quantitative measures should be used when creating assessment instruments to ensure validity of the test design and application; and 3) many alternative ideas about the Earth are difficult to change, as evidenced by very little change between pre- and post-test scores nationwide.

ED22E-07 1510h INVITED

The Retention of Geologic Misconceptions: Alternative Ideas That Persist After Instruction

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We used a 30 item multiple-choice instrument called the geoscience concept test (GCT) to study learning in introductory college-level science courses. The GCT uses common misconceptions as wrong answers, and allows us to pre- and post-test individual courses to gauge the effectiveness of instruction. The GCT was given at the beginning of the semester to 2215 college students in 42 classes at 32 different institutions in 19 different states (21 public and 6 private four-year institutions, 4 community colleges, and one tribal college). The pilot was also given to 1907 students as a semester-end post-test in 30 different classes. We were able to match pre- and post-test results for 967 students through an analysis of volunteered personal and demographic data. Although statistical analysis shows that learning occurred in all classes, closer inspection of the data show that the student population retained a number of misconceptions. Students retained several incorrect ideas relating to geologic time despite instruction. For example, 71% of post-tested students believe that the study of fossils, rock layers, or carbon is the most accurate means for calculating the age of the Earth. Nearly 25% of students believed that dinosaurs only existed on Earth for 500,000 years, and 40% believe dinosaurs came into existence about halfway through the geologic time scale. Many alternative ideas about plate tectonics and the formation of rocks also existed after instruction. Nearly half of the post-tested students (47%) believed that tectonic plates do not extend all way to the surface of the Earth, and 65% did not believe that animals could form oceanic rocks. Identification of strongly held misconceptions in a post-tested student population provides instructors with information that could impact the way they present material to their introductory classes.

ED22F MCC: 3012 Tuesday 1600h

Assessment of Geoscience Education Tools and Approaches II *(joint with C)*

Presiding: **C Gautier,** University of California, Santa Barbara**; D Schweizer,** NASA Headquarters

ED22F-01 1600h INVITED

Teaching General Education Students How to Write Scientific Arguments Using Real Earth Data

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Writing activities can improve student understanding of scientific content and processes. We have studied student writing to identify the challenges that students face in composing scientific arguments and to clarify features that constitute quality in scientific writing. We have applied argumentation analysis for the assessment of students' use of evidence in a general education oceanography course. Argumentation analysis refers to the systematic examination of ways that conclusions are supported with evidence. The student writers were supported by an interactive CD-ROM, "Our Dynamic Planet," which provided students with "point and click" access to real earth data and allowed them to solve many problems associated with plate tectonics. Plate boundary types (using quakes, volcanoes, elevation profiles, and heat flow) and plate motion can be determined (seafloor age, island ages/hot spots) with this technology. First, we discuss the structure of scientific argument and how this structure can be made accessible to undergraduate students. Second, we present examples of argumentation analysis applied to student writing. These examples demonstrate how use of large scale geological data sets can be used to support student writing. Third, we present results from a series of studies to show ways that students adhere to the genre conventions of geological writing through use of theoretical claims, multiple lines of evidence, and cohesive terms. These results, combined with our evidence-based orientation to instruction, formed the basis for modifications in the course instruction. These instructional modifications include providing detailed examples of data based observations and interpretations, heuristics for assessing other students' arguments, and quick write exercises with similar but simplified writing tasks. More information about the CD-ROM may be found at http://oceanography.geol.ucsb.edu/.

ED22F-02 1615h

The Design, Use and Revision of Scoring Rubrics to Enhance Student Performance in a Multidisciplinary, Student-Directed Course on Global Climate Change

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Efforts to promote increasingly student-centered learning environments in the geosciences have resulted in a need for new tools for enhancing and assessing levels of student performance. Over the past several decades, educators of many disciplines have been researching and promoting the use of scoring rubrics for both evaluating student work and providing feedback based on that work. As part of a research project on assessment, scoring rubrics were used in an upper-division undergraduate geography course entitled "Mock Environmental Summit." In this course, students act as representatives of groups of countries or non-governmental organizations and research topics related to the causes and consequences of global climate change. Based on this research, the students select topics that they believe to be of key importance and present oral and written summaries of the information they have gathered on those topics. The course culminates with a "summit" and drafting of an international agreement modeled on the Kyoto Protocol. Due to the emphasis on writing and presentations during the class, scoring rubrics were designed to provide guidelines that students could use for self-assessment when preparing oral and written reports, to facilitate detailed feedback from instructors to students, and to serve as a standard upon which course grades would be based. In this paper, we present an overview of scoring rubric design, the way in which our rubrics were presented to and utilized with students, and the impacts of their use on student performance. We will also comment on the revisions that we made to our rubrics based on student outcomes, and our ideas about other areas of student performance to which they could be applied.

