with video tapes replacing the classroom. The students complete assignments and two exams (processed by the National Weather Service). A Certificate in Broadcast Meteorology is offered to those completing the first ten courses. Students completing the entire program of study are in excellent position for both the American Meteorology Societies' and the National Weather Association's Seals of Approval.

By having a program for students learning the discipline and also a program for those already working in the field, MSU is trying to further educate today's and tomorrow's television weathercasters. This is one step towards further educating the general public in meteorology.


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Recent legislation in North Carolina has prompted the University's General Administration to require each campus to review its degree programs with respect to course requirements and graduation rates. The state legislature set limits for the total number of hours that it will subsidize, and hours taken beyond that limit are subject to a 25% surcharge. This legislation also requires campuses to maintain an average per-semester course load of 15 credit hours. These actions fly in the face of the social profile of many geoscience students who do not fit into the preconceived model for the "traditional" student. We evaluate a ten year record of geoscience students in the Department of Earth Sciences at UNCW. These data find that geoscience students commonly declare a major in their late sophomore or early junior year, placing them behind with respect to the ideal four-year program. Many of these students work up to 20 hours per week for support, commonly have co-dependent who are also in school, are veterans or reservists, and often withdraw from school during periods up to years before completing their degree. This conflict between legislative fiscal responsibility and the non-traditional student has resulted in changes that could affect the quality of undergraduate education. In an effort to increase graduation rates and to appease legislative interests, the following were implemented at UNCW: reductions in required hours and courses for the major, reductions in GPA retention standards, and relaxation of course repeat and course withdrawal policies. Thus, the Department is under pressure to adjust to this conflict while attempting to maintain quality geoscience degree programs.
Redefining the Earth Sciences: Geology as the Paradigm Science for the 21st Century

Robert Frodeman (CB 250, Dep. of Geology, University of Colorado-Boulder, Boulder, CO 80309)

Geology's role in our culture is undergoing radical change. We see simultaneous movement in two directions. On the one hand, undergraduate majors have been in decline, exploration has dropped off within the U.S., and the budgets of organizations such as the USGS have been steadily eroding. These are signs that the traditional role of geology as resource identification and exploitation is ending, or at least has passed its peak. On the other hand, the importance of issues such as ecosystems management, global warming, acid rain, and hazardous waste disposal has been rapidly increasing.

These latter issues fall squarely within the purview of the geosciences: any understanding of them will be based upon geophysical data and an Earth Science perspective. But answers to these problems will also require that we combine geologic information with a larger political, ethical and philosophic perspective—a combination of science and humanities which is alien to the way geology has traditionally been taught and practiced.

My own work has been directed toward the bridging of the two culture of geology and philosophy in order to confront these vital societal issues. With a Ph.D. in Philosophy, and a soon-to-be completed MS in the Earth Sciences, my goal is help geology become the integrative science, using its global perspective to address the synthetic problems we will face in the 21st century.

In the future I hope to pursue this goal through teaching on the undergraduate and graduate level. For the last year I have been working for the USGS as it reevaluates its mission as the Federal Earth Science Agency, delivering a series of seminars in the philosophy of science for the USGS at its various centers around the country. In this presentation I will discuss the results of these seminars and what conclusions we can draw for the future of Earth Science Education.

Thursday, September 8, 1994

Afternoon Session II: UNDERGRADUATE CURRICULUM

Undergraduate Geology Education—The Carleton College Experience

Edward Buchwald (Geology Department, Carleton College, Northfield, MN 55057; 507-663-4403; EBUCHWAL@CARLTON.EDU) (Sponsor: Dorothy L. Stout)

The geology program at Carleton College is arguably one of the most successful in the USA. From a small (1800 students) coed liberal arts college approximately 18 students (men, 52% and women, 48%) graduate each year. A substantial proportion of them go on to graduate school with many obtaining the Ph.D. degree. What makes this program successful? Are there lessons for other colleges and universities?

The geology curriculum at Carleton was explicitly designed to create a sense that geology is not so much a body of fact as it is a way of finding out and knowing about the earth. The curriculum is not linear and sequential, but it is staged. The faculty and students agree on such major goals as: all courses need to create and execute research protocols, evaluate results, and communicate results to broad audiences. Geology is taught as a liberal art and as such the relationship of geology to society is a central concern. Students are expected to be imaginative, inquisitive, creative, cooperative, and responsible, and they live up to those expectations.

Designing Viable Undergraduate Geology Curricula—A View From the California Trenches

A.H. Barabas (Department of Geology; 2345 E. San Ramon Avenue; California State University, Fresno; Fresno, CA 93740-0024; 209-278-2912)

This presentation summarizes efforts over the past 10 years at CSU Fresno to design a geology curriculum responsive to evolving student needs; it also includes the author's personal view of likely future developments. Recent curricular changes have been driven by the need (1) to offer viable introductory experiences for both geology majors and non-majors; (2) to streamline the traditional geology curriculum to facilitate student exposure to applied geology, so that geology graduates are better prepared for geotechnical employment; and (3) to diversify the curriculum by developing new constituencies (e.g. earth science teachers) and by applying new technologies (GIS and digital image processing, computer-assisted mapping, field geophysics and hydrogeology, etc.), all within the context of California's on-going budget crisis.

High-enrollment introductory courses are now exclusively designed to meet the science requirement for non-majors; they emphasize local geologic history and application of physical science principles to societal problems of the San Joaquin Valley and nearby areas (e.g. groundwater supply and quality; conservation of prime agricultural land; salinization of arid areas; availability of construction materials; flooding, landslide, and earthquake hazards; geological consequences of air pollution). A separate entry course for the major is being designed, combining introductory field methods with traditional physical and historical geology lab topics (mineral and rock description, geologic time, stratigraphic principles, dating methods, geologic maps and sections, basic structures, etc.).

Hydrogeology, engineering geology, geochemistry, and mineral deposit courses have been developed as electives for undergraduate majors and as entry-level requirements for Master's students. To facilitate undergraduate students enrolling in these applied geology courses, the required units in mineralogy-crystallography-optical mineralogy have been reduced by 25%. Under consideration are extension and regular enrollment courses.
for teachers at the upper division and graduate level, as well as streamlining other groups of courses (structural and field geology; sedimentology-sedimentary petrology-stratigraphy-paleontology).

The success of these efforts has depended on (1) maintaining a dialogue with geoscience employers and with alumni, especially recent geology graduates; (2) the faculty’s commitment to defining curricular goals and desired outcomes for students; and (3) the faculty’s acceptance of the evolving nature of the geological sciences and their willingness to open proprietary curricular areas to discussion and scrutiny by colleagues, especially recent hires.

Engineering Practices Introductory Course Sequence at the Colorado School of Mines

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EPICS is a four-semester, 11 credit hour sequence of courses for freshmen and sophomores, designed to prepare students for their upper-division courses and to develop some of the key skills of the professional scientist or engineer: the ability to solve complex, open-ended problems; the ability to self-educate; and the ability to communicate effectively. An award-winning program, EPICS replaces the traditional core courses in computer programming, graphics, and technical communication. The instructor serves primarily as a coach rather than lecturer. Problem-solving skills are developed through projects which the students solve in teams. Starting with simple case studies, the projects grow in complexity to a final, full-semester project submitted by an external client. Written and oral communications are studied and practiced as an integral part of the project work. The second semester freshman project this year was a site characterization study of the effects of a section of highway I-70 in the mountains on the water of Clear Creek. For the sophomores, more than 50% of the projects were based on earth-science themes. Examples include design of a data base for the USGS Water Resources Division, mine safety curriculum design, and design and construction of electrodes for a permanent array for electromagnetic monitoring.

Education in the Geoscience - Hydrologic Science

Mark E. Grismer (Department of LAWR, Hydrologic Science Section, UC Davis, Davis, CA 95616; phone: 916-752-5243; fax: 916-752-5262; Internet: megrismer@ucdavis.edu)(AGU Sponsor: G.E. Fogg)

In an effort to capitalize on existing though diverse expertise and the need for trained hydrologists with both quantitative and qualitative earth science skills, we have developed a coherent curriculum spanning the undergraduate through graduate levels at UC Davis during the past three years. Beginning with a broadly based graduate program (M.S. & Ph.D.) formed in 1991 from the Earth Sciences & Resources program, we implemented an undergraduate minor (1993), and finally, the major (1994). The teaching programs are modeled after the 1991 NRC report, "Opportunities in the Hydrologic Sciences", that defined hydrologic science as a distinct geoscience. All three programs are designed for students from the natural, physical, or environmental sciences and share a common core of coursework in mathematics, physics, chemistry, biology, numerical methods, structural geology and transport processes. Students can specialize in such areas as subsurface hydrology, surface processes, water resources management (including irrigation and drainage), hydrobiology and hydrogeochemistry. Our goal is to link the qualitative analysis skills of the classical geologist with the quantitative skills used for characterization of processes such that contemporary water-related problems can be addressed in an integrated fashion. Interest in the undergraduate programs is high even though they have only just been approved; while the graduate program continues to grow rapidly with approximately 20 applicants in 1992 increasing to over 70 applicants for fall 1994. It is our hope that the undergraduate curriculum be developed into a standard for use by other institutions across the nation as we work towards professional certification of hydrologists.

Integrating Hydrologic Models Into the Undergraduate Curriculum

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Scientists, engineers and other practitioners working in the field of hydrology routinely apply numerical models to solve a wide range of hydrologic problems. Therefore, undergraduate students should develop a methodical approach for applying models to real-world problems early in their education. In addition, an undergraduate curriculum should also provide students with some experience in using models which are used in practice. Unfortunately, many numerical models are extremely complex and a complete understanding of the models requires understanding of fairly advanced subject material. Limited class time also makes it difficult to adequately address all theoretical and numerical details associated with these models.

The concerns of providing students with essential theoretical background within limited time constraints will be discussed in this presentation. Case studies include models for surface water runoff, stream water quality, and ground water flow. Cooperative learning approaches to teach the proper use of numerical models are also presented. Using these cooperative learning approaches, students become actively involved in the learning process while working together in groups to solve problems. These approaches can help students learn new software packages quickly and better equip them to work in interactively with others in practice.

