ED22E MCC: 3012 Tuesday 1340h

Conceptions, Cognition, and Change: Student Thinking About the Earth I

Presiding: **J C Libarkin,** Ohio University**; S Anderson,** Black Hills State University

ED22E-01 1340h

Student Levels of Cognitive Development: Establishing Links between Logical Thinking Skills and Success in Earth Science

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Students in inquiry-based, general education Earth Science courses were found to display a wide range of logical thinking skills that are known indicators of success in science courses. The Group Assessment of Logical Thinking instrument that tests six logical operations was administered on the first day of class and near the end of the course. Such tests can be used to assess a student's overall level of cognitive development (concrete, transitional or formal) and specific logical thinking strengths or weaknesses. Results from paired pre- and post-course logical thinking tests of 393 students indicated that 25% of the incoming students were concrete, 30% were transitional and 45% were formal thinkers. Concrete and transitional thinkers were far more likely to withdraw from or fail the course when compared to their formal thinking peers (35%, 25% and 10% respectively). Differences in scores between genders were significant with 210 females testing at 30% concrete, 35% transitional and 35% formal on the pretest compared to 183 males who tested 15% concrete, 25% transitional and 60% formal. Overall logical thinking scores of students increased significantly in every inquiry-based class with lecture-based classes showing overall lower increases. Post-test data indicated that there were fewer concrete thinkers (16% female, 7% male), little change in the number of transitional thinkers (30% female, 23% male) and more formal thinkers (54% female, 70% male) toward the end of the inquiry-based course. Scores on two of the logical operations, conservation and probability, were sufficient to separate those who received a high grade (A or B in course) from those were unsuccessful (D, F or withdrew). Students who score low in conservation operations (n=46) tend to rely on intuition rather than logic when trying to understand typical Earth System concepts such as plate tectonics, atmospheric processes and climate change. Students who score low in probability skills (n=46) have difficulty distinguishing the difference between unrelated, but possible, data and those data that confirm a supposition. Such skills are necessary to properly apply the scientific method. By the end of the course, unsuccessful concrete students improved conservation reasoning skills to the same levels of their higher performing concrete peers on the post-test but remained behind them in probability skills. Successful transitional thinkers (n=50) displayed better correlation-reasoning skills than their lower performing contemporaries (n=51). Correlation reasoning skills are necessary to understand some of the many causal relationships routinely developed in the Earth Sciences (e.g. those associated with plate tectonics and earthquakes or volcanoes; CO2 and global climate change).

ED22E-02 1355h

Dating the Earth: What Students "Think" They Know About Radioactivity

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Contemporary science education research emphasizes the importance of considering students pre-instructional beliefs when designing effective, student-centered instructional strategies. When scientists teach about dating the Earth, most often the concepts of radioactive decay and half-life are presented. However, our research illustrates that students bring to the classroom many inaccurate beliefs and reasoning difficulties on the topics of ionizing radiation, radioactivity, and radioactive decay that are well-poised to interfere with students' understanding of how half-life is used to determine geologic time. In an effort to uncover the range and frequency of the dominant student beliefs with regard to radioactive phenomena, we performed individual demonstration interviews and administered open-response concept tests to students from a wide-range of science backgrounds. Our results show that students are often unable to differentiate between the ideas of irradiation and contamination, and that many of these students' reasoning difficulties about radioactive decay and half-life stem from their inaccurate mental models regarding the atom.

URL: http://shiraz.as.arizona.edu

ED22E-03 1410h

Probing the Effectiveness of the Conventional Introductory Science Lecture

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For quite some time now, the repeated call for a more student-centered approach to teaching due to the ineffectiveness of lecture has been gaining prominence in the earth and space science teaching community. However, our extensive review of the literature suggests that this claim of ineffectiveness of lecture has not been validated in the context of the conventional introductory science course for non-science majors. At the beginning of a large-enrollment introductory astronomy survey course, we administered 68-multiple choice items as a pretest to 81 students. At the end of each lecture we administered the specific items related to that particular day's lecture a second time as a posttest. The average score on the 68 items administered as a pretest was 30 percent correct and the posttest average score was 52 percent correct. Although this does represent a statistically significant gain in scores, we judge this level of success to be insufficient for long term learning achievement. These results illustrate that instructor-centered strategies are largely ineffective at promoting meaningful conceptual gains on traditional earth and space topics presented to non-science majors. This work was supported by NSF CCLI #9952232 and NSF Geosciences Education #9907755.

