


Developing the QL Habit of Mind in Multiple Contexts: Geoscience Education Modules

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 University of South Florida
 Tampa FL



1. Spreadsheet modules – Vacher
 a. In geological-mathematical problem solving.
 b. Across the curriculum.
2. Resources for spreadsheets in education – Fratesi

Creating and Strengthening Interdisciplinary Programs in QL
 PREP Workshop, Macalester College, St. Paul, MN
 6/15/05

Vacher's part

- General comments.**
- NSF DUE-0126500 (5/15/02 – 4/30/03): Modules for geological-mathematical problem solving. Proof of concept.**
- NSF DUE-0442629 (7/05 – 6/08): Spreadsheets across the curriculum. Full development.**

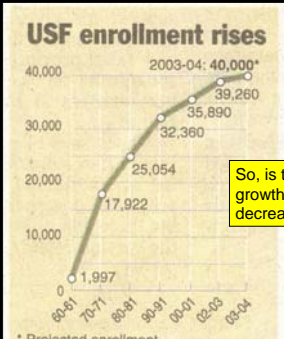
Another idea – Saturday, 4 pm, NNN meeting

Hands-on math as a lab course – a perspective from introductory geology.

Where I'm coming from

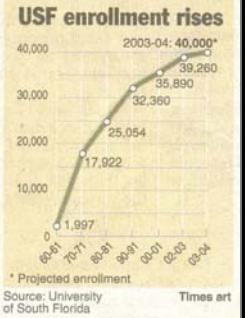


USF enrollment rises

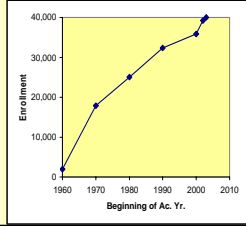


Source: University of South Florida

QL: Create SS to redraw graph with a quantitatively literate x-axis.



Fall	N
1960	1,997
1970	17,922
1980	25,054
1990	32,360
2000	35,890
2003	40,000




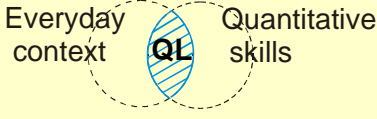
Key fact: Every course that uses tables and graphs is an opportunity to enhance QL.

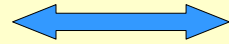
QUANTITATIVE LITERACY (NUMERACY)

Voltaire: If you want to converse with me define your terms.


QL: A habit of mind in which one engages numbers in everyday context.



Everyday context  Quantitative skills

QL  **Math phobia**
Math anxiety
Math avoidance


A WORLD AWASH IN NUMBERS!



Are our students being prepared to handle numbers?

- A workplace issue.
- A citizenship issue.

See *Mathematics and Democracy* at www.math.dartmouth.edu/~nnn



Attitudes of Full-Time Faculty Members (1998-1999)

Goals for undergraduates noted as essential or very important

Develop ability to think clearly.	99.4%
Prepare students for employment after college.	70.7%
Enhance students' self-understanding.	61.8%
Prepare students for responsible citizenship.	60.0%
Help students develop personal values.	59.7%
Enhance racial/ethnic diversity.	57.8%
Develop national/global awareness.	57.5%
Prepare students for the workforce.	56.0%
Enhance the out-of-class experience of students.	41.2%
Provide for students' emotional development.	38.2%
Instill in students a commitment to community service.	36.2%
Teach students the classic works of Western civilization.	28.4%
Prepare students for family living.	17.8%

Note: Fully 130.7% of full-time faculty members are in-step with the goals of QL!

CHE Almanac, 8/31/2001, p. 29
On designing new courses →

Barbara J. Tewksbury, R. Heather Macdonald, Cathryn A. Manduca, and David W. Mogk, 2004: *On the Cutting Edge: Improving Faculty Ability to Design Innovative Courses*.

The method that faculty use most frequently for designing new courses and developing course syllabi involves making a list of the most important topics in a discipline, culling topics until the list is of reasonable length, arranging the topics in a logical order, and developing syllabus, lectures, labs, assignments and exams around the list of topics....

As part of a workshop program for faculty development in the geosciences, (we have) ... developed and offered workshops ... that guide participants ... (to) articulate goals and design effective and innovative courses that both meet those goals and assess outcomes. The process begins, not with a list of content items, but with setting goals by answering the question, "What do I want my students to be able to do on their own when they are done with my class?", rather than the question, "What do I want my students to know in this subject?"