Hydrology Curriculum for Geoscience majors and non-majors

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A small number of hydrology courses are currently offered in most Geoscience programs. Most of these courses are offered as upper level courses. These courses may meet many needs of geology students, but they often present hydrology and fluid mechanics as separate from other geoscience disciplines rather than integral to the study of many geological processes. Geoscience students are not the only students who need to be trained in hydrology. There are significant numbers of students who are undergraduate and graduate majors in fields such as ecology, natural resource management, and other fields who have significant needs for training in hydrology. Some of these students have had few if any geology or related science courses. This presents the problem of teaching students with diverse backgrounds in science in the same class. I have found that integrating lectures with problem sets, field trips, and individual research projects works well for diverse classes.
THE ROLE OF EARTH SYSTEM SCIENCE EDUCATION IN GEOSCIENCE UNDERGRADUATE PROGRAMS

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Earth System Science (ESS) focuses on interconnections and interactions among the four subsystems of the Earth System: geosphere, hydrosphere (taken to include the cyrosphere), atmosphere, and the biosphere. While every undergraduate should obtain a strong foundation in one of the traditional disciplines of geology/geomorphology, oceanography, or meteorology, recent developments suggest that students in the Geosciences need an exposure to ESS for two reasons:

- Context -- students need to see the knowledge bases of the traditional disciplines in relation to one another in order to appreciate what is known (and not known) about the world. This can be accomplished in a survey course covering both classic themes and recent major findings: planetary formation and structure; structure of Earth's fluid envelopes; co-evolution of life with Earth's surface, ocean and atmosphere; plate tectonics; Milankovitch cycles and climate fluctuations of the last 200,000 years; the water and carbon cycles; and the atmospheric dynamics and chemistry leading to the "ozone hole". Particular emphasis should be given to discussions of how data collected over the last 150 years has been continually extended and reinterpreted.

- Integration -- toward the end of their undergraduate studies, students need to integrate what they have learned, not only within their discipline but also with knowledge from outside their chosen field of study. One method of accomplishing this is through a senior-level course in Earth System modeling. Working in teams comprised of students from the traditional disciplines, perhaps augmented with students from the life sciences, and using friendly modeling software such as STELLA, undergraduates can develop sophisticated toy models for biogeochemical cycles and other Earth processes. Such models require students to reach out for information from all the traditional disciplines and the life sciences.

A systems approach to providing context and integration of information from the traditional disciplines exposes the student to fundamental concepts, such as feedback and regulation, not well covered in disciplinary course offerings. Further, it produces a much more scientifically literate bachelors graduate, better equipped to work on a multi-disciplinary team. It provides much needed breadth to many narrowly focused undergraduate programs, preparing students to look at phenomena from a broader perspective.

Undergraduate Geosciences Education: SUNY Brockport Experience

J. E. Hubbard, R. S. Weinbeck, G. P. Byrd and J. A. Maliekal (all at Department of The Earth Sciences, SUNY College at Brockport Brockport, NY 14420; 716-355-2636)

Dispersing ignorance about the earth is the theme that unites a broad spectrum of geosciences disciplines from solid earth geology to space sciences. Undergraduate geosciences curriculum must reconcile two conflicting requirements; the need to provide students with a body of knowledge broad enough to dispel their ignorance about the earth, yet specialized enough to prepare them to be productive scientists in specific areas such geology, meteorology, or hydrology. Undergraduate educators must also develop courses to introduce geosciences to students at large, so that, they are better equipped to make a decision about the earth and its environment, when inundated with information through the mass media. Although several graduate schools are now in the process of integrating various geosciences disciplines into one multi-disciplinary Earth Systems program, the pace of progress is too slow. To accelerate the progress, there is a need for a 'grass-root' level movement. Time is ripe for undergraduate educators to step in and take charge.

SUNY College at Brockport has a unique program that is born out of close collaboration among geologists, meteorologists, and hydrologists. Our strategy is to provide both general and specialized education. Students have the option of pursuing specialized degree programs in Geology, Meteorology, or Water Resources. Students desiring a broader education have the option of pursuing a degree program in Earth Sciences by choosing an appropriate blend of geology, meteorology and hydrology courses. Earth Science majors also have the option of seeking an environmental track by selecting courses such as Environmental Climatology, Environmental Geology, Water Resources Issues, Introduction to Soil Sciences, Computational Methods in the Field Sciences, and Air Pollution Meteorology. These courses also provide students specializing in specific areas an opportunity to learn more about various environmental issues within the context of their discipline.

Perhaps the biggest challenge facing geosciences educators is the enormous amount of resources needed for the collection, analysis, and display of vast amounts of spatial data. We strongly feel that the geosciences community will be better served if resources are pooled either nationally or regionally to establish support networks for the efficient acquisition and use of geosciences data. Almost universal access to the Internet can render this monumental task achievable, with limited resources. The NSF funded Unidata program is an example of one such program established to help university departments acquire and use atmospheric data in a cost effective manner.

Inquiry-Oriented Hands-on-Science Teaching in Geophysics

E.A. Kereta (Geology Department, Potsdam College, Potsdam, NY 15676; 315-267-2287)

Inquiry-oriented hands-on-science teaching in exploration geophysics is an effective way of teaching science as inquiry to science and non science majors. The course uses a hands-on-approach in which students use geophysical methods (seismic, electrical, magnetic and gravity) to work on geologic, environmental and hydrologic problems of local communities. The course requires the students to practice science by collecting appropriate data and to analyze and interpret that data by computer techniques. This method stimulates interest in scientific inquiry and science as a process. The course makes science education more like science and deviates from the lecture-textbook method that now dominates science teaching. Applying the methods solve their geologic, environmental and hydrologic problems motivates the students and makes them appreciate the practicality of science. Some problems worked in the past summer are depth to bedrock, landfill studies and depth to groundwater.

The real learning in the course comes from doing, not being told. Science is no longer the drudgery of memorizing facts for examinations since no examinations are given. Students are evaluated on attendance to acquire field data, written reports and oral discussions on the interpretation of data. Several student class projects will be presented to illustrate the teaching effectiveness of this hands-on-method of teaching.

Diversification of the Geology Curriculum: A Remedy For the Early 1980's or Vanguard for Geoscience Programs in the 21st Century?

Donald W. Flossinger (Dept. of Geology, Utah State University, Logan, UT 84322-4505; 801- 797-1274; e-mail: FATA@cc.usu.edu)

After a catastrophic decline in enrollments in the early 1980's, the Geology Department at Utah State University responded by creating a diversified curriculum for its undergraduate majors. There are four options or tracks which may be pursued to obtain a BS/BA in geology: a) general geology, b) hydrogeology - engineering geology, c) geoaehaeology, and d) earth science teaching. Common to all options is a core: physical geology, his-
torical geology, sedimentation - stratigraphy, structural geology, geologic field methods, field camp, 1 year of chemistry, 1 year of physics (or biology for geoaecology), 2 courses in calculus, and a computer science or statistics course. The core provides students with one to two years to decide on their choice of options. Choices are usually based on personal professional goals and perceived success in completing the respective required courses.

The development and success of these options has required the cooperation and participation of other campus units, such as the departments of Civil & Environmental Engineering, Anthropology, and Secondary Education. An unanticipated outcome has been the increased appreciation of geology as a scientific discipline and consequent increased recognition of the Geology Department as a valued academic unit.

Curriculum diversity must be accompanied by faculty and administrative adaptability: faculty must be willing to shift teaching emphasis to areas of demand and administrators must provide an environment or atmosphere where teaching and course development are valued and rewarded. An annual Geology faculty retreat is utilized for a process of curriculum review and revision.

Friday, September 9, 1994

Morning Session III: IMPROVING THE TEACHING OF GEOSCIENCE

Issues and Challenges in Teaching the Large Lower Division Science Class.

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Large lower division general science classes present formidable challenges to the instructor whose goal is to present an effective learning experience to all students. Diversity of learning styles, inadequate mathematics and physics preparation, the large numbers of students, lack of student contact, and difficulty in evaluating student performance present serious barriers. Furthermore, the professor's concept of how students learn is often unnecessarily narrowed by the use of "self as model" viewpoints. A recognition of the variety of ways students assimilate information and concepts is important in order to effectively teach non-majors. The use of multi-media for lecturing can be an effective strategy, but its high content density can result in student frustration over "going too fast".

A "hands-on" oceanography course being developed at UCSB will be described. This course includes a smaller role for the lecture and a larger role for interactive laboratory type experiences. It is both computer and "real world" observation based and has elements that address student grading, student access to course lecture media, "discovery" learning, and peer reviewed writing exercises. Testing of some of the software (2 lab modules have been completed) has been conducted with small groups of students, and the reaction has been positive. Small scale implementation of some of the software will begin Fall 94, with full scale implementation in Winter, 1995.

The Role of Constructivism and the Learning Cycle in the Reform of Geoscience Courses at the Collegiate Level

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Science education reform efforts emphasize the need for content comprehension and an understanding of the nature of science. Traditionally, however, most college level science courses are based on the positivist view of scientific knowledge and treat science as a set of universal truths that can be transmitted from one person to another. Students in a positivist-based classroom play a passive role, putting most of their energy into memorizing and later regurgitating "facts" on a test. Since many students' views of science tend to match the way the material is presented, this may lead to misconceptions about the nature of science.

In contrast, the constructivist view of scientific knowledge is based on the argument that knowledge is created by humans based on previous experiences. As a result, students actively construct their own interpretations of events in order to learn. In a constructivist classroom, students are involved in the learning process, forming a partnership with the instructor. The role of students is to examine their existing knowledge, evaluate their ongoing experiences, and adjust their understanding accordingly. The teacher's role is to guide students' viewpoints and how they are making meaning, propose alternative frameworks, cause disequilibrium of students' preconceived ideas, and develop classroom strategies that promote knowledge construction and higher order thinking skills. Students taught in a constructivist classroom are more likely to have a deeper understanding of the material and to have a better understanding of the nature of science.

An effective instructional framework in a constructivist classroom must emphasize active participation of the students, opportunities to allow the students to construct their own meanings, and should model the nature of science. The three-phase Learning Cycle, developed for use in the Science Curriculum Improvement Study, is one such framework. The constructivist approach and Learning Cycle were used in the revision of 2 introductory geology courses at the University of Tulsa. Throughout the 3 year project, there has been a significant increase in student understanding of basic concepts of geology and in their ability to solve geologic problems, which can be correlated to increased confidence of the instructors in the use of the Learning Cycle. In addition, there was a significant increase in their understanding of many aspects of the nature of science.

Change in Geoscience Undergraduate Education: The View From a Liberal Arts College

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Review of undergraduate geoscience education is underway across all of higher education, driven by changes in the character of the student clientele, in the professoriate, in the focus of research, in the job market, in the resource base, in teaching methods, and by the formulation of K-12 educational standards. Although the tendency for a system to preserve itself should never be underestimated, instruction in geoscience is certain to change in the face of such pressures and is likely to become more interactive, lab-rich, collaborative and research-oriented calls for a faculty that is adaptable and flexible faculty. Anecdotal evidence from several liberal arts colleges suggests that these pedagogies, while not appropriate in every situation, are becoming major elements in geoscience curricula in liberal arts colleges and PUI's in many parts of the country. Resources to develop and implement curriculum revision are, as usual, in short supply but they do exist in greater degree than many faculty think.
What is the Role of the Community College in Geoscience Education?

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An NSF-based study, Matching Actions and Challenges, recommended that "professional associations need to recognize the role of the two-year faculty in the area of science, engineering, and mathematics, and seek to enhance their participation as active and valued members." The increasing numbers of students attending community colleges demand that greater attention be given to better preparing these students which requires increased efforts by government, industry, academia and supporting professional organizations.