URL: http://shiraz.as.arizona.edu

ED22E-04 1425h INVITED

Conceptions About Standards-Based Lunar Concepts

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This paper summarizes results from three research studies, which focused on conceptions of lunar concepts. Study 1 focused on the conceptual understandings held by 78 preservice elementary teachers about the cause of moon phases, before and after instruction. Participants in the physics groups received instruction on moon phases in an inquiry-based physics course; participants in the methods group received no instruction on moon phases. The instructive effect of two different types of preinstruction interviews also was compared. Results indicated that without the instruction, most preservice teachers were likely to hold alternative conceptions on the cause of moon phases. Participants who had the instruction were much more likely to hold a scientific understanding after instruction. The instruction appeared to be more effective in promoting a scientific understanding of the cause of moon phases than instruction previously reported in the literature. It also appears that using a three-dimensional model or making two dimensional drawings during the preinstruction interviews does not have instructive value. Study 2 examined preservice teachers' conceptions of moon phases over an extended period after instruction. This research, a continuation of work in Study 1, included longitudinal data from 12 participants who had received instruction on moon phases in an inquiry-based physics course. Participants who had been interviewed before instruction and three weeks after instruction were given delayed postinterviews six or thirteen months after instruction. Results indicated a majority continued to hold a scientific understanding months after instruction. However, some participants reverted to alternative conceptions they had shown during the preinterview. Study 3 described the conceptual understandings held by 52 preservice elementary teachers about standards-based lunar concepts for grades K-4, including the observable shapes of the moon and the monthly pattern of observable changes. Results indicated that without instruction, most preservice teachers did not have a scientific understanding of observable moon shapes and patterns of monthly changes in the shapes. Participants who completed the instruction were more likely to hold a scientific understanding. Thus, the instruction appeared to be effective in promoting a scientific understanding of moon shapes and patterns of change in the shapes

ED22E-05 1440h

College Students' Alternative Conceptions About Petrified Wood: Implications for the Integration of Geological and Biological Knowledge

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An understanding of petrified wood (including formation, composition, and properties) requires a broad and integrated conceptual framework. As a paleontological topic that addresses both geological and biological content, petrified wood is an ideal knowledge probe concept for revealing knowledge gaps and conceptual difficulties that students bring into introductory geoscience and biology classrooms. Our integrated geo-bio education research study addressed both (a) introductory college students' alternative conceptions (ACs) about petrified wood and (b) implications for improving the integration of geological and biological knowledge. We investigated the ACs of students enrolled in a large introductory historical geology course (n=188) at a research university in Louisiana. Having conducted and reviewed alternative conceptions research studies in science education across the past 20 years (Clary & Wandersee, 2003; Wandersee, Mintzes, & Novak, 1994), we developed and administered a set of 15 free-response and forced-choice knowledge probes about petrified wood. Resultant findings indicated that the phenomenon of petrified wood was typically addressed several times in our participants' prior K-12 science lessons. However, these college students' geological and biological knowledge of the topic was systemically flawed in four fundamental areas: (a) the geologic time scale; (b) uniformitarianism; (c) biological properties and structure of wood; and (d) fossil-rock-mineral distinction. Our data set advanced the development of a typology for the learning problems that we uncovered for petrified wood. We propose that our typology serve as a heuristic for anticipating students' conceptual difficulties for other biogeoscience topics as well. Our study also documents the need for more geological and biological knowledge integration by bridging college science departmental divides.

URL: http://www.EarthScholars.com

ED22E-06 1455h INVITED

The Geoscience Concept Test: Linking Grounded Theory, Scale Development, and Item Response Theory

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Over 6000 students from more than fifty universities and colleges nationwide participated in a study aimed at developing an assessment instrument for entry-level geoscience courses. Short, open-ended questionnaires from 1000 students and interviews with 200 students provided insight into ideas about the Earth held by entry-level students, and these ideas drove the development of test questions and answers. The test was created in two phases: a small, 29-item test was piloted in Fall 2002 and evaluated using item response theory and qualitative validation techniques. Based upon the success of this initial testing, a second set of 45 questions was created for piloting in Fall 2003. Our experiences with the Geoscience Concept Test indicate that 1) assessment questions created in direct response to student interviews are particularly useful in large-scale testing of student ideas; 2) a variety of qualitative and

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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