NSF and AAAS, Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics, A Conference of the Course, Curriculum and Laboratory Improvement (CCLI) Program, April 16-18, 2004, Crystal City, Virginia. , p. 39.

What do I want my students to be able to do on their own when they are done with my class?

Solve problems.

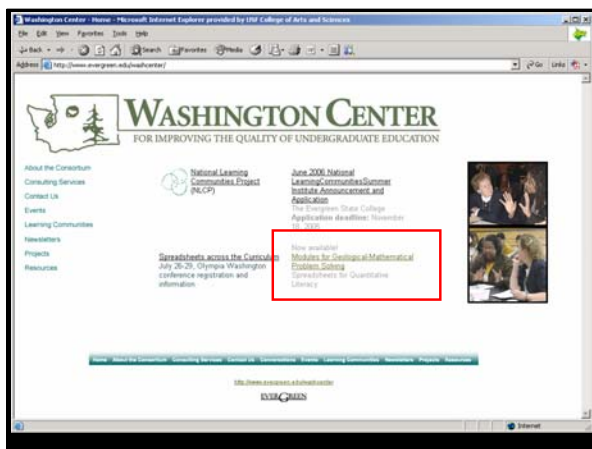
Polya.

Our knowledge about any subject consists of *information* and of *know-how*. If you have genuine *bona fide* experience of mathematical work on any level, elementary or advanced, there will be no doubt in your mind that, in mathematics, **know-how is much more important than mere possession of information.**

What is know-how in mathematics? The ability to solve problems -- not merely routine problems but problems requiring some degree of independence, judgment, originality, creativity. (p. vii-viii)

A problem is a 'great' problem if it is very difficult, it is just a 'little' problem if it is just a little difficult. Yet some degree of difficulty belongs to the very notion of a problem: **where there is no difficulty, there is no problem.** (p. 117)

Mathematical Discovery: On Understanding Learning, and Teaching Problem Solving (Wiley, v. 1, 1962, 216 pp; v. 2, 1965, 191 pp.



Washington Center Home - Microsoft Internet Explorer provided by UW College of Arts and Sciences

Address: <http://www.evangelist.edu/washingtoncenter/>

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FOR IMPROVING THE QUALITY OF UNDERGRADUATE EDUCATION

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National Learning Communities Project (NLCP)
June 2006 National Learning Communities Summer Institute Announcement and Application
The Evangelist State College Application Deadline: November 15, 2005

Searchlights across the Curriculum
July 26-29, 2006 Christian Theological conference registration and information

New Analytical Modules for Geometrical Mathematical Problem Solving
Contributions for Quantitative Literacy

WU Online

Modules for Geometrical-Mathematical Problem Solving

Lon Vacher presented preliminary versions of some spreadsheet modules at our August 2003 QL Institute.

Washington Center is pleased to post 14 student modules that you can use in your classes. Visit the "Notes for Faculty" page for more information.

This year's QL Institute will be held Aug 17-20.