Statistics bear out the need to address the needs of community college students. In 1991 43% of all postsecondary matriculating students in the United States were taking courses for college credit from two-year institutions. These more than 1400 public and private two-year institutions were serving more than five million students. California State University statistics show that in the 1990-1991 years 52% of the 50,352 degrees awarded were to transfer students from community colleges. More than 50% of geoscience majors in California are products of community colleges.

The large number of introductory geoscience course sections, low student/teacher ratios, commitment to lower division courses, and enhanced faculty-student interaction possible at two-year institutions are all advantages in creating an initial interest in the geosciences. Updating and enhancing of two-year faculty, and increasing the lower division load of transferable courses would increase the time students have to develop an interest in the geosciences. The transfer of sufficiently rigorous lower division two-year institution geoscience courses needs to be encouraged. The probability of this occurring increases with a better qualified faculty.

I hasten to add that I am not suggesting that students (and ourselves) should not be appreciative of the structure which has been imposed upon knowledge, for it is that very structure that illuminates and guides our search for understanding. At the same time, however, I submit that it is important to help our students, non-majors as well as majors, to better understand the underlying organizing principles upon which our knowledge is based. In particular, I believe that we need to provide students with significant opportunities to become actively engaged in constructing their own knowledge. Yes, we can see better because we stand on the shoulders of giants who have come before — I suggest, however, that our students, and ourselves, need to occasionally revisit the ground on which those giants have stood if their knowledge and their understanding is truly to become our own.

Turning Undergraduate Education on its Ear

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In most undergraduate science courses, material is presented in a bottom up sequence starting with small abstract details and building to larger concepts. In some courses, the implications and applications are barely discussed before the semester is over. This order, which in part is dictated by textbooks, makes sense to instructors because terms and basic theory are presented early in the course and act as the foundation for what follows. Students, however, do not think like instructors. They have a hard time understanding the significance of definitions and abstract theory when they are presented in vacuo. They become bored, unactivated, and start memorizing instead of comprehending.

If the goal of a course is to teach students to think like scientists, material should be presented in the same order in which scientists discovered it: from the top down. Large, concrete, easily understood, things should be considered first. Questions should be asked, which lead naturally to focussing on smaller details. When theory and abstractions are discussed, their implication should be obvious to all students. A big advantage to presenting from the top down is that important concepts are presented free from distractions. The key things can be emphasized, and students naturally ask questions as they try to figure out why things are as they are. They become actively engaged in the learning process.

A modern petrology course should start by looking at the surface of the earth and asking questions. Soon it will become clear that rocks fall naturally into groups. The similarity of certain rock types will lead to inferences about processes on the surface and within the earth. The presence of certain minerals in certain rocks will lead to discussion of chemical systems and phase diagrams. Classification schemes and nomenclature are not important. Students will learn how science works, and how to think like scientists.

Cooperative Learning, Writing, and Research Activities in the Geology Curriculum

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We wish our students to become independent learners who are able to think critically, communicate effectively, solve problems, work effectively with others, and be open to new ideas. Having the skills to learn throughout one’s life is fundamental to surviving in a rapidly evolving, technological society. The traditional lecture format does not encourage students to become independent learners.

Writing, cooperative group activities, and research projects are complementary methods to circumvent some of the shortcomings of the traditional lecture format. Cooperative learning provides strategies for designing effective group activities and helps students

Undergraduate Education in the Geosciences: Some Reflections on Teaching and Learning

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In most physical geology courses we ask our students to learn the names, properties, and uses of various rocks and minerals; we (or their lab books) also typically present students, as a fair accomplice, with the classification and organizational structure into which they are expected to fit those individual rock and mineral samples. Among other things, however, science is about classifying and organizing knowledge – yet, in the case of rocks and minerals, we usually ask our students to accept what is already in place without offering them the opportunity of developing for themselves an understanding of the principles on which classification schemes are necessarily based.

In teaching introductory geoscience classes over the past several years I have been consciously placing greater emphasis on how and why we organize and classify than on expecting my students to simply accept the schemes that are part of every physical geology text and lab manual. In physical geology labs, for example, I present students with the stuff of geology (e.g., rocks and minerals) without imposing a priori the various organizational schemata that have been developed over the years by geoscientists. I have found that by asking students to cooperatively create their own classification schemes that they develop their own insights into why and how rocks and minerals can be classified; in the process I find that they slowly but steadily also develop deeper understanding of how and why we classify and organize in the first place. In this way students move from being passive recipients of knowledge that has been defined and organized by others and become active participants in constructing knowledge.
become aware of the skills needed to work together. Class Research Modules (CRMs) are research projects integrated into upper-level geology courses so that students learn and apply course content by doing field work, literature search, sample preparation and analysis, and interpretation and presentation of results. Techniques from the Writing Across the Curriculum Program provide a useful framework in which to structure some activities. Group work on the CRMs is organized into specific tasks, each of which requires a written piece that receives peer review. The final product is composed of the written assignments from each task assembled into a report or poster. These techniques promote exchange of ideas and constructive criticism, make large tasks seem more manageable, and enhance understanding.

Using a Constructivist, Cooperative Learning Approach in an Historically Based Introductory Undergraduate Space Physics Course

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Science education in this country is in its greatest period of ferment since the post-Sputnik frenzy a generation ago. At the heart of this movement is the realization that the ability to observe, measure, think quantitatively, and reach logical conclusions based on available evidence is a set of skills that everyone needs, and that science is the best way to teach them. Undergraduate and graduate science education have in general lagged in implementing this philosophy. However, many of the ideas solidify in the mainstream of post-Sputnik space science education reform (such as a constructivist, interdisciplinary approach) are now being advocated for college science teaching. In this paper I describe the background and structure of an introductory undergraduate space physics course that was developed as part of the Honors Program at the University of Maryland. The course made heavy use of cooperative learning, and used an inquiry-based methodology. Moreover, the approach was historical, and a central goal for the course was to provide students with an understanding of how science develops, as well as an understanding of the near-Earth space environment. Possible applications of this kind of course in other areas of geophysics will also be discussed.

Tell Me A Story: Interdisciplinary Justification for Narrative Teaching, With Application to the Atmospheric Sciences

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Educational reform has created a false dichotomy between the "traditional lecture" and the "innovative technology" approaches to teaching. What is basic to both of these approaches, and indeed to any pedagogical method, is the efficient communication of information that students will remember. A central question for curricular reform is: Are the structures—not the tools—through which we communicate to students the best available, or are there other structural models of communication besides the fact-laden lecture or the problem-focused laboratory which can help students comprehend and retain scientific knowledge better?

A promising and venerable alternative to conventional college-level science pedagogy is "narrative teaching"—the casting of information in the form of stories. This approach is amply justified historically, since both factual and quite abstract information types have been transmitted for millennia through oral storytelling traditions. Furthermore, recent evidence from a wide variety of academic disciplines—among them journalism, educational psychology, feminist anthropology of science, and computer science—points to the efficacy of narrative approaches in conveying information in ways that "stick" with students, particularly those who do not respond well to more conventional teaching approaches. Finally, current interdisciplinary work by Rob Schank at the boundaries of artificial intelligence and cognitive psychology is providing a theoretical rationale for why narrative teaching is indeed the preferred mode of communication between humans.

I have employed narrative teaching techniques as a laboratory teaching assistant for a junior-level atmospheric dynamics class at the University of Wisconsin-Madison. This mathematics-intensive course presents an "acid test" for qualitative storytelling teaching methods. I will present examples of narrative teaching from this course as well as evidence from teaching evaluations which tend to support the notion that storytelling and geoscience education are compatible, even at the advanced undergraduate level. I will also present a model for expanding the range of available story types well beyond the hackneyed "chronological history" mode.

Promoting Active Learning in Large Introductory Courses

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Large entry-level geoscience courses are commonly taught primarily by lectures, which may not be the most effective method of teaching the students in these courses. The challenge is to design courses that will foster active learning rather than passive listening and encourage student interactions in a small-group learning community within the larger class, while recognizing time constraints and style of the instructor. A variety of writing assignments and cooperative learning structures can be used to meet this challenge. At one end of the spectrum, the use of informal and ungraded assignments completed by students in a few minutes at different times during a lecture requires a relatively small investment of instructional time. For these informal assignments, students might write the answer to a question or problem, summarize the most important point of the lecture, give a perspective on a particular environmental issue, or ask a question they have about the material. This provides a break from lecturing and time for students to reflect on the science topic. Commonly students form pairs (and then quads) to discuss their answers, resulting in a relatively high proportion of the class discussing some aspect of geoscience at a given time. Whether selected students report out from the groups or all students turn in their written work, instructors receive feedback on what students are learning. At another end of the spectrum, writing assignments and group structures can replace lectures. The use of groups in which the same students regularly work together throughout the semester on a variety of assignments that are graded requires a greater investment of instructional time, both to construct the assignments and to evaluate the final products. Each student contributes something to the group project that is necessary for its success, all students are responsible for all the material, and each is held individually responsible. The use of informal and formal writing assignments and a variety of cooperative learning structures in my introductory geology courses has students actively participating as well as listening, and has personalized the large classes.

Faculty Metamorphosis: An Examination of the Changing Roles of Geoscience Faculty and Geoscience Departments

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Today's geoscience faculty have multiple roles and responsibilities. They are asked to develop and fund high quality geoscience research programs, teach undergraduate majors, non-majors, and graduate students, serve on departmental and university committees, act as advisors, publish their research, and communicate science to the general public, the media, and K-12 students. Trained by other scientists to be good researchers, many geoscience faculty have received only minimal training as teachers, administrators, advisors, and public speakers.

As undergraduate tuition climbs, students take longer to graduate, and quality jobs become more difficult to find, parents, legislators, and the public are putting pressure on universities to increase faculty workloads and commit additional resources to improving undergraduate education. This increased external pressure is occurring at the same time that many university budgets are decreasing and non-major class enrollments are increasing. With both external and internal forces squeezing both geoscience departments and faculty, change is inevitable.

Three important factors are necessary to bring about positive change. First, geoscience faculty must reexamine and redefine their departmental mission in the context of their University's mission, student needs, and
community concerns. Second, the university promotion and tenure system must change to encourage and reward high quality teaching and service activities on an equal basis with high quality research. Third, geoscience graduate students and new faculty must be given more opportunities to develop high quality teaching, administrative, public communication, and advising skills.

Undergraduate College Faculty Workshops in Oceanography and Ocean Engineering, 1987-1992.

