Geoscience Education Research: A Brief History, Context and Opportunities

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The “Roots” of Geoscience Education in America

COMMITTEE of TEN (1893)

Emphasized importance of physical geography in the secondary school curriculum.

- 4th Secondary School Year
- Geog. or Physiography
  3 periods for 1/2 yr.
- Meteorology
  3 periods for 1/2 yr.
- Geology
  Excluded from the curriculum

Slide courtesy of Robert Ridky, USGS
The Earth Science Curriculum Project (ESCP, 1963)—9th Grade

- Earth science education languished in the first half of the 20th Century
  - Emergence of physics, chemistry, biology
  - Largely descriptive, taxonomic

- Post-Sputnik (but pre-Plate Tectonics; 1963)
  - Renewed interest and urgency in science education
  - "an integrated and up-to-date story of planet earth and its environment in space."
Earth Science Curriculum Project

• Strongly influenced by Piaget
  – Hands-on, Experiential learning

• ...science is “what scientists do” led quite naturally to the use of behavioral terms to describe expected outcomes. The writers included behavioral objectives as well as content objectives in the teacher’s guide.

*Irwin, 1970*
Earth Science Curriculum Project

• “The materials produced by ESCP must be written with full understanding of the intellectual capacities and subject-matter background of the secondary school students for whom they are intended.”

• “Materials developed by ESCP should place strong emphases on laboratory and field study in which the student actively participates in the genuine process of scientific inquiry, rather than mechanically repeating “cookbook exercises”.”
Earth Science Curriculum Project

- Science as inquiry
- Universality of change
- Flow of energy
- Adaptation to environmental change
- Conservation of mass and energy
- Prediction
- Presentation

- Significance of components and their relationships in space and time
- Uniformitarianism
- Comprehension of scale

Compare with the Earth, Ocean, Climate and Meteorology “Literacies”!!!
Geoscience “Literacies”

http://www.earthscienceliteracy.org/
http://coexploration.org/oceanliteracy/documents/OceanLitChart.pdf
http://www.earthscienceliteracy.org/
http://eo.ucar.edu/asl/index.html
http://cleanet.org/cln/index.html

Still, there is no “canon” of geoscience content. What and how to teach are still matters of choice by individual instructors.
However, there are commonalities, emphasized in an Earth System Science approach:

- Geologic “Deep Time”
- Transfer of energy and mass
- Spatial and temporal reasoning across many scales
- Incomplete evidence
- Uncertainty, ambiguity, inference

These are profound concepts or approaches: how can we facilitate and optimize student learning?
Science for All Americans, AAAS, 1989

- Engage students actively
- Concentrate on the collection and use of evidence
- Start with questions about nature
- Provide historical perspectives
- Insist on clear expression
- Use a team approach
- Acquire scientific knowledge scientific habits of the mind.
Recognizing that DBER was alive and well in Physics, Chemistry....why not geoscience?

“We recommend that GEO and EHR both support research in geoscience education, helping geoscientists to work with colleagues in fields such as educational and cognitive psychology, in order to facilitate development of a new generation of geoscience educators.”

NSF 97-171
Research on Learning—A Disciplinary “Mixer”, 2002

• Goals
  – Develop an understanding of current state of research on learning in the geosciences
  – Identify research questions of high interest to geoscience and learning scientists
  – Develop a plan to apply research on learning to geoscience instruction

• Mutual Discovery
  – A wealth of shared interests

• Participants
  – geoscientists, science educators, cognitive scientists

• Sponsored by NSF/REC and Johnson Foundation
Research on Learning—Research Plan

• What characterizes expert thinking?
• What concepts and skills are essential?
• How do we understand the Earth system that is heterogeneous, dynamic, ambiguous, uncertain?
  – Geologic time
  – Spatial relations
  – Complex systems
  – Visualizations
• What learning environments are most effective?
  – Field; laboratory, using data
What is Discipline-Based Education Research?

- Emerging from various parent disciplines, with deep grounding in the discipline’s priorities, worldview, knowledge, and practices
- Investigates teaching and learning in a discipline
- Informed by and complementary to research on human learning cognition
- Most commonly applied to higher education
Strength of Evidence

DBER is an emerging field, and the strength of evidence that support findings have been variable ranging from anecdotal to robust.

• **Limited Evidence:** Few peer-reviewed studies with some convergence, OR Convergence with practitioner wisdom

• **Moderate Evidence:** Well designed, replicated study, OR Moderate number of small-scale studies, OR A few large-scale studies

• **Strong Evidence:** Numerous well, designed qualitative and/or quantitative studies with high convergence of findings.
“Practitioner’s Wisdom”

- Geoscientists have had an innate sense of “what works” based on experience:
  - “Field Work is Good”
    - Boyle, Riggs, Petcovic, Mogk/Goodwin
    - Experiential learning, Problem-solving
- How to document, provide evidence of mastery?
- Need for codified, validated method and metrics
Building Community—
On the Cutting Edge Program

• Importance of catalytic events
  – Face to face workshops
  – Virtual workspaces, connections

• Proactive recruitment of participants
  – Geosciences
  – Cognitive/learning/social sciences

• Sustained networking opportunities

• On-line resources to further work
Visualizations, 2004 and 2008

Teaching Geoscience with Visualizations: Using Images, Animations, and Models Effectively

Teaching Geoscience with Visualizations

Visualizing the Earth, its processes, and its evolution through time is a fundamental aspect of geoscience. The use of visualizations - diagrams, images, animations, maps, and more - is an essential tool in helping students to visualize the Earth and its processes (e.g., references in the recommended reading list and many others).