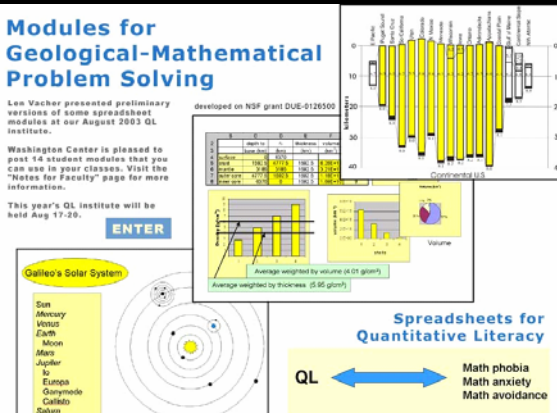
ENTER

Galileo's Solar System

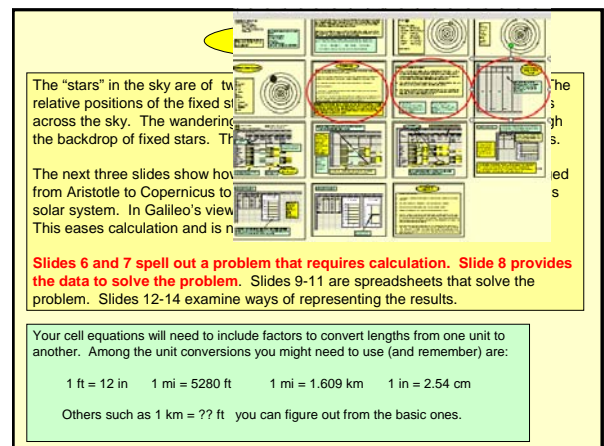
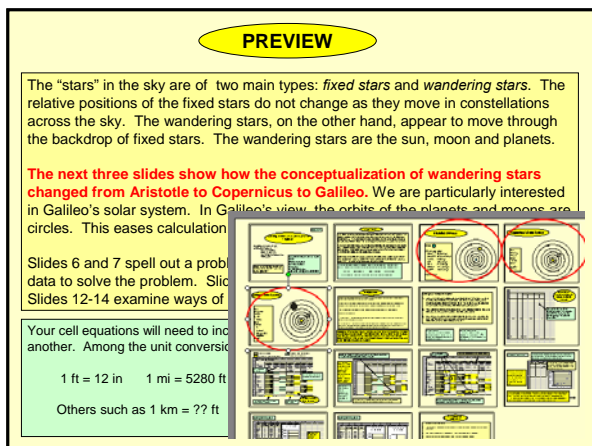
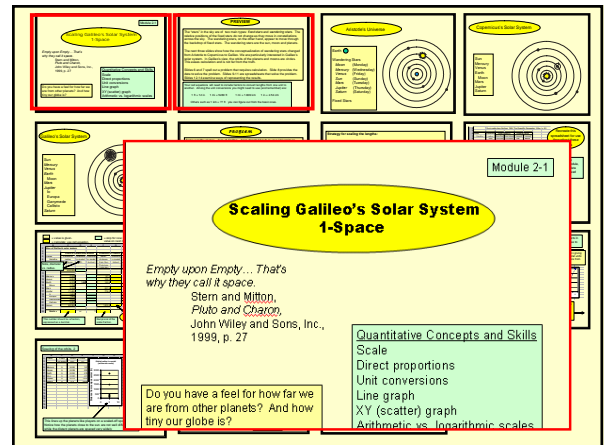
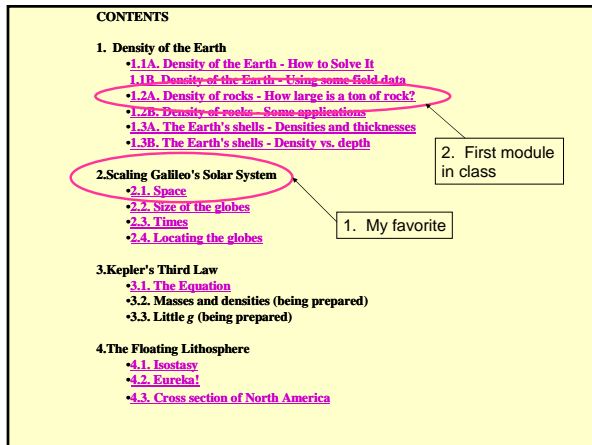
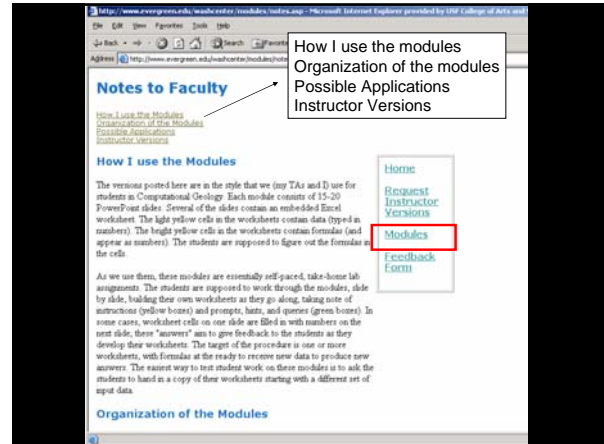
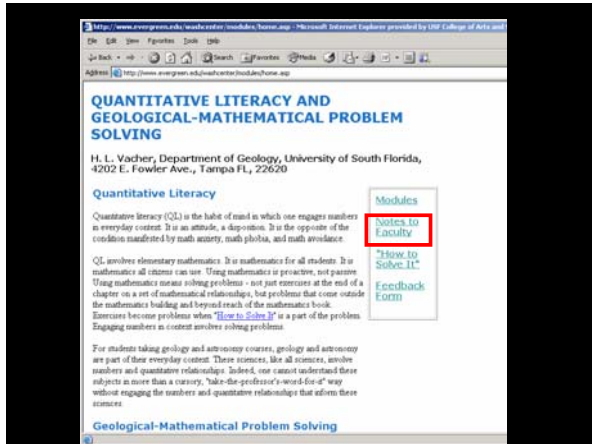
- Sun
- Mercury
- Venus
- Earth
- Moon
- Mars
- Jupiter
- Europa
- Quaymode
- Callisto
- Saturn