A.L. Peirson, III and J.W. Farrington (WHOI, Woods Hole, MA 02543)

Workshops to introduce faculty of undergraduate colleges and institutions to oceanography and ocean engineering research, graduate education opportunities, and careers for ocean scientists and ocean engineers were convened for a week in each of three years: 1987, 1989, and 1992. The workshops were supported by the Office of Naval Research and took place at the University of Washington and Woods Hole Oceanographic Institution in 1987; at the University of Washington, Woods Hole Oceanographic Institution and Scripps Institution of Oceanography in 1989, and at Woods Hole Oceanographic Institution in 1992. Initially the workshops were convened to increase the numbers and quality of the applicants for graduate study at the Joint Oceanographic Institutions by outreach to faculty advisors of undergraduate students. In 1989, and more so in 1992, there was also an emphasis on involving faculty from schools with a high percentage of underrepresented groups among their students in an effort to recruit more minorities into ocean sciences and ocean engineering.

The format of the workshops, impact of the workshops, and post-workshop activities are presented and discussed. There were 107 participants in the workshops from 85 different colleges and universities located in 30 different states, the District of Columbia, the Virgin Islands, and from Mexico (Baja California). Participants were from several categories of institutions: 54% from liberal arts colleges, 26% from comprehensive universities, 18% from doctorate granting universities, and 3% from specialized institutions.

The explosive emergence of environmental issues at national and global levels in recent years requires a well-informed core of college-educated citizens who can understand, debate, and formulate wise environmental policies. The almost universal interest among young people in environmental matters, and the intrinsic scientific content of these matters, has the potential to bring students previously not interested in conventional science courses into direct and stimulating involvement with sciences — and with the interaction among science, technology and society.

VTEC is a two-year project to develop, demonstrate and evaluate:

- An interdisciplinary, problem-oriented, team-based environmental curriculum development strategy involving faculty from universities and community colleges, enhanced by direct involvement of students as well as consultants from industry, government, and supercomputing centers.

- Environmental curriculum case studies and instructional materials which effectively integrate the power of computer networking and visualization technology in enhancing understanding of scientific concepts and their interrelationship with other disciplines in the solution of complex environmental issues. These case studies are intended to ensure the highest quality education for students in a broad spectrum of undergraduate courses in environmental sciences/studies, or traditional science, social science, or humanities disciplines.

- Comprehensive, project-driven computer visualization and networking skills development for collaborators to enable excellence in curriculum development at participating universities and community colleges.

Enrichment of Introductory Geology Courses by Use of Electronic Networks and Computer-Assisted Learning

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Significant enrichment of the educational environment in introductory geoscience courses can be accomplished through the use of electronic networks and computer-aided learning software. Electronic communication among class members and between them and the instructor(s) provides a new avenue for questions-answers, group projects, supplemental instruction, collaborative learning, and informal discussion of course-related topics. This purportedly impersonal electronic medium can significantly increase personal contact and dialogue between students and instructors through near real-time interchanges and expansion of the "window of opportunity" for discussion far beyond the class time. Discussion forum software such as Pacer Forum allows incorporation of graphics and audio into messages and also operates on all major microcomputer platforms.

Electronic collaborations between college students and students in K-12 classes can provide another means for enriching learning at all educational levels. Cross-age collaborative learning efforts may be particularly well suited for students planning careers as teachers, but have been used effectively with students from many disciplines taking a general education geology course. College students gain disciplinary competence through formulating answers to send to the K-12 students.

Network access, which can be taught in a few two-hour lab sessions supported by user instruction handouts, allows students to make use of the rich informational and educational resources of the Internet and aids their development of electronic literacy. In assigned class-related projects or in equivalents of the Internet Hunt, students can be introduced to the Internet as a communication link for interactive discussion and networking, and as a tool for finding and acquiring learning resources, such as on-line documents (e.g., the Oxford English Dictionary), images (NASA, NOAA, USGS), library systems, navigation aids, and many others.

The preparation of CAL (Computer-Assisted Learning) modules for tutorial or in-class use is greatly facilitated by new developments in easy-to-use authoring software. It is now much easier to prepare very effective graphic animations which are far more effective in conveying understanding of dynamic earth processes than standard blackboard drawings or static figures from the literature. CAL can serve in a diversity of educational settings including supplemental instruction, review of material, viewing of dynamic processes, quiz practice, and online quizzes with automated scoring and score posting.

Friday, September 9, 1994

Afternoon Session IV: UNDERGRADUATE CURRICULUM MATERIALS

Visualization Technologies in Environmental Curricula (VTEC)

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Stand-alone Hypermedia Programs Designed for Geologic Education and Geologic Map/Image/Data Dissemination

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The hypermedia programming environment makes it possible to design programs for disseminating a variety of graphics-based information as stand-alone applications. These programs can be made available on diskettes, CD-ROM, or by Internet and are ideal for instructional use. Because of the non-linear access capabilities of hypermedia programs, and the standardized Macintosh user interface, a wide range of audiences can be reached in a single easily used application. For example, a SuperCard program containing four color thematic geologic maps of the Sprinerville volcanic field in east-central Arizona is being published by GSA on CD-ROM in the Fall of 1994. This SuperCard program in addition includes geologic text, correlation charts, over 1000 analyses including whole-rock and mineral chemistry, Sr, Nd and Pb isotopes, paleomagnetic data and 74 digital photographs. All can be accessed from menu selections or by clicking on buttons embedded in figures, text or on maps. Maps, images and data can be saved to disk files; analytical data in these files can be imported to spreadsheet programs directly. Petrologists might want only to examine the maps and chemical data, while geomorphologists, lay users, and beginning geology students might be more interested in examining the digital photos - each can pick and choose, allowing single program to reach a large audience, none of whom need to invest in software to access it. Additional similar SuperCard programs are being constructed, one for NOAA, of the Florida Keys National Marine Sanctuary, and another which is a Mars Geologic Atlas and Reference Guide. Once the basic data are inserted into a program designed with SuperCard, additional manuscripts, aimed at levels from elementary school to the research scientist can be easily added. Each document can be linked to call windows to screen containing maps, figures, etc., by "hot" buttons in the text, as appropriate to its level. All data included can be formatted using standard Macintosh software, such as word-processing, computer aided drafting and image processing programs, and imported into the program using SuperCard. With increasing data, accompanied by diminishing money for research, and the pressing need to bring the public into the various fields of science, hypermedia programs offer one solution to these problems.

One of the authors has developed several very simple prototypes of such systems in Russia. They proved to be an effective teaching tool.

The software also can be used for optimization of field explorations, inverse problem solving, evaluations of different models' performance under different typical geological conditions and available data.

Simple systems modeling: a step toward critical thinking

Alexandra Moore, (Department of Geology, Hartwick College, Oneonta, NY 13820, moorees@newton.hartwick.edu)

Critical thinking is a central theme of undergraduate education at all levels, across all disciplines. Thus the ability to provide students with a flexible set of tools to achieve this end serves all students, both majors in the geosciences and non-majors. In an introductory "Earth systems" course students use the combination of a simple physical model with computer models constructed with Stella II software in order to understand steady state and non-steady state systems behavior. By building a physical model and a computer model of the same system, the students further their understanding of the system in question, gain confidence in computer modeling, and learn how theoretical models can be extended to study more complicated systems.

In lab students construct a physical representation of a one-box model, consisting of reservoir, input and output. A Coleman cooler half-filled with water represents the reservoir. Opening the drain tap on the cooler provides an output, and running water from a hose provides the input. Students calibrate the input and output so that the two flow rates are equal. They observe the steady state system with constant volume, constant input and output, and calculate the residence time for this system. The system is then perturbed by doubling the rate of input. The students monitor the rate of output and the volume of the reservoir over a period of 30 minutes. Students observe that the rate of output is dependent on the size of the reservoir, that the output increases to become equal to the new input, and that their system achieves a new steady state with a new residence time. Students then construct a Stella II model of a "cooler system," identical to their physical system. Their computer model produces graphical output identical to their lab observations.

This particular model is quite useful as it describes many phenomena of geological interest. Students gain an understanding of an important physical process applicable to a wide variety of behaviors in natural systems. The second advantage of this experiment is that students are able to create more sophisticated models by beginning with a firm tie between their theoretical work and a physical system that they understand, students are better able to make the transition to the more abstract problems and concepts that are so important in all areas of inquiry.

TEACHING DECISION MAKING UNDER CONDITIONS ON GEOLOGIC DATA FAUCITY

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Effective development of geological resources, irrigation, pollution clean up strategies, and stability of buildings, dams, and slopes, and many others depend on taking geological structures into account correctly in mining, projecting, and implementing corresponding development projects. Miss information on complex geological structures, however, can cause great loss to students, as well as professionals, should be avoided. A decision making system under conditions on data processing should be created to help geological sites cannot be used for this as there are insufficiency of information for them. Artificial geological sites are used for this purpose. All information is available upon request, stored and used to this end. A software system is designed for geological sites used for artificial geological sites. The system will simulate different geological sites processing (drilling, sampling, testing, etc.), producing the corresponding documentation. Using the system a student can mimic all geologist's activities for solving a problem and make corresponding conclusions, estimations, and recommendations. Then the system produces the geological settings "actual" responses for the planned impact. Comparison of the "actual" response and the response modeled by the student (using the data obtained and common geological models) allows on evaluations of the effectiveness (technical, geological, environmental, economical, etc.) of the project and its implementation, and analysis of any errors made.

Access and Utilization of Scientific Data Sets i, Undergraduate, Geologic Instruction

Robert W. Risky (Dept. of Geology, University of Maryland, College Park, MD 20742)

National studies assessing the effectiveness of undergraduate science instruction indicate that data, much of what has taken place in the science lecture or laboratory, is predetermined, rather routine experiences that all too often, either in content or approach, have little scientific merit. CD-ROM technology, paired with today's powerful desktop computers and further supported by on-line Internet access, is providing professors and students with a wide range of comprehensive, up-to-date, scientific information. Access to the same data sets that scientists work with on a daily basis provides unprecedented opportunities for studying critical, earth science based, global issues in a way that is more consistent with the spirit and character of scientific inquiry and values.

At the same time, a technologically driven instructional approach presents a significant educational challenge. Wide availability of CD-ROMs archiving all types of scientific data and Internet access to a plethora of current information requires a major effort in identifying and acquiring data sets that have been particular educational merit. Criteria for data set
selection should be consistent with nationally defined and professionally based fundamental understandings for our discipline. Additionally, they should be chosen with the intent of supporting national and professional recommendations calling for more effective discipline integration (Solid-Earth Sciences and Society, Board of Earth Sciences and Resources, NRC '93).

Global system science provides a comprehensive conceptual focus and unprecedented opportunities for undergraduate students to understand the practice of science. Most importantly, data sets must be supported by exemplary, instructional materials that have been developed, tested and refined.

The Joint Education Initiative, a major NSF supported program, is one program that is bringing together the research and educational communities for the purposes of accessing and utilizing comprehensive scientific data for earth science instruction.

