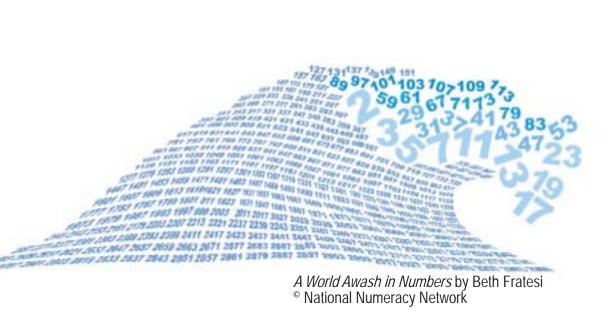
INFUSING QUANTITATIVE LITERACY INTO INTRODUCTORY COURSES:

BEST PRACTICES, COURSES AND ACTIVITIES

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ABSTRACT



As universities, employers, and the mass media place more emphasis on quantitative and problem solving skills, the geosciences must shed the public's misperception that they are a descriptive science. In particular, the role that quantitative literacy (QL) plays in understanding

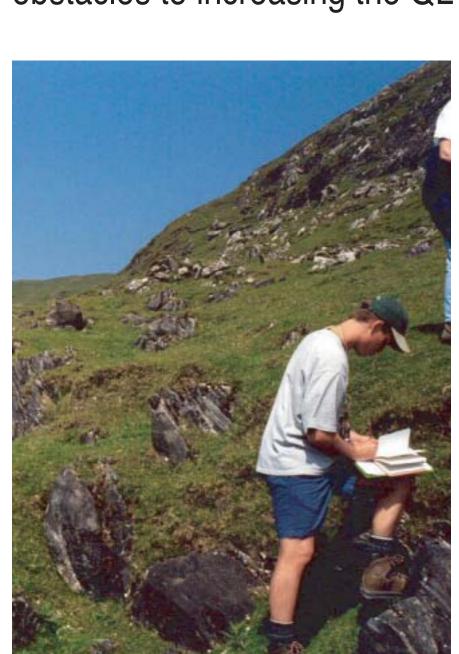
the world around us can and should be stressed in general education introductory geoscience courses, where the general public can be reached. In June 2006, the NSF funded, DLESE supported project "Teaching Quantitative Skills in the Geosciences" held a workshop for geoscience instructors to generate courses and activities designed to help them to increase the QL of introductory students. The workshop, entitled "Infusing Quantitative Literacy into Introductory Courses", brought together 29 faculty members from high schools, 2year, and 4-year institutions to discuss the importance and implementation of courses and activities that include QL in introductory geoscience

Workshop participants explored challenges and best practices for increasing students' QL, recognizing and working on ways to overcome obstacles such as student and faculty attitudes and preparation, lack of institutional and textbook support, and insufficient problem-solving skill instruction. Because the inclusion of QL must incorporate essential instruction, work time and support for students, participants worried that some loss of geologic content may be necessary. Nonetheless, participants identified multiple broad geologic topics and best practice strategies for incorporating QL into their courses without significant loss of content. We present best practices, perceived obstacles, and participants' quantitatively-rich student activities and model syllabi for courses suffused with student practice of quantitative skills. Sample syllabi and activities can be found among the growing collection of materials that support teaching quantitative skills: http://serc.carleton.edu/quantskills/.

WHAT IS QL AND WHY IS IT DIFFICULT?

Quantitative literacy (QL) involves a "habit of mind" that engages students (and citizens) in using data in everyday context. QL is increasingly important for an educated citizenry because data drives decisions - political, economic and social. Geoscience courses provide excellent context for timely data problems. So, why don't more geoscience courses include QL?

Participants at a workshop that met in June 2006 discussed numerous difficulties and obstacles to increasing the QL of their courses:



- Student attitudes: not "cool" to be smart, anxiety about math /being wrong, lack of motivation/persistence, want "right" answer
- Student Preparation: wide variety of skills, lack of experience/ patience/critical thinking/common sense
- Difficulty integrating QL and geoscience: terminology/ vocabulary barriers, application is difficult.
- Faculty concerns: time constraints, design is challenging, textbooks lack quantitative content, lack of preparation/confidence
- Faculty resistance: time constraints, content vs. QL, assessment
- Lack of institutional/departmental support: no vertical integration in quantitative skills, lack of commitment by department/administrators to QL, classroom/curriculum design
- Public perception that Earth Sciences are descriptive
- **Negative (?) impact on enrollments and evaluations**

WORKING TO OVERCOME PERCEIVED OBSTACLES

During the workshop, participants discussed a variety of ways that they, their departments or institutions are working to overcome barriers to inclusion of QL in their introductory courses.