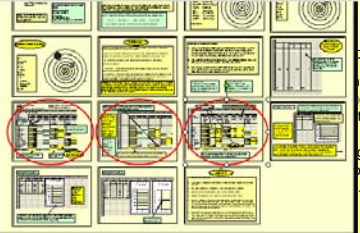
Spreadsheets for Quantitative Literacy

QL ↔ Math phobia
Math anxiety
Math avoidance



Average assigned by volume: 0.11 grams
Average assigned by thickness: 0.56 grams





The "stars" in the sky are of relative positions of the fixed stars across the sky. The wandering stars have the backdrop of fixed stars.

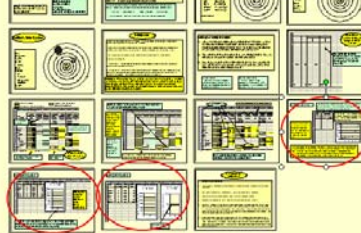
The next three slides show how the heliocentric model from Aristotle to Copernicus to Galileo's solar system. In Galileo's view, this eases calculation and is

Slides 6 and 7 spell out a problem that requires calculation. Slide 8 provides the data to solve the problem. **Slides 9-11 are spreadsheets that solve the problem.** Slides 12-14 examine ways of representing the results.

Your cell equations will need to include factors to convert lengths from one unit to another. Among the unit conversions you might need to use (and remember) are:

1 ft = 12 in 1 mi = 5280 ft 1 mi = 1.609 km 1 in = 2.54 cm

Others such as 1 km = ?? ft you can figure out from the basic ones.



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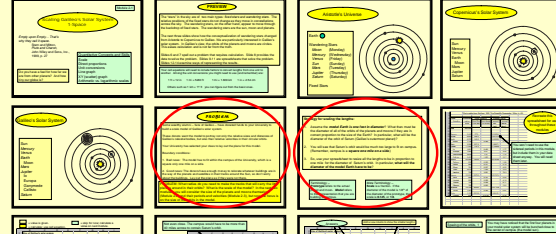
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Others such as 1 km = ?? ft you can figure out from the basic ones.



PROBLEM

Some wealthy alumni -- fans of Galileo -- have donated funds to your University to build a scale model of Galileo's solar system.

These donors want the model to portray not only the relative sizes and distances of Galileo's celestial bodies, but also their relative velocities in their circular orbits.

Your University has selected your class to lay out the plans for this model.

Boundary conditions:

- Bad news: The model has to fit within the campus of the University, which is a square only one mile on a side.
- Good news: The donors have enough money to relocate whatever buildings are in the way of the planets and satellites in their tracks around the Sun, so don't worry about the buildings. Lay out the plans as if they were not there.

PROBLEM: What radius do you need to make the tracks that will carry the little planets around in their orbits? What is the scale of the model? In the next two modules, you will consider the size of the planets and moons themselves (Module 2.2) and their periods and velocities (Module 2.3), but now the focus is on the size of the orbits in the model.

Strategy for scaling the lengths:

- Assume the **model Earth is one foot in diameter?** What then must be the diameter of all of the orbits of the planets and moons if they are in correct proportion to the size of the Earth? In particular, what will be the diameter of the orbit of Saturn (Galileo's outermost planet)?
- You will see that Saturn's orbit would be much too large to fit on campus. (Remember, campus is a **square one mile on a side.**)
- So, use your spreadsheet to resize all the lengths to be in proportion to one mile for the diameter of Saturn's orbit. In particular, **what will the diameter of the orbit for the model Earth have to be?**

Terminology --
Prototype refers to the actual planet and moon. **Model** refers to the representation that you are building on campus.