A SYSTEM DYNAMICS APPROACH in TEACHING GEOLOGY

ROGER S. STANLEY (Department of Geology, University of Vermont, Burlington, Vermont, 05405) (Sponsor: University of Vermont)

System dynamics involves analysis of interrelated elements that interact in such a way as to operate as a unified whole without external influences, although these influences can be taken into account. The boundaries of a system are arbitrarily defined so that the behavior of the system can be analyzed using such software as STELLA, a modeling system based on finite difference mathematics. Causal phenomena are related either directly or indirectly in a series of “feedback loops” which defines the structure of the system. System dynamics analyzes the behavior of these phenomena over time ranging from seconds to millions of years. The analysis of a system begins with the definition of a potential system, works through a qualitative assessment of the structure of the system, and involves repetitive quantitative testing with generalized or “real-world” data. Such computer-based analysis challenges students to find the cause and effect and relationship of behavior and to quantify these relationships using numbers, graphs, equations, and sensitivity comparisons. Analysis of the results commonly leads to a clearer understanding of the process and highlights the similarity among systems in other disciplines other than the geological sciences.

Simulation models of isostatic decay, erosion and isostatic adjustment of topography, mountain evolution, sedimentation, glaciation, river systems, chemical reactions and population scenarios have been used in undergraduate and graduate courses at the University of Vermont for the last 5 years. Systems courses covering the physical and life sciences have involved high school teachers supported by Eisenhower funds during the last two summers. This summer work is an effort to introduce systems thinking at the pre college level. A systems approach to the geological sciences provides a broad, unified overview that has the detail and quantification needed to stimulate creative and critical thinking in undergraduate education. A goal in the future will be to link systems models to graphics so that, for example, the evolution of mountain systems can be modeled for a variety of parameters.

Atmospheric Science Education Using Multimedia, Mosaic, Current and Historical Weather Data, and the Internet

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A revolution is underway in the area of information technology enabling computer-aided learning using interactive multimedia environments over broad band network services like the Internet that have access to current and historical weather data. In addition, the Internet makes possible collaboration and sharing of materials amongst instructors in teaching.

Over the past several years the Department of Atmospheric Sciences at the University of Illinois has developed a World Wide Web based information server called The Daily Planet™. It is a full-scale environmental information server for both research and education, offering the power and flexibility of HTML and the NCSA Mosaic interface. Weather World, a World Wide Web version of UI's popular Weather Machine built using Gopher, is accessible from The Daily Planet™ menus. Current features of The Daily Planet™ include Weather World's up-to-date weather information (170 current images, 600 archived images, and 60 MPEG animations, many of which are updated hourly), lists of other weather servers and sources of weather data, information about the atmospheric sciences community and about the UIUC Department of Atmospheric Sciences, and online hypermedia instructional modules for an introductory undergraduate course atmospheric sciences. The latter are now Internet based Mosaic modules that include text, voice, graphics, and animations. Updates can be easily made including linkages to current weather data. Current modules include an introduction to weather maps, a cloud catalogue, the Coriolis force, and the pressure force. The modules and weather data are being used regularly in our undergraduate teaching and their use has notably increased student interest in atmospheric phenomena. The Daily Planet’s URL is http://www.atmos.uiuc.edu/.

Mathematica in Undergraduate Education

Mark D. Licker (Wolfram Research, Inc., 100 Trade Center Drive, Champaign, IL 61820; 217-398-0700; mlicker@wrl.com)

Mathematica is a comprehensive software system and high level programming language for technical computation introduced in 1988. The built-in functions enable the user to perform numerical, symbolic, and graphical calculations in an integrated environment; the language permits the programming of applications to fit the user’s specific needs. Electronic documents in the form of Mathematica “Notebooks” containing text, active graphics, animations, and sound can be transmitted on-line or on disk, thus serving as a medium for interactive communication in education and research. In academic research and commercial R&D, 75% of the engineers are using computer science, physical sciences, and mathematics. There is also substantial application in business and finance, biomedical sciences, and social sciences. In education, Mathematica is widely used by instructors as a supplement to texts and traditional teaching methods, and in some cases as the primary instructional medium. The initial thrust was in the calculus curriculum. Courseware is now available in other areas of mathematics and computer science, engineering specialties, physical sciences, etc. Such technology can now be used on commonly available computers, with "electronic text" materials adaptable to local needs. Students can work with prepared materials, as with a traditional textbook, but with the added advantage of gaining insight into scientific principles through visualization. They can rework examples and problems with their own data and communicate the results to teachers and fellow students with electronic documents. The computer allows the student to focus on devising solutions to realistic problems and modeling the results. The student can play a more active and responsible role in the learning process. This talk will survey the use of Mathematica in education presenting examples relating to the geosciences education. Technological innovations in the latest release will be discussed from the standpoint of geoscience instruction and publishing.

Beyond Mosaic: Interactive Graphics on the Internet

Perry J. Samson (Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI 48109-2143; 313-763-6213; samson@umich.edu), Alan Sennberg, Derek Price, Chris Schwerzer, and Michael Kamprath (Electrical Engineering and Computer Sciences, University of Michigan, Ann Arbor, MI 48109-2121)

A new protocol for imagery on the Internet, dubbed the interactive image format (.iif), has been released. The .iif imagery allows for truly interactive investigation of geosciences information using Gopher. The nature of this format is that the image may contain "warm spots", for which embedded information (e.g. geographical reference, current weather) is displayed in a capture as the mouse is moved over it, and "hot spots", wherein clicking produces a request for additional resources (e.g. imagery, animations, text, sounds, etc.) available over the Internet. Warm and hot spots may be dots, polygons, or discrete colors on the image. The interactive nature allows learning by discovery as the student can tunnel from an image of current conditions to explanations of the phenomena represented on the image. The .iif images are relatively small, so they provide a faster interface to the Internet than does .gif. Undergraduate classroom uses for our Gopher client, BLUE-SKEESM, which makes use of this new image format, is presented and instructions for how to construct interactive images will be made available.
Saturday, September 10, 1994

Morning
Session V: COLLABORATIONS AND OTHER MECHANISMS

Infrastructure as a Mechanism for Driving Change

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As faculty conceive and develop new programs and curricula, it is common for them simply to assume that the necessary infrastructure will be available. All too often, this approach results in last-minute crises when the existing infrastructure is not adequate to support the new programs and funds are not available to upgrade or replace the existing systems. More importantly, this approach does not recognize and take advantage of the key role that infrastructure can play in motivating and helping faculty and students move in new directions.

In 1989 the earth-science/engineering departments at CSM were challenged to develop programs that would encourage faculty to take a much more interdisciplinary approach to both education and research. The departments of Geophysics and Geology/Geological Engineering worked closely with CSM's Academic Computing Center to develop a strategy based on the concept that infrastructure, used effectively, can be the single most-effective factor in driving change. A remodeled facility used environmental factors such as lighting and noise control to encourage a sense of community. A robust workstation network enhanced communication. A new administrative infrastructure circumvented the barriers in the established departmental structure and rewarded desirable activity.

Two important results of this experiment are that an increasing number of faculty are choosing to participate enthusiastically in interdisciplinary research and education, and they have been able to move more quickly in implementing new concepts because the necessary infrastructure is already in place.

Project ALERT (Augmented Learning Environment and Renewable Teaching): A Collaborative California State University (CSU), Historically Black Colleges and Universities (HBCU), and Jet Propulsion Laboratory (JPL) Program for Earth and Space Science Instruction Using Hypermedia and Internet Science

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Since the spring of 1994, Earth and Space science educators and hypermedia specialists at three CSU campuses at Long Beach (CSULB), Los Angeles (CSULA), and San Diego (SDSU), two HBCUs - Clark Atlanta University and Central State University, and JPL, have been working together to use hypermedia technology in the physical science classroom. The goal of our project is to improve existing introductory courses on Earth and space, to introduce new interdisciplinary courses on global environment and planetary science, and to explore new ways to present science to large lecture and laboratory sections of pre-K-12 teachers and general education students. The CSU-HBCU-JPL partnership brings cutting-edge technologies and information distribution systems to bear on science education in a demographically diverse population. The CSU-HBCU group has practical experience in the classroom – the JPL group has the expertise in Internet science and in organization and rapid dissemination of large volumes of Earth and space data. We have named our project ALERT to express the two main strengths of our approach. First, the learning environment is augmented as geoscience educators and students at the CSU campuses and HBCU's can incorporate the vast information archives and expertise of scientists at JPL, through network linkage in the classroom. Second, lesson plans can be easily constructed through network linkage to specially designed file systems (WWW-Mosaic) and display tools for Earth and space science images and text files. Geoscience educators will literally be able to "mix and match" pieces of information using hypermedia technology to design new lectures and demonstrations rapidly and with an element of creativity not generally found in standard audio-visual packages.

Summer Field Courses: An Opportunity for Inter-University Cooperation

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The cost of operating summer field courses in applied geophysics is extremely high. At CSM, for example, the field course uses more than $1 million worth of equipment, including two seismic systems, gravity meters and magnetometers, resistivity, electromagnetics, and logging systems, surveying equipment, a drill rig and half-a-dozen computer workstations. The equipment requires a fleet of 14 trucks and a computing trailer, and the field operations consume several thousand dollars worth of fuel, recording tape, etc. Safety considerations alone mandate a staff of six or more instructors, whose salary, travel and subsistence costs must be covered. Maintaining and upgrading the field equipment adds an additional cost of approximately $50,000 per year.

Clearly such an expensive field operation cannot be justified unless it serves a significant number of students. As a result of declining enrollments in Geophysics, many field courses have been eliminated or reduced in scope. However, the impact of the largest cost -- maintenance and upgrading of equipment -- can be ameliorated by sharing equipment between field courses operated by different universities. This year, as an experiment, CSM and SAGE (Summer of Applied Geophysical Experience operated by the University of California at San Diego at Los Alamos National Laboratory) are sharing seismic equipment, including two Vibroseis™ trucks, a 48-channel DFS-V recording system, cables and geophones and a Micro-Max™ data-processing system. If the experiment is successful, it should pave the way for more cooperation in the future, both between universities and between disciplines.
ENRICHING THE GEOSCIENCE CURRICULUM THROUGH COLLABORATIVE TEACHING: ENGINEERING GEOLOGY AT THE UNIVERSITY OF THE PACIFIC

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A course in engineering geology has been developed at the University of the Pacific, as part of a developing curricula in geology and geotechnical engineering. The goal of the course is to expose student majors in both geology and civil engineering to the basic geotechnical problems in each profession. This is an upper division class with a course in physical geology as a prerequisite. The course is developed and taught jointly by members of the Department of Geology and the Department of Civil Engineering. This collaborative approach brings very different perspectives and approaches to the course.

The course is divided into segments covering various aspects of engineering geology. Each segment consists of: 1) lectures given from a geological perspective, outlining the scientific background and setting the stage for the associated problems; 2) lectures on the design and analysis of engineering operations to remedy or mitigate the problems; 3) case-study presentations of geotechnical problems prepared and given by the students; and 4) laboratory exercises designed to provide the students hands-on experience with the subjects (including: map interpretation; basic materials testing; computer-based data analysis and simulation; and geophysical investigations).

In addition, field trips which allow students to see both geotechnical problems and mitigation measures, and presentations by practicing professionals round out the curriculum.