URL: http://www.crseo.ucsb.edu/esrg/Geog135_Sum03/135.index.html

ED22F-03 1630h

A Concept-Mapping Strategy for Assessing Conceptual Change in a Student-Directed, Research-Based Geoscience Course

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The concept mapping technique has been proposed as a method for examining the evolving nature of students' conceptualizations of scientific concepts, and promises insight into a dimension of learning different from the one accessible through more conventional classroom testing techniques. The theory behind concept mapping is based on an assumption that knowledge acquisition is accomplished through "linking" of new information to an existing knowledge framework, and that meaningful (as opposed to arbitrary or verbatim) links allow for deeper understanding and conceptual change. Reflecting this theory, concept maps are constructed as a network of related concepts connected by labeled links that illustrate the relationship between the concepts. Two concepts connected by one such link make up a "proposition", the basic element of the concept map structure. In this paper, we examine the results of a pre- and post-test assessment program for an upper-division undergraduate geography course entitled "Mock Environmental Summit," which was part of a research project on assessment. Concept mapping was identified as a potentially powerful assessment tool for this course, as more conventional tools such as multiple-choice tests did not seem to provide a reliable indication of the learning students were experiencing as a result of the student-directed research, presentations, and discussions that make up a substantial portion of the course. The assessment program began at the beginning of the course with a one-hour training session during which students were introduced to the theory behind concept mapping, provided with instructions and guidance for constructing a concept map using the CMap software developed and maintained by the Institute for Human and Machine Cognition at the University of West Florida, and asked to collaboratively construct a concept map on a topic not related to the one to be assessed. This training session was followed by a 45-minute "pre-test" on the topic of global climate change, for which students were provided with a list of questions to guide their thoughts during the concept map construction. Following the pre-test, students were not exposed to further concept mapping until the end of the course, when they were asked to complete a "post-test" consisting of exactly the same task. In addition to a summary of our results, this paper presents an overview of available digital concept-mapping tools, proposed scoring techniques, and design principles to keep in mind when designing a concept-mapping assessment program. We also discuss our experience with concept map assessment, the insights it provided into the evolution in student understanding of global climate change that resulted from the course, and our ideas about the potential role of concept mapping in an overall assessment program for interdisciplinary and/or student-directed curricula.

URL: http://www.crseo.ucsb.edu/esrg/Geog135_Sum03/135.index.html

ED22F-04 1645h

ROAST: Peer Review as a Learning and Assessment Tool in Graduate Education

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Constructivist learning theory and inquiry-based educational practice stress the parallels between learning and research. Although peer review has long been a central feature of the working lives of research scientists, it has rarely found its way into the classroom. Motivated by this thought, an imaginary journal, Reviews of Atmospheric Science Topics (ROAST), has been integrated into a graduate-level course in atmospheric thermodynamics. The instructor acts as editor of ROAST. Students in the class are divided into teams and assigned topics on which to write survey papers and give in-class presentations, using the text, the Internet, the library, and other resources. The assigned topics range over the subject matter of the course. The submitted survey papers are sent by the ROAST editor to other members of the class, acting as anonymous reviewers. Just as in the case of real research journals, the editor asks the authors to respond to criticisms of reviewers and then sends the revised papers back to the reviewers. Each student is thus a researcher and co-author of one paper as well as an anonymous reviewer of several others. ROAST has proven to be not only a useful means of fostering learning, but also a natural and effective assessment tool. The peer review mechanism allows the student authors to address the defects in their papers, and hence in their learning, as pointed out not by an authority figure or an examination but by their own peers. As an important side benefit, the students gain experience with the peer review process itself and come to appreciate its strengths and weaknesses in evaluating scientific papers.