More Terminology --
Scale is a fraction. If the diameter of the model is 1/8th of the diameter of the prototype, the scale is **0.125**, or **1:8**.

End of Module Assignments

- Do the two side exercises.
- The term solar system does not apply to Aristotle's concept of planets, sun and moon. Why not?
- How does Galileo's solar system differ from Copernicus's solar system?
- Why would one use a logarithmic, rather than an arithmetic, scale?
- What is the advantage of an XY (scatter), as opposed to a line, graph?
- Use an XY (scatter) graph to plot orbital radius (y) vs. planet number (x). Add Uranus, Neptune and Pluto, so that x will range from 1 (Mercury) to 9 (Pluto). Make a second XY graph using a logarithmic scale of the orbital radius. Fit an exponential trend line to each graph and record the R² value (right click on a data point in the graph, select Trend line, select exponential, select options).
- Repeat Exercise 6, inserting a planet (x = 5) to represent the asteroids between Mars and Jupiter. The asteroids lie at an average of 2.4 AU from the sun. Now x will range from 1 (Mercury) to 10 (Pluto). Draw both graphs: one with an arithmetic scale and the other with a logarithmic scale. How does the fitted exponential trend line compare to the one in Exercise 6?

CONTENTS

- Density of the Earth**
 - 1.1A. Density of the Earth - How to Solve It
 - 1.1B. Density of the Earth - Using some field data
 - 1.2A. Density of rocks - How large is a ton of rock?
 - 1.2B. Density of rocks - Some applications
 - 1.3A. The Earth's shells - Densities and thicknesses
 - 1.3B. The Earth's shells - Density vs. depth
- Scaling Galileo's Solar System**
 - 2.1. Space
 - 2.2. Size of the globes
 - 2.3. Times
 - 2.4. Locating the globes
- Kepler's Third Law**
 - 3.1. The Equation
 - 3.2. Masses and densities (being prepared)
 - 3.3. Little g (being prepared)
- The Floating Lithosphere**
 - 4.1. Isostasy
 - 4.2. Eureka!
 - 4.3. Cross section of North America

2. First module in class

Module 1-2A

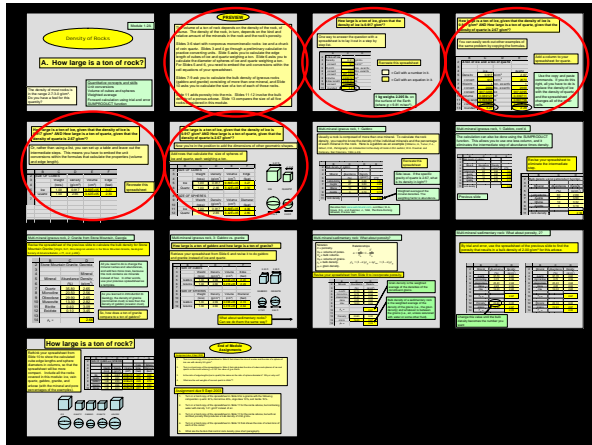
Density of Rocks

A. How large is a ton of rock?

The density of most rocks is in the range 2.7-3.0 g/cm³. Do you have a feel for this quantity?

Quantitative concepts and skills
 Unit conversions
 Volume of cubes and spheres
 Weighted average
 Forward calculation using trial and error
 SUMPRODUCT function

1



PREVIEW

The volume of a ton of rock depends on the density of the rock, of course. The density of the rock, in turn, depends on the kind and relative amount of the minerals in the rock and the rock's porosity.

Slides 3-6 start with nonporous monomineralic rocks: ice and a chunk of vein quartz. Slides 3 and 4 go through a preliminary calculation to practice converting units. Slide 5 asks you to calculate the edge length of cubes of ice and quartz weighing a ton. Slide 6 asks you to calculate the diameter of spheres of ice and quartz weighing a ton. For Slides 5 and 6, you need to embed the unit conversions within the cell equations of your spreadsheet.

Slides 7-9 ask you to calculate the bulk density of igneous rocks (gabbro and granite) consisting of more than one mineral, and Slide 10 asks you to calculate the size of a ton of each of those rocks.