The unique aspect of this course is that it is a team effort by faculty from divergent, but related, disciplines. This provides students with expertise in both the fields of geology and civil engineering, and gives them exposure to differing viewpoints of geotechnical problems.

The Cooperative Developmental Energy Program: an Innovative Partnership to Increase Minority Participation in the Geosciences

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Isaac J. Crumby (Director, CDEP, Fort Valley State College, Fort Valley, GA 31030)

The Cooperative Developmental Energy Program (CDEP) is designed to encourage under-represented population to pursue careers in the energy industry. CDEP began at Fort Valley State College (FVSC) in 1983, with funding from the US DOE, as an internships program. In 1988 J. Crumby met with J. Buffeteler and A.J. Frisinger of Cities Services Oil Company who arranged a meeting with officials of the School of Geology and Geophysics in the College of Geosciences at Oklahoma University (OU). The dual-degree program in Geology or Geophysics and the formation of the Geosciences Consortium to support the program, resulted from that meeting.

Students enrolled in the dual-degree program attend FVSC for 3 years and then transfer to OU for 2 years. The successful students will earn a degree in Mathematics or Chemistry from FVSC and a degree in Geology or Geophysics from OU. The program combines the strengths of the two institutions to prepare students in the geosciences. FVSC, a historically black college, is a small, intimate environment where the emphasis is on teaching and nurturing of students. OU provides a technically sophisticated research environment and a strong alumni network. At FVSC students complete introductory geology, general education, and cognitive science courses. At OU students take two or three geology courses per semester and complete a six-credit hour summer field course. The geophysics program at OU is similar.

The Minority Student Summer Energy Internship Program (MSSSEP) continues to be an important component of CDEP. Since 1991, approximately 30 students have participated in 40 internships with major oil companies, the USGS, and U.S. DOE national laboratories.

In summary, CDEP and the dual-degree program in the geosciences is designed to create an opportunity for academically-talented minority students to pursue a career in the geosciences and then maximize their success in reaching that goal.

How the Coalition for Earth Science Education Supports Undergraduate Geoscience Education

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The Coalition for Earth Science Education (CESE) represents a broad spectrum of earth, space, and environmental science organizations who are involved in science education reform. The purpose of CESE is to promote communication among the member organizations, to coordinate projects in Earth/Space science education, and to act as an advocate for earth science education at all levels.

As geoscience departments examine and revise their undergraduate programs to meet the demands of a changing world, they will want to know about, and have access to effective curricula, materials, assessment strategies, and faculty development practices. Many of these items currently exist or are being developed. Collectively, and through its member organizations, CESE can aid geoscience departments and faculty to access and effectively use these educational resources and information. CESE can also assist geoscience departments in establishing partnerships with the K-12 education community and stronger linkages with nation, state, and local science education reform efforts.

A NASA funded University-based Effort to Develop Earth System Science Curricula and Infrastructure Within Universities

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Motivated by expanding population and third world development, meeting future demands for Earth resources is becoming a high priority on the world's agenda. Students in today's college classroom listen attentively when enlightened to political and social consequences that are likely to result from accelerating demands on finite resources. A more holistic approach to the study of the Earth, as embodied in Earth system science and global change concepts, can provide a compelling, socially relevant focus to Geoscience instruction. However, the means to integrate specialized scientific interests into a unified and cogent perspective of the Earth System requires an infrastructure which brings together scientific talent and interests of various disciplines in the classroom.

Under the auspices of NASA and the Universities Space Research Association, 22 universities have been engaged since 1991 in a cooperative effort (ESSE ) to develop programs and curricula in Earth System and global change science at the undergraduate level. Each university in this program has developed and offered courses at the survey level and senior levels to provide a scientifically based appreciation of topical issues in global change, and to engage advanced students and faculty from different disciplines in addressing earth science and global change issues. The faculty and TA's in the the program come together

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twice annually in meetings and workshops to constitute a forum for addressing common problems in developing effective interdisciplinary curricula and programs both within the individual classroom and within the university.

The experience from three years of the ESSE program attests to the still critical need for effective collaboration among universities in the creation of educational resources which bridge disciplinary interests. Key resources to provide for this integration are emerging through advances in broad band communication, computer networking and electronic libraries with archives for large Earth Science and other data bases.

Student Collaborations and Faculty Connections: Geophysics Research and Education at a Liberal Arts College
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The increasing relevance of the quantitative geosciences in addressing environmental problems and the wide-ranging benefits of research opportunities for undergraduates are both well-documented. Engaging undergraduates in geophysical studies has often been limited, however, to research institutions and REU sites. Two key ingredients have enabled a single faculty member at a liberal arts college to sustain ongoing research projects, both inside and outside the classroom. Topics range from large-scale teosonic research involving general cruises (e.g., the development of oceanic fracture zones) to local environmental studies involving field work (e.g., estimating salt-water intrusion from conductivity measurements). I find it essential to both encourage students to work in groups and to collaborate with colleagues at other institutions. A group of three to five students, those with more experience can mentor those with less, which benefits both sets of students and greatly increases everyone’s productivity. A cooperative environment supports students with disparate backgrounds, and replicates to some degree a scientific work environment, helping students make choices about career paths. On research projects outside the classroom, students need to begin their involvement early so they have time to learn computer skills, absorb background material, and do field work. Combining their research skills with their classroom math experience, they can be remarkably productive, creative, and confident by their junior or senior years. Connections to researchers at institutions and consulting firms have proven invaluable in identifying tractable problems and supporting research. Contact with other geophysicists and geologists in industry work environments also increases students’ exposure to career opportunities and the process of doing science.

Supporting a productive and enthusiastic research program in a small college is difficult due to the limited time available to both write proposals and supervise research and publications. Only grants from programs requiring short proposals and a flexible Young Investigator Award have made it possible to support three-five undergraduates on an ongoing basis. Research in small undergraduate departments, both inside and outside the classroom, is facilitated by flexible multi-year grants and programs that encourage collaboration with colleagues in research institutions and industry.

The University of Hawaii Marine Option Program

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Geological Education must get broader and deeper to survive
William I Rose, Suzanne Beske-Diehl, Alex Mayer (Geological Engineering, Michigan Technological University, Houghton MI 49931; 906 487-2331; raman@mtu.edu)

We believe that our program’s success comes from its breadth and diversity, its commitment to quantitative methods and its overall engineering flavor. If we don’t produce geological engineers, other engineers will take many of the new jobs, not graduates in geology. We have awarded mostly geological engineering degrees since the 1940s. Our approach to redefinition of geoscience has been to broaden our curricular scope by embracing the hydrosphere and the atmosphere and to add depth by emphasizing engineering skills and geophysics. Our program merges degree programs in geology, geological engineering and geophysics under one roof, all in an engineering college. An interdisciplinary team of 13 faculty teaches degree programs suited for designing practical solutions to problems posed by human interactions with earth systems. Broad exposure to earth systems and earth materials is vital for geological engineers, distinguishing them from environmental engineers and adding realism to their models. Engineering skills provide quantitative skills for accurate models for earth systems and make key areas such as fluid dynamics accessible. Geophysics, emphasizing subsurface visualization, the atmosphere and remote sensing, adds scope to our program. Thrust research areas are groundwater systems, Natural Hazard Mitigation, Resource Engineering, Geophysical Engineering, and Remote Sensing. Students are given a choice in programs: geological engineering, applied geophysics, geoenvironmental engineering, environmental geology and geology. Most classes have either changed radically, or are new. Advanced workstations which can handle large data sets, industry software and images are used throughout the curriculum. Enrollment in classes by non-majors is high and there are many crossover students, especially in graduate programs. Senior classes are interdisciplinary team projects. We are frustrated with teaching materials, which seem to avoid problem solving approaches. We have forged linkages with other departments: Materials, Electrical, Environmental and Civil Engineering, Biological Sciences, Forestry and Physics, resulting in joint research and integrated curricula.

Withdrawn

Scrutiny of Undergraduate Geoscience
A Divisional System for Teaching Undergraduate Geological Engineering at the University of Toronto: Flexibility at Low Cost

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G.R. Brown (Department of Geology, Faculty of Arts and Sciences, University of Toronto, Toronto, Ontario MSS 3B1, Canada)

The University of Toronto is in the downtown of the largest urban area in Canada, where there is a wealth of industrial expertise and the second largest number of head offices of mining companies in the world. Geological engineering is offered as an accredited interfaculty program with concentrations in mineral exploration, mineral processing, geotechnical engineering and environmental engineering. For financial reasons, the organizational structure adopted is that of a "division" whereby teaching of fundamental pure science, engineering science, design and humanities is delivered through existing courses in mainline departments in the faculties of Applied Science and Engineering and Arts and Sciences. A key ingredient is a dynamic first year course that will retain or attract students who may be uncertain of their career choice. Specialized senior courses such as exploration management and mining are taught by local outside experts hired as Adjunct Professors. Our program has the advantages of being very low cost and remarkably flexible, enabling us because of our Adjuncts to add or remove courses at will without regard for the capabilities of a teased faculty. As an example, Adjuncts present the only course in petroleum exploration and recovery in Ontario and, to our knowledge, the only course in ecological engineering (as related to the minerals industry) in Canada.

Such a program is possible only where there is this outside expertise.

Undergraduate Research Experiences and the Research Methods Course

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Research universities are uniquely positioned to offer undergraduate students an opportunity to be involved in research programs; however, it is a great challenge to generate interactive and supportive relationships between faculty and these students. Once such relationships are established, the possibilities for improving the undergraduate experience are greatly expanded. We have developed a program for undergraduate research that is anchored to a course in scientific inquiry and research methods. The program places undergraduate students in research labs and provides one-on-one interactions between faculty and students. A workshop-style course, Research Methods and Computer Applications, focuses on development of organizational, computational, and communication skills vital for an earth scientist to be successful. Our goal is to define a path for undergraduate research that encourages and guides every student toward at least one research experience.

Students that participate in the program enroll in the research methods workshop and choose a research project from a list of projects and faculty sponsors. Faculty sponsors direct the scientific aspects of the research and provide financial support. Research projects are linked to faculty research to increase the scientific level of the projects and their likelihood of success. The weekly workshop course provides a framework of instruction and guidance for the student to carry out their project and allows the students to regularly share their experiences with their peers. The program provides independent research experiences without the isolation of working alone.

In the workshop, a student develops a formal research proposal and work plan based on information provided by the faculty sponsor. Through regular, oral reports students periodically update and educate one another on their progress while developing public-speaking and graphical-presentation skills. Students also present their work at an annual research symposium held during the Spring semester at the university and presentations at local and national meetings are strongly encouraged. Technical writing skills are taught in the workshop by writing proposals, abstracts for the research symposium, and project summaries.

Saturday, September 10, 1994

Afternoon Session VI: ISSUES IN K-12 EDUCATION

A Snapshot of K-12 Earth Science Education.