February, 2008 workshop

Teaching with New Geoscience Tools: Visualizations, Models, and Online Data
February 10-12, 2008 at the University of Massachusetts, Amherst

Visualization Collections

Guest Conveners: Jim Slotta (University of California, Berkeley), Barbara Tversky (Stanford University)

http://serc.carleton.edu/NAGTWorkshops/visualization/index.html
Affective Domain, 2007

As science faculty, we naturally emphasize the cognitive domain in our teaching. After all, students think and learn with their brains (we hope!). Yet the affective domain can significantly enhance, inhibit or even prevent student learning. The affective domain includes factors such as student motivation, attitudes, perceptions and values. Teachers can increase their effectiveness by considering the affective domain in planning courses, delivering lectures and activities, and assessing student learning.

Resources for learning more about the affective domain

- [What is the affective domain?](http://serc.carleton.edu/NAGTWorkshops/affective/index.html) Includes background information, definitions and relevance of the affective domain in teaching.
- [A framework for applying the affective domain in science education](http://serc.carleton.edu/NAGTWorkshops/affective/index.html), including a summary of some current research on the topic and relevant questions to consider.
- [Literature review of affective domain](http://serc.carleton.edu/NAGTWorkshops/affective/index.html) books and journal articles, including teaching methods, measuring affective outcomes, and examples in the geosciences.

Guest convener: Thomas R. Koballa, Jr., Department of Mathematics and Science Education, University of Georgia

http://serc.carleton.edu/NAGTWorkshops/affective/index.html
Metacognition, 2009

The Role of Metacognition in Teaching Geoscience

The Role of Metacognition in the Classroom

An awareness of the learning process can improve learning dramatically (e.g., How People Learn, NRC 2000). Yet students are rarely taught how to develop this awareness. We can help our students to improve their learning by incorporating metacognition into our courses: by having them think about their thinking and by helping them to become aware of and monitor their learning strategies.

Resources for Teaching Metacognition

- This brief introduction defines metacognition and related terms and describes the results of research on the teaching and learning of metacognition.
- Teaching metacognition summarizes some of the recent research on teaching and learning metacognitive behaviors and describes some effective, easily incorporated teaching activities.
- We have a collection of teaching activities that focus on or include the teaching of metacognitive skills. If you have a teaching activity that incorporates metacognition, please share it.
- Strategies for teaching metacognition can provide ideas to incorporate metacognitive tactics into your classroom.

Guest Convener: Jenefer Husman, Psychology in Education, Arizona State University

http://serc.carleton.edu/NAGTWorkshops/metacognition/index.html
Research Collaborations

• Synthesis of Research and Learning in the Geosciences
  – Funded by NSF/REC
  – Journal Club
  – Synthesis review articles written by teams of geoscientist and learning/cognitive scientist
  – Earth and Mind Blog
    http://serc.carleton.edu/earthandmind/index.html

• Spatial Intelligence and Learning Center (SILC)
  – Multi-institutional collaboration
  – Interdisciplinary

• Geoscience Affective Research Network (Garnet)
  – Derived from Affective Domain workshop
Institutions and Degree Programs—A Sampling

• Michigan State University; Julie Libarkin
  – Geocognition Research Laboratory
    https://www.msu.edu/~libarkin/LIBARKIN.html
• Nir Orion, Weizmann Institute, Israel
• Arizona State University; Steve Reynolds
  – E.g. Visualizing Topography http://reynolds.asu.edu/
• North Carolina State University; David McConnell, Karen McNeal
  – Marine, Earth and Atmospheric Science Education Research
    http://www.meas.ncsu.edu/faculty/mcconnell/mcconnell.html
The Role of Professional Societies

Primary Dissemination—Print and Presentations

• National Association of Geoscience Teachers
  – Journal of Geoscience Education

• Geological Society of America,
  – Geocognition: Researching Student Learning in the Geosciences, 2008

• American Geophysical Union
  – Geocognition and Geoscience Education Research: Impacts on Course Curriculum and Student Learning, 2009
  – EOS articles
From Theory to Practice

• Target Audiences
  – Indigenous People

From Theory to Practice

• Learning Environments
  – Field Setting
    • Riggs, Balliet and Lieder (2009), Effectiveness in problem solving during geologic field examinations: insights from analysis of GPS tracks at variable time scales. GSA Special Paper 461
Moving research into practice

An emphasis on question-asking and problem-solving.

Use of visualizations, natural examples and graphics; annotations showing key features and process
Moving research into practice

Emphasis:

• Scale
• Knowing what to look for (disembedding)
• Interpreting process and history
• Metacognition
Future GER

• Learning in the laboratory, in the field
• Upper division teaching and learning
• MOOC’s and other on-line learning
• What “works” for diverse student audiences
• Geoscience habits of mind/ ways of knowing
• Research experiences for undergraduates
• How to assess mastery of:
  – Spatial, temporal, systems thinking
• Research technologies
  – Eye tracking, GPS, click-stream analysis….
• GER in K-12 and informal education
• Education around controversial issues (fracking, GMO’s, climate change)