Student preparation and faculty concerns: At Highline Community College, near Seattle, Eric Baer and his colleagues designed a onecredit course called MathPatch. MathPatch is:

- a required component of introductory Geology at HCC
- designed to give students experience just before quantitative geologic context is presented in class

Dr. Baer indicates that results are contrary to what faculty and administrators fear:

- Increased quantitative content does not lower enrollments
- Increased student retention (73% pre- to 85% post-MathPatch)
- Improved student performance

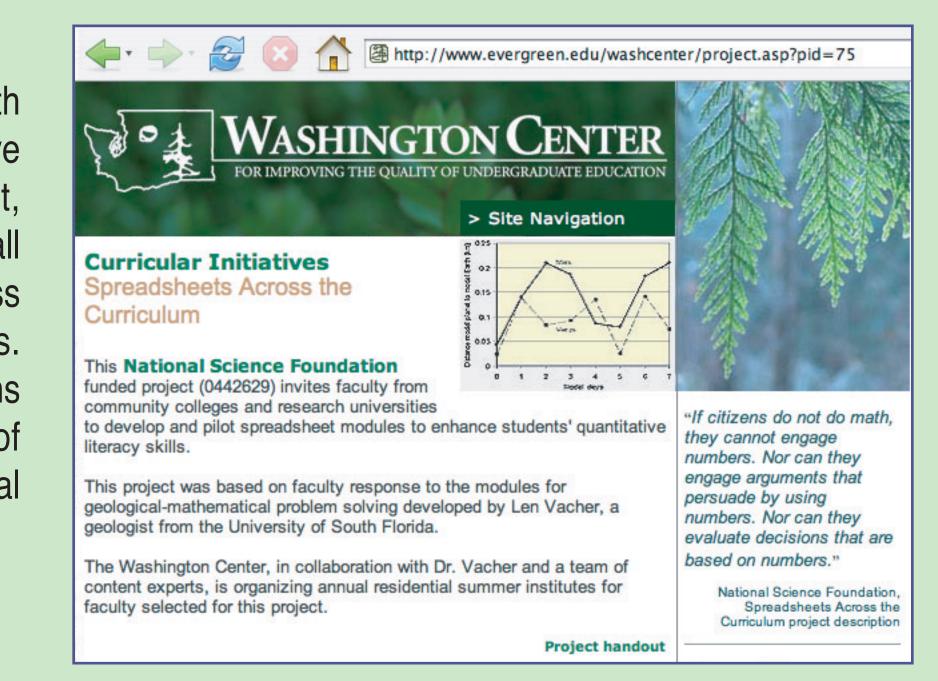
Difficulty integrating QL and geoscience: The geosciences can provide the rich context needed for thinking about and using data (QL). Participants at the workshop worked to identify topics that must be included in introductory geoscience. When building courses around topics, the groups determined which quantitative concepts were involved in each of the topics (see grid by A. Awad, P. Selkin and C. Dodd below).

Introduction to Earth Systems Science	Find a system in your home / everyday life	Travel and Traffic Conceptual Model	Thermostat as a model	Energy Balance in the Atmosphere	Evaporation Measurement and Calculation	Mass Balances and Evaporation / Precipitatio	Greenland Ice Metting Case Study	Geochemical Tracers and the Rock Cycle	Simulated Ecosystem Game	Simulated Ecosystem Model	Carbon Cycle / Climate Change	Biodiversity
Quantitative Skills and Topics												
Order of magnitude	x		×	×	×	×	×	×	×	×	×	×
Units	×		×	×	×	×	×	×	×	×	×	×
Graphing / Time series			×	×		×	×	×		×	×	>
Graphing / Spatial series, contouring, and mapping					×	×	×					×
Graphing / General				×	×	×	×	×			×	×
Trends and correlation				×	×	×	×	×			×	×
Ratios					×	×	x	×			×	×
Descriptive statistics										×	×	×
Distributions / Histograms										x		×
Modeling / Descriptive	×	×	x	x	x	×	×	x	×	x	×	×
Modeling / Predictive						×	x			x	x	×
Modeling / Diagrammatic	x	x	x	x	x	x	×	x	×	x	x	×
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Content issues: During a break-out session at the workshop, one group explored the question of depth vs. breadth for geoscience courses. They identified some broad, key topics that all agreed must be included in introductory geoscience and still make room for QL:

- * Plate tectonics
- * Earth as a system
- * Climate change
- * Deep time * Energy resources
- * Water cycle
- * Rock cycle

Curricular initiatives: Len Vacher (University of South Florida) spoke about initiatives to integrate quantitative literacy across the curriculum. Len's project, "Spreadsheets across the Curriculum", promotes QL in all disciplines at the college level and gives students access to an important quantitative/data tool - spreadsheets. The Teaching Quantitative Skills website also contains information about ways to include QL in all levels of geoscience. Other organizations include the National Numeracy Network, QL-SigMAA and QELP.





Institutional support: Discussion in one break-out group focused models of institutional support. Mona Sirbescu (Central Michigan University, at left), Alan Whittington (University of Missouri) and Len Vacher (USF) talked about QL general education requirements at their universities and how geology departments can take advantage of these requirements. Others without QL requirements emphasized the importance of being deliberate about teaching QL in geoscience courses - recognizing topics that are quantitative and pushing students slightly outside their comfort zones.

MODEL COURSES

At the workshop, faculty worked to infuse courses with quantitative literacy exercises. Their many models often addressed the obstacles of student attitudes/preparation. For example, at California State University-Chico, Dr. Rachel Teasdale builds students' quantitative skills by scaffolding quantitative exercises

throughout her introductory geology lab. Multiple labs reinforce quantitative skills learned earlier in the semester:

- · Lab 1: Campus walk measure pace, river velocity. Sets rigor/expectations.
- Lab 5: Topo maps 3-D visualization.
- Lab 9: Field trip topo map interpretation, stream measurements.
- Lab 12: Homework calculate stream characteristics and enter data from Lab 1 to prep for comparison in Lab 13.
- Lab 13: Rivers and Streams grain size analysis, carrying capacity, comparison of data from Labs 1 and 13.

Workshop groups worked to build courses that clearly integrated geoscience with QL. For example, a group of educators interested in Earth Systems Science built a summary grid of essential topics and the associated quantitative skills (Working to Overcome Perceived Obstacles, left) Each topic in their syllabus has an associated exercise that uses quantitative skills and essential tools such as STELLA and spreadsheet programs (e.g., Excel).

All of the model courses and syllabi can be found on the Workshop website:

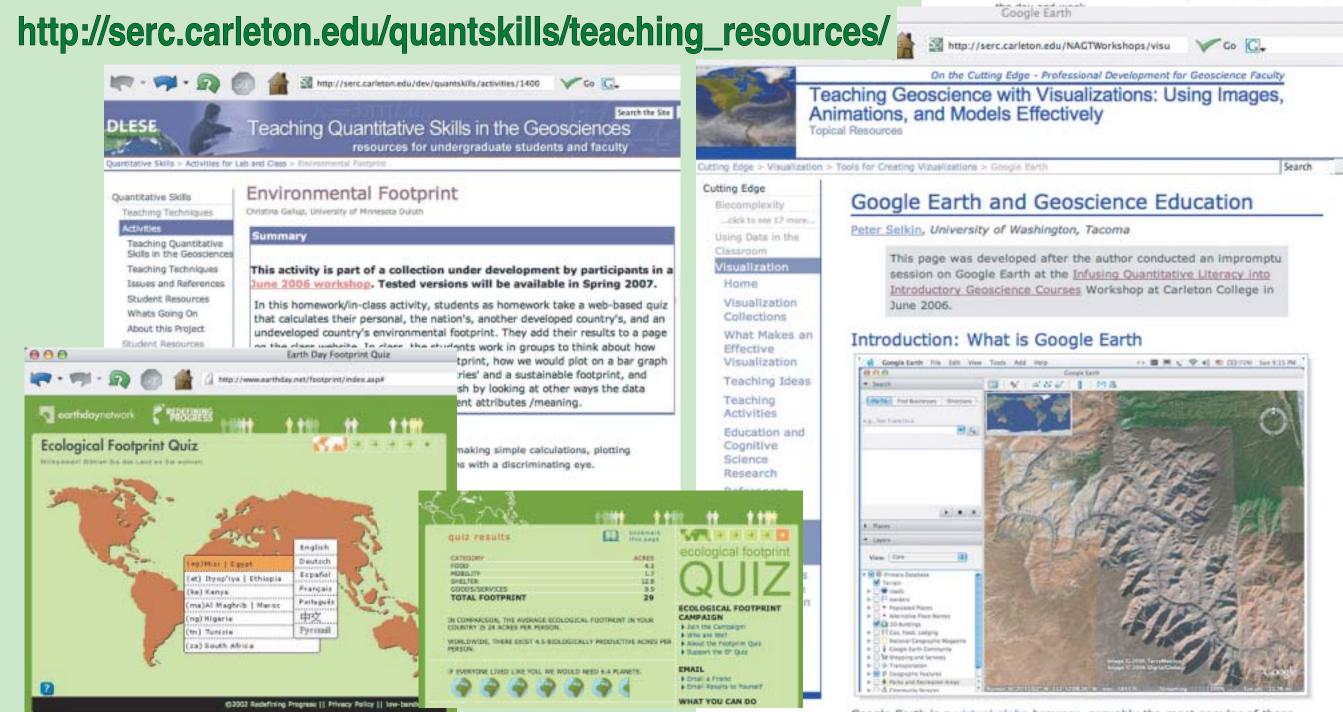
http://serc.carleton.edu/quantskills/workshop06/browse_courses.html

READY-TO-USE ACTIVITIES, LABS AND TUTORIALS

Workshop participants also produced a number

Teaching Quantitative Skills in the Geosciences

Teaching Quantitative Skills in the Geosciences of ready-to-use, downloadable activities laboratory assignments and tutorials. Each is integrate quantitative literacy **EUSGS** into introductory courses. These and many other QL Quantitative Skills Website housed at SERC:



http://serc.carleton.edu/quantskills/workshop06/activities.html

INFUSING PROBLEM SOLVING INTO GEOSCIENCE COURSES: LESSONS FROM PHYSICS

Ken Heller, Professor of Physics at University of Minnesota, was invited to speak to the workshop participants about numerous ways that physics has supported students' quantitative learning.

What is Problem Solving?

Process of moving toward a goal when path is uncertain -- if you know how to do it, it's not a problem

Problems are solved using general purpose tools -- not specific algorithms

Problem Solving Involves error and uncertainty

A problem for your student is not a problem for you! -- Exercise vs. Problem

M. Martinez, *Phi Delta Kappan*, April, 1998

How do we as faculty reinforce this?

- require students to memorize equations

-- allow students to bring "crib" sheets

Teach students a framework for approaching problems [e.g., Polya (1957)]

1. Recognize the problem

http://serc.carleton.edu/quantskills/courses/14007.html 🔻 🔘 Ğ youtube

eaching Quantitative Skills in the Geosciences

Introduction to Earth Systems Science

resources for undergraduate students and faculty

- 2. Describe the problem in the context of geology
- 3. Plan a solution
- 4. Execute the plan
- 5. Evaluate the solution

How do we reinforce this?

Single step problems



or, deal with numbers not equations (plug in #'s ASAP)

-- an organized framework

Assign and discuss problems that require:

- -- conceptual knowledge from Geology -- connection to existing knowledge
- Use existing course structure no modification required!:

-- Lectures act as modeling sessions (professors model problem solving

- skills for students)
- -- Labs act as coaching sessions (TA's and/or professors coach students on how to solve problems)

Students' Misconceptions about Problem Solving Need to know the right formula to solve a problem The "magic" is in the Mathematics (numbers) so, memorize formulas or solution patterns so, manipulate equations quickly (plug & chug)

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http://serc.carleton.edu/quantskills/workshop06/