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As part of an information gathering program the American Geophysical Union (AGU) recently surveyed the membership of National Science Supervisors Association (NSSA) and the National Earth Science Teachers Association (NESTA). Data collected from the surveys included information on the status of Earth science education. These data will be used by AGU in future programs.

The NSSA survey dealt with the current status of Earth science education in the supervisor's district, the acceptance of Earth science for college entrance credit, and their district's involvement in national reform efforts. Of the 138 surveys sent to individuals randomly selected from the NSSA mailing list, 53 (38.4 percent) were returned. The returned questionnaires represented 39 states and two Department of Defense Schools. The NESTA survey questioned teachers about their school, their preparation, text books and assignments, and outside resources used in their classrooms. Of the 200 surveys sent to individuals randomly selected from the NESTA mailing list 136 (68 percent) were returned. The returned questionnaires represented 38 states.

The information collected from these surveys provide a "snapshot" Earth science education in K-12 schools. With a wide variety of reform efforts, multiple suggestions for pedagogical style, and numerous resources for classrooms K-12 education is in a state of continual transition.

How Should Preservice Elementary Teachers Learn Science?

Edward Buchwald (Geology Department, Carleton College, Northfield, MN 55057; 507-663-4603; EBUCHWA@CARLETON.EDU)

(Sponsor: Dorothy L. Stout)

In The Liberal Art of Science, the American Association for the Advancement of Science (1990), p. 21) notes that "certain ideas transcend disciplinary boundaries and are essential to understanding intellectual relationships among all the disciplines of science." The Major AAAS integrative concepts are: causality and consequence, scale and proportion, dynamic equilibrium, and change and evolution. Elementary school teachers need to learn science in this context. Specific content and strategy of courses
will be dictated by local needs and resources, but all students should be able to explain their own world in these views. In addition to developing ways of thinking and knowing, elementary school teachers need to develop habits of mind such as desiring to know, being skeptical, relying on data, accepting ambiguity, being willing to make number of approximations, cooperating in answering questions and solving problems, respecting reason, and being honest (Bybee and others, 1989, p. 51).

University students should be doing things which parallel the activities of scientists; they should do science. They must learn to ask questions of nature, develop and implement research protocols, evaluate the results, and report to their peers. Two examples of how geoscientists can select appropriate science-learning activities are exercises in accelerated erosion and the behavior of dinosaurs. They can serve to illustrate several major integrative concepts.

An Interdisciplinary Introductory Science Course for Preservice Elementary Teachers

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The practice of science is by its very nature interdisciplinary. Most high school curricula, however, present the "alma mater" with one year each of earth science, biology, chemistry, and physics. Students are too often left with a fragmented view of the sciences as separate and distinct bodies of knowledge with no continuity of scientific thought and the universal interdependence of ideas such as the conservation of energy, rates of change, and the nature of matter are not seen. Such is the preparation of students entering college. Teachers of young children are potentially one of the most powerful allies in increasing our country's scientific literacy, yet most remain at best uneasy about science. At Wheelock College, we are designing a course for elementary education majors to be taught collaboratively by a biologist and a planetary astrophysicist. In the course we will address the special needs of many in this population, including science anxiety and poor preparation in science and mathematics. A broad conceptual understanding of a few key concepts will take precedence over rote memorization of facts.

Modeling Appropriate Pedagogy in a Geoscience Course: Project PRISM at the University of Wisconsin, Eau Claire

K G Havholm and R Hooper (Both at: Geology Dep't., University of Wisconsin at Eau Claire, Eau Claire, WI 54702-4004; 715-838-2945; e-mail: havholkg@uwec.edu)

R E Hollon (Dept. of Curriculum and Instruction, University of Wisconsin at Eau Claire, Eau Claire, WI 54702-4004)

Post-secondary science courses, particularly at the introductory level, have traditionally been taught through a combination of lecture and "cook-book" laboratory format. This style of pedagogy implies that science consists of a set of facts to be acquired from an authority. It does not mirror the reality of how science is done, and it falsely implies that scientific "knowledge" is static and in final form. Under project PRISM (Project to Improve Science Models, a 3-year NSF-funded project designed to change the way elementary and middle school teachers are prepared to teach science), a new general education course in earth science is being developed. The new approach varies the style of instruction, de-emphasizing the lecture format and requiring students to select and interpret evidence and construct appropriate models and explanations of earth phenomena, both in the field and in the classroom. In addition to basic earth science concepts, students learn how an earth scientist inquires into the nature of the earth, how major concepts are developed and modified over time, and the role conceptual models play in scientific thinking. Development of this course is proceeding in conjunction with development of similar courses in life science, physical science and science teaching methods. Additional input on course content and pedagogy is being solicited from in-service teachers and from an experienced earth science educator. Although this course is specifically designed to meet the needs of elementary and middle school teachers, the content and style of pedagogy are appropriate for any college-level introductory earth science course.

The Teaching of Geosciences for Future Middle-School Teachers

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There is now an educational need for Geoscience Departments to take a more active role in the academic preparation of middle school teachers. Local environmental issues can be observed easily, both quantitatively and graphically, and may be readily expanded to a global scope. This exploration can be an excellent foundation for fostering academic growth in science and mathematics and for building upon the natural interests that children, their parents, and their teachers have in these issues. The interdisciplinary nature of Geoscience fits well into the middle school curriculum. The technology-oriented nature of earth system science data and their analyses offers an opportunity for future teachers to familiarize themselves with scientific applications of computers and the Internet. Geoscience departments should take the initiative in seeking ways to encourage direct middle school classroom interactions between future teachers and experienced classroom teachers, enable the undergraduates to assist teachers in bringing technology into the classroom and providing on-site classroom experiences for the undergraduates.

Because a large fraction of teachers do not select their careers until after graduation, programs should be developed to introduce Geosciences to those who whitewashed the subject while undergraduates. Geoscience Departments should explore the possibility of being more active participants in the conferring of middle school credentials, perhaps by introducing an interdisciplinary Geoscience/Math course as part of the certification process and by reinforcing connections with the science education community.

The Precollege Educational Initiatives of the American Meteorological Society: Project ATMOSPHERE and the Maury Project

Ira W. Geer (American Meteorological Society Education Program, Washington, DC), and David R. Smith (Oceanography Department, United States Naval Academy, Annapolis, MD)

Project ATMOSPHERE is the American Meteorological Society's precollege educational initiative in atmospheric science. This teacher enhancement program, in its fourth year of operation, is directed towards encouraging investigations of the atmospheric environment to generate interest in science, mathematics, and technology among young people. Project ATMOSPHERE has two major components: a national network of middle-school science teachers as educational resource agents and a materials development program. The national network of teachers, called Atmospheric Education Resource Agents (AERAs) is nearing full implementation. These teachers conduct peer-training sessions on selected meteorological topics to enhance the content background of teachers across the country. In addition, AERAs serve as agents of change, providing leadership at state, regional and national levels to promote studies of the atmospheric environment across the K-12 curriculum. To support this effort a variety of instructional resource materials have been developed.

The Maury Project, modeled after Project ATMOSPHERE, is a teacher enhancement program on the physical foundations in oceanography. This program is a partnership of the American Meteorological Society (AMS) with the U.S. Naval Academy, assisted by the National Oceanic and Atmospheric Administration and the State University of New York at Brockport. The central component of the Maury Project is a series of two-week workshops conducted at the U.S. Naval Academy to train 72 master precollege teachers on selected topics in physical oceanography.

This presentation will focus on aspects of both programs, with particular emphasis on the summer workshops for teachers as well as the production of scientifically accurate resources materials for teaching meteorology physical oceanography at the precollege level. In addition, major accomplishments and planned activities of these programs will be examined to show how these initiatives are enhancing precollege science education nationwide.
Afternoon Session VII: Geoscience Education for Everyone

Knowing Science vs. Being Scientific: What Approach to Geoscience Education for Non-Scientists?

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(Sponsor: John A. Hadsen)

Most non-science-trained citizens have little need for the traditional, content-driven, information-heavy geoscience education common today. They will never need to "know science". However, all people need to understand processes, to "be scientific". All need to be able to make rational, reasoned decisions based on evidence, and then own and stand by those decisions. Many such decisions may involve the impact of geosciences on their lives. Thus, the goals of non-scientist geoscience education should be to (1) help students become "scientific", and (2) use situations where geoscience intersects their lives to focus the process learning.

These tenets formed the basis for a large, terminal introductory geology course. The primary learning format was small groups, that encouraged peer teaching, posing questions, digging for evidence, and ownership of content. Group members were required to explain their evidence, discussed and defended. Hands-on involvement came in group position papers on various controversial geoscience topics, research papers, and oral presentations. These were executed with minimal "geologic content" training; correct processing counted more than correct answers.

Student reaction was mixed, but generally positive. They showed greater awareness and depth of understanding of the concepts and processes they did encounter than traditionally taught students (in my experience), and a deep understanding of the potential impact of geoscience phenomena in their lives. They had much longer retention times, developed better attitudes, and were more relaxed and confident when called upon to "be scientific".

Understanding the Earth: Earth Systems Science for Non-Major Students in the Geosciences

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Appropriate geoscience education for non-majors depends on the type of student and the intended goals of the Department for those students. For the non-science student, the goal is to improve understanding of 1) principles and facts, 2) key events in history of science, 3) scientific methods, and 4) technological, philosophical, and social implications of discoveries. Although geosciences includes the physical and biological sciences, with global change, sustainability and carrying capacity for humans, we need to expand the teaching of science and society. The Earth Systems Science (ESS) approach fits this need. At OSU, Earth Systems I: Geologic Environment is followed by Earth Systems II: Atmospheric Environment or by courses such as Geology and the Environment; Water Resources; Energy, Mineral Resources, and Society; and Physical Oceanography and Marine Geology. The capstone experience in Geography is Integrated Earth Systems: Confronting Global Change; the proposed capstone for Geoscience is Population and Resource Dynamics. All courses include laboratory/recitation components. Some include up to 50 percent guided problem-solving activities with many using group-studies and peer-teaching formats. Implementation of the ESS approach requires appropriate materials and instructors. For other non-majors (engineering, science/science education), goals, formats, and course contents vary. ESS is covered but the focus is on courses related to their majors.

An Issues-Based Environmental Geology Course for Non-Science Majors

Asthana, Philip M. and John R. Carpenter (Center for Science Education, University of South Carolina, Columbus, SC)

For many years the Department of Geological Sciences at the University of South Carolina has presented an Environmental Geology course which is one of its two large general enrollment offerings. Each semester the course has one or two large lectures sections which range in size from 125 students to over 300. In addition, each student is enrolled in a laboratory section which contains about 20 people. We believe the course to be unique in two primary ways. First, the lecture portion is designed to consider environmental problems and solutions through the examination of specific environmental issues which are then related to a variety of disciplines. Second, the laboratory sessions are designed to allow the students to examine these issues on a more personal level through the use of simulations, role-playing, and values clarification. The effectiveness of this design has been evaluated with pre-tests and post-tests which reveal the extent to which the student's attitudes toward these issues and environmental education in general changes over the time of the course. Recently this basic format has been adapted for use with greater success with inservice teachers.