ED22F-05 1700h

Assessment Strategies for Data Intensive, Upper Division Earth Science Course on Global Change

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There is a particular value in developing tools for assessing the "scientific operation" we attune to doing science. All too often, we instruct our students to gain scientific knowledge through a series of contrived labs, and even subject a few of them to performance assessments commonly known as "senior projects." If we are to begin using more performance related activities in our geoscience courses, we need evaluation and assessment methods rich enough to provide reliable information for course improvement. Scientists know that at the heart of science is the struggle with understanding data - learning how to make higher order data-based decisions that go beyond the ability to construct graphical representations. We will present an evaluation plan that evaluates a student's ability to conduct scientific operation focused upon three sub-categories, all of which are interdependent: scientific knowledge; scientific communication; and scientific data user ability. We will also present preliminary results from a focused study.

ED22F-06 1715h

Strategies for Assessing Learning Outcomes in an Online Oceanography Course

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All general education courses at the San Jose State University, including those in the sciences, must present a detailed assessment plan of student learning, prior to certification for offering. The assessment plan must state a clear methodology for acquiring data on student achievement of the learning outcomes for the specific course category, as well as demonstrate how students fulfill a strong writing requirement. For example, an online course in oceanography falls into the Area R category, the Earth and Environment, through which a student should be able to demonstrate an understanding of the methods and limits of scientific investigation; distinguish science from pseudo-science; and apply a scientific approach to answer questions about the Earth and environment. The desired learning outcomes are shared with students at the beginning of the course and subsequent assessments on achieving each outcome are embedded in the graded assignments, which include a critical thinking essay, mid-term exam, poster presentation in a symposium-style format, portfolio of web-based work, weekly discussions on an electronic bulletin board, and a take-home final exam, consisting of an original research grant proposal. The diverse nature of the graded assignments assures a comprehensive assessment of student learning from a variety of perspectives, such as quantitative, qualitative, and analytical. Formative assessment is also leveraged into learning opportunities, which students use to identify the acquisition of knowledge. For example, pre-tests are used to highlight preconceptions at the beginning of specific field studies and post-testing encourages students to present the results of small research projects. On a broader scale, the assessment results contradict common misperceptions of online and hybrid courses. Student demand for online courses is very high due to the self-paced nature of learning. Rates of enrollment attrition match those of classroom sections, if students are informed of the instructor's expectations at the beginning of the course. The level of faculty-student and student-student communication is very high, both in terms of quantity and quality, and exceeds that experienced in classroom sections. Student scores on graded assignments compare favorably to classroom sections. Overall, online courses offer a cost-effective means of addressing top priority issues, including increasing student access to learning, accelerating rates of graduation, and improving outreach to K-12 educators, especially those working on credential requirements.

ED22F-07 1730h

Prototypical Concepts and Misconceptions of Plate Tectonic Boundaries

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Students of geology encounter many prototypical/exemplar concepts* that include representative, but not necessarily defining, features and characteristics. This study of students' prototypical representations of plate tectonic boundaries indicates that their representations are rich sources of information about their misconceptions about plate tectonics. After lectures in plate tectonics and mountain building, 353 students in a general education geology class were asked to draw a continent-continent convergent boundary. For this study, a correct answer is defined as having the major features in correct proportions as depicted in the plate boundary diagrams on the USGS web. Fifty-two percent of the drawings were either incorrect or incomplete such that they could not be interpreted. Only 48% were readily interpretable, and of these 22% drew the boundary correctly, showing a thickening of crust where two continents collide. Thirty-three percent drew the boundary showing concave slabs of continental crust as one might imagine two pieces of firm rubber pushed together on a rigid surface and 45% depicted mountains as one might imagine inverted ice cream cones on a rigid plank. Twenty-one senior class geology majors and graduate students were given the same assignment. Forty-eight percent rendered a correct drawing, whereas 38% drew the same ice cream cone on a plank type picture that 45% of the general education students drew. In a second class of 12 geology majors, only 1 student drew a cross section of a continent-ocean boundary similar to standard representation. Four of 12 drew mountains on the top of continental crust over a subduction zone but did not draw a compensating mass within the crust or lithosphere. Prototypical drawings provide more information about students' concepts than do most multiple-choice questions. For example, sixty-two percent of theses students who drew mountains similar to foam rubber pads pushed together on a desk or ice cream cones on a plank correctly answered a multiple-choice question that would appear to indicate a better understanding than the drawings reveal. Furthermore, 12 interviewed students made statements that could be interpreted to indicate that they understood the concept of mountain building at plate tectonic boundaries better than their drawings suggest. Incoherence of multiple-choice responses, verbal statements and drawings may be common in novice learners. If cognitive scientists are correct in their model of multiple types of mental representations for the same term, then the fact that novices may hold inconsistent representations is not surprising. The fact that students at various academic levels draw very similar prototypes that are incorrect is evidence that students have distinct and persistent prototype misconceptions. * Cognitive scientists define a prototypical/exemplar concept as a mental representation of the best examples or central tendencies of a term.