This year we have redesigned the course's grading strategy so as to use a modified "Portfolio" system in which the student select some of the items on which their grade will be based. Next year we plan to adapt locations at which on-site instructors will conduct laboratory activities before and after the broadcast of lectures.

Experiences With an Introductory, Non-Science Majors Geoscience Course

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I teach a one-semester, non-science majors, geoscience course to 120-190 students per semester. The course includes 3 hours of lecture per week, has no laboratory component, and provides a brief introduction to Earth, atmosphere, ocean, and astronomical sciences. Because most of the students in this course are liberal arts or elementary education majors, I emphasize some fundamental science skills and present material which should be of use to future teachers of Earth Science in elementary and middle schools and which relates to Earth hazards, resources and environment - topics which will be important to our increasingly technological and high-population society. Teaching such a course is challenging because of the breadth of material, the wide range of background and capability in science of the students, and the need to motivate students who are generally more interested in other subjects and may see science courses as an obstacle to getting their degree. Teaching strategies that I have found to be somewhat successful for this course are: (1) reducing jargon and memorization, (2) emphasizing the relevance of topics to the student or society, (3) stressing the connection between the main subject areas (for
example, Earth, ocean and atmosphere interactions), and (4) providing a variety of assignments (homework, exams, quizzes, term paper) and instructional approaches (lecture, demonstration, in-class activity, slides, videotape segments).

Weather and Life: A Cognitive Apprenticeship in Personalized Multidisciplinary Problem Solving

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The traditional approach to science instruction has centered on the teaching of disciplines of study in which students often fail to see relevance to their own lives. This is particularly true in science courses and is one reason why undergraduate education in the sciences has been viewed as inefficient and unsuccessful. Students therefore often complete lower division science courses without seeing the relevance of the topics to other disciplines and in their lives.

This has serious implications in that students lack the tools necessary for problem solving that involves scientific information. In particular, they may lack decisions based on their comprehension of science. Therefore, to improve undergraduate science education to incorporate learning, and incorporate "hands-on" learning environment with "hands-on" situations.

To accomplish this, a multidisciplinary course entitled "Weather and Life" has been developing. Weather has a broad appeal because of its commonality of experience and an active learning environment. This provides a resource link between personal experience, problem finding, problem solving, and scientific concepts. Thus the course is designed to provide personalized situated learning, cognitive apprenticeship through peer association, and problem finding/solving combined with traditional approaches. The course also builds upon associations between various disciplines and the conceptual basis of the managerial and the sciences.

These combined with cooperative and collaborative learning, and facilitated by multimedia integration, will provide for improved scientific awareness, capability, and literacy of undergraduate students. This approach could be beneficial in many other courses in other disciplines. The course is expected to benefit primarily non-science majors, but will facilitate interaction with science majors as well.

Approaches for Increasing Participation of Underrepresented Groups in Earth System Science Education by Linking Global Processes to Local Issues Through Active Learning

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Working with a diverse team of interdisciplinary scientists, we have developed a two-semester sequence of Earth System Science courses for non-science majors. Course development was funded, in part, by USRA's Earth System Science Education Initiative. The experience of teaching concepts of Earth System Science to classes that typically include significant numbers of women and Mexican-American students has prompted us to evaluate the effectiveness of our teaching strategies with respect to the needs and interests of traditionally underrepresented groups.

We are developing a model for curriculum development that explicitly forges links between global processes and local environmental issues. A key to developing this linkage is engaging students in active learning about local and regional environmental issues. Current thinking in science education and equity projects posit that active, student-centered approaches foster positive attitudes and achievement, potentially leading to increased interest in science as a field of study. Constructivist pedagogy argues that students need to connect new knowledge to their own experience and proceeds via the study of problems have clear relevance to the students' lives. We are increasing persuaded that addressing local issues is a powerful way of developing students' senses that their attitudes and behavior can make a difference in the quality of their lives and tends to counteract the tendency for global environmental issues to overwhelm students.

We are currently explicitly testing these ideas in the context of (1) further refinement of our courses for non-science majors, and (2) the design of in-service middle school teacher development model that addresses equity issues in rural Mexican-American communities of the border region of the southwestern United States.

Thematic and Awareness Goals for Teaching Non-majors in the Geosciences

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Goals for teaching non-majors in geoscience courses should be defined at the beginning of every course and be broken down into two categories, thematic goals, related to the interconnectedness of course content, and awareness goals, related specifically to course content.

First, thematic goals should be established in geoscience courses for instructors to follow. Thematic goals should provide unifying models or concepts so that students learn that all topics within the geosciences are an interconnected body of knowledge and that they are also connected with topics in other sciences. Unifying thematic models/concepts might include plate tectonics, a comprehensive rock cycle, or dynamic equilibrium of landforms. Second, awareness goals should be established to increase the knowledge and interest on the part of the student in specific facts, ideas, or concepts within the geosciences. These course-content goals could even be partially defined by the students themselves. Nonetheless, awareness goals should be stated in terms of, "The goals of this course are to increase the awareness of;" Examples are numerous, but certainly some major ones are to increase the student's awareness of: the antiquity of the Earth; the role of the oceans in the evolution of life on Earth; the primary energy sources that drive geologic processes; the temporal-spatial scales of major geologic processes; the limited nature of the Earth's mineral and energy resources; and the indifference of geologic processes to human civilization.

Do You Teach Geoscience differently to Non-majors?

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Courses offered to non-majors allow educators to demonstrate that geoscience is exciting and relevant to members of the community who may be unaware of its importance to their everyday lives. These courses also benefit geoscience departments by increasing the total number of students taught and recruting new majors. Students have diverse reasons for enrolling in geoscience courses including amateur interests, intellectual curiosity and degree requirements.

Students who are not majoring in geosciences come from heterogeneous backgrounds and are more likely to have weak math
Towards Training a New Generation of "Citizen-Scientists"

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An informed citizenry is essential to the successful conduct of the affairs of a democratic society; however, our public is generally uninformed about the concepts and products of scientific and their attendant technologies. The earth sciences are particularly well-suited to introduce fundamental scientific principles, to develop scientific habits of the mind, and to demonstrate the connections between natural and societal systems to non-science majors. In particular, the topics of natural hazards, environmental degradation, and exploitation of natural resources provide rich material to engage students in both the acquisition of scientific knowledge as well as participation in scientific investigations. Three types of activities can readily be integrated into earth sciences to facilitate the product of the process of Science: 1) Start with questions about nature (Project 2061: AASL, 1989); 2) topical issues derived from the popular press and photographs are an effective way to introduce a problem and to provide the basis for students to discover the underlying scientific principles. An "opening question" can be used to lead students into a deeper exploration of a given topic through personal reflection (writing), or collective exploration (discussions) and a debate format can be used to reproduce the facts of a given issue (e.g. Lucas v. South Carolina regarding zoning of coastal areas); 2) Make the students responsible for the acquisition of relevant information; and 3) Apply the information in a meaningful way through service-based learning activities (e.g. public forums on natural resources or hazards). This approach introduces a new pedagogy for science education, makes Science more accessible and interesting to students, reinforces the connections between Science and personal or societal lives, and responds to the societal imperative to train a new generation of scientifically literate citizens.

Geosciences as the Catalyst for Education Reform

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Geosciences, as a rich, real-time source of experiences offers a unique potential to lead in science education reform. This presentation outlines the design of a first-year undergraduate course which uses the geosciences as the catalyst to train incoming engineering students how to access and present information. The course is designed to build an experience wherein the participants are required to work with local K-12 schools to develop a plan for networking to the Internet explicitly to allow science class access to geosciences information. Students learn networking, education, administrative and financial issues, limiting classroom access to the Internet, but also are provided an overview to the kinds of people present on the Internet. The course is interesting to student over the Internet which they use as incentive to science classrooms to connect. This unique blend of geosciences and engineering in the context of community outreach is offered as a model for providing geosciences training in non-traditional ways to a broader undergraduate audience.

Hózhó and Hutton Together: Toward Autochthonous Geoscience Education for Navajo Students

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In the well-exposed Southwest, the proverbial "open textbook," it is easy to introduce undergraduates to most of the basic principles and mechanisms of physical and historical geology directly, in the field. A greater challenge in teaching geology to autochthonous Diné (Navajo) students, particularly non-science majors, is to relate Western geological concepts directly to their other cultural experiences with the Earth, so as to increase comprehension and enable students and instructor to share aspects of the other's worldview.

In the case of Navajo Community College (NCC), which is tribally-controlled and serves an exclusively Native American student population, the integration of Diné pedagogy and philosophy into the geoscience curriculum is not only considered desirable, but is also mandated by the community it serves. Because many issues now confronting the Navajo Nation involve the land and the environment, it is also necessary for NCC geoscientists to be able to explain geologic concepts and offer opinions to Diné individuals who speak only their own language. These are no simple tasks for a non-Native instructor, who must gradually become steeped in a difficult language and alternate worldview before he or she can discuss Hózhó as easily as Hutton.

Toward these ends, NCC geoscience faculty and traditional scholars are developing these approaches to a Diné geoscience curriculum: (1) topical, in which geologic case studies of direct interest to Navajos are incorporated into regular classes; (2) linguistic, in which a workable geologic lexicon is to be translated into Diné for use by native speakers (students and non-students alike); and (3) integrated: a gradual blending of Diné scientific pedagogy and language with Euro-American geoscience, while still retaining the meaning and value of both. The latter approach, in particular, is still new and mostly unexplored, but thus far it appears that Diné scientific interpretation is essentially concordant with modern unified concepts in Euro-American geoscience, such as petrogenetic cycles, Earth systems, and plate tectonics.

Illustrated examples of each of these approaches will be presented. Because of popular interest in Southwestern Native cultures, much of this material would be appropriate for a general student audience, and could be used in any introductory geology curriculum.

Challenge of a Geoscience Curriculum at a Small, Private, Liberal Arts College

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College of the Atlantic was created in 1969 at a time when it was thought that conventional education was inadequate as preparation for students to deal with the interactive business environment, and social issues. A curriculum was established without traditional departmental structures, and a four-year degree in Human Ecology was begun, which persists today. Student enrollment in the 1993-94 academic year was 230; full-time Faculty number 25, and about 15 are Adjunct and Visiting. A Faculty to Student ratio of 1:15 is normal, with a class limit of 15.

A formal course in geology was begun in the 1991 Spring Term (10 wks), and has been a regular feature of the curriculum since then. The course title is "Geology of Mount Desert Island," which emphasizes the local geology where the students attend college, but the course format includes all aspects of a standard introductory geology term. Classroom time is three hours per week, plus a three-hour lab/field trip. Mount Desert Island provides an excellent geologic setting for field trips, with examples of basic rock types, structures, and glacially developed topography.
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