ED22F-08 1745h

Evaluating an Introductory Geoscience Classroom Exercise using Pre- and Post-Exercise Assessments

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Discovering Plate Boundaries is a data-rich classroom exercise that has been used successfully in middle school, high school, and college-level science classes. It is an active learning exercise that encourages students to discover the theory of plate tectonics based on their observations of maps containing earthquake, volcano, topography, and seafloor age data. Students and educators have responded with enthusiasm to this exercise, especially the jigsaw component that promotes random group interaction. We now focus our attention on assessing the impact of the exercise on student learning in order to determine whether it conveys sufficient content knowledge. We designed a pre-exercise assessment consisting of questions relating to introductory geoscience concepts, with particular emphasis on plate tectonics. These questions were based on student learning goals for introductory geoscience courses that utilize the Discovering Plate Boundaries exercise. The questions have evolved with repeated use in order to more effectively gauge student knowledge. The pre-exercise assessments have been completed by middle school, high school, and college students, and have identified some common student misconceptions about geoscience. For example, many students believe that earthquakes are a key component of mountain-building, while volcanoes are not. This type of information should be used by the instructor to stress certain concepts during the course in order to address these preconceived notions. A post-exercise assessment consisting of the same questions was administered at the end of the courses and we found that some of the initial misconceptions remained. We conclude that more pre-exercise assessments should be administered in order to establish a database of student misconceptions so that educators can focus instruction in these areas.

ED31A MCC: 3012 Wednesday 0800h

The GeoWall in the Earth Science Classroom I *(joint with P, SM)*

Presiding: **P J Morin,** University of Minnesota**; P van Keken,** University of Michigan

ED31A-01 0800h

The State of the GeoWall

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. The GeoWall Consortium

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The GeoWall stereo projection technology has been widely adopted within Earth Science. Over 20,000 undergraduate students per year use a GeoWall in classroom and lab settings at over 80 institutions around the world using over 200 GeoWalls. We believe that critical mass for this technology has been reached in the Earth Science. Many collaborations have been initiated. With Iris, GeoWall is exploring new ways to monitor seismic networks in real-time and to visualize extremely large, whole Earth seismic simulations. We are also working with a number of drilling organizations including JOI, DOSECC and LacCore to bring modern visualization technology to core interpretation and drill site selection. Also, over 15 museums now have or are building GeoWalls for informal education. Much of the science that is being performed on the GeoWall is finding its way directly into the classroom and science museum. One of the success stories has been the GeoWall Consortium's interaction with industry. The basic hardware for the GeoWall has been spun off to companies that now sell variations of the hardware. In addition, many software companies including ESRI and Dynamic Graphics have added support for the GeoWall in their products. The future of GeoWall is four fold. Curriculum development will bring more material to all GeoWall users. Assessment of the curriculum and educational psychology will give us GeoWall best practices. In technology development, the GeoWall 2 is a 20+ million pixel, tiled display which brings more resolution to the Earth Sciences than ever. To support research the consortium is developing a volume rendering application to visualize extremely large datasets.

URL: http://www.geowall.org

ED31A-02 0825h

ENHANCEMENT OF SPATIAL UNDERSTANDING IN AN INTRODUCTORY FIELD METHODS PROJECT THROUGH A GEOWALL INTERVENTION

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The implementation of the GeoWall (www.geowall.org) in introductory geology labs as a visualization tool is on the increase at the undergraduate level. We report on a new project that examines how introductory field students' understanding of basic mapping skills may change after a GeoWall intervention. GLG 240 is a required field methods course for students majoring in Geology at Northern Arizona University. In this class, students learn to describe different kinds of rocks, self locate on a topographic map, use a Brunton compass, and map relatively simple geologic structures. The class is a prerequisite to upper-division classes (mineralogy, petrology, structure, etc) and is open to any student who has completed physical and historical geology. In