Slide 11 adds porosity into the mix. Slides 11-12 involve the bulk density of a porous arkose. Slide 13 compares the size of all five rocks considered in this module.

Slide 14 gives the assignment to hand in.

2

How large is a ton of ice, given that the density of ice is 0.917 g/cm³?

One way to answer the question with a spreadsheet is to lay it out in a step by step list.

	B	C	D
2	A ton of ice		
3	Density	0.917	g/cm ³
4	convert	917	kg/m ³
5	Weight	1	ton, exactly
6	convert	2000	lbs, exactly
7	convert	907.0295	kg
8	Volume	0.989127	m ³
9	Edge length	0.996362	m
10	convert	3.269665	ft
11	rounded	3.27	ft

Recreate this spreadsheet

= Cell with a number in it.
 = Cell with an equation in it.

1 kg weighs 2.205 lb. on the surface of the Earth (where g = 9.81 m/sec²).

3

How large is a ton of ice, given that the density of ice is 0.917 g/cm³ AND How large is a ton of quartz, given that the density of quartz is 2.67 g/cm³?

You can easily work out other examples of the same problem by copying the formulas.

	B	C	D	E
2	A ton of ice and a ton of quartz			
3				
4		ice	quartz	
5	Density	0.917	g/cm ³	2.67
6	convert	917	kg/m ³	2670
7	Weight	1	ton, exactly	1
8	convert	2000	lbs, exactly	2000
9	convert	907.0295	kg	907.0295
10	Volume	0.989127	m ³	0.339711
11	Edge length	0.996362	m	0.697756
12	convert	3.269665	ft	2.289396
13	rounded	3.27	ft	2.29

Add a column to your spreadsheet for quartz.

Use the copy and paste commands. If you do this right, all you have to do is replace the density of ice with the density of quartz, and the spreadsheet changes all of the other cells.

4

How large is a ton of ice, given that the density of ice is 0.917 g/cm³ AND How large is a ton of quartz, given that the density of quartz is 2.67 g/cm³?

Or, rather than using a list, you can set up a table and leave out the intermediate steps. This means you have to embed the unit conversions within the formulas that calculate the properties (volume and edge length).

	B	C	D	E	F
2	SIZE OF CUBES				
3		Weight	Density	Volume	Edge
4		(tons)	(g/cm ³)	(cm ³)	(feet)
5	Ice	1.00	0.917	9.89E+05	3.27
6	Quartz	1.00	2.65	3.42E+05	2.30
7					

Recreate this spreadsheet

5

How large is a ton of ice, given that the density of ice is 0.917 g/cm³ AND How large is a ton of quartz, given that the density of quartz is 2.67 g/cm³?

Now you're in the position to add the dimensions of other geometric shapes.

Add rows that calculate the size of spheres of ice and quartz, each weighing a ton.

	B	C	D	E	F
2	SIZE OF CUBES				
3		Weight	Density	Volume	Edge
4		(tons)	(g/cm ³)	(cm ³)	(feet)
5	Ice	1.00	0.917	9.89E+05	3.27
6	Quartz	1.00	2.65	3.42E+05	2.30
7					
8	SIZE OF SPHERES				
9		Weight	Density	Volume	Diameter
10		(tons)	(g/cm ³)	(cm ³)	(feet)
11	Ice	1.00	0.917	9.89E+05	4.06
12	Quartz	1.00	2.65	3.42E+05	2.85

ICE QUARTZ

6

Multi-mineral igneous rock, 1: Gabbro

Usually a rock is composed of more than one mineral. To calculate the rock density, you need to know the density of the individual minerals and the percentage of each mineral in the rock. Here is a gabbro as an example (Williams, H., Turner, F.J., Gilbert, C.M., *Petrography: An Introduction to the study of rocks in thin section*, W.H. Freeman and Company, San Francisco, 1954, p.49).

	B	C	D	E
2	Bulk density of gabbro			
3				
4	Mineral	Abundance	Density	
5		(%)	(g/cm ³)	C*D
6	Labradorite	60	2.69	1.61
7	Augite	27	3.50	0.95
8	Olivine	10	3.32	0.33
9	Apatite	3	3.19	0.10
10				
11	rock density			2.99

Recreate this spreadsheet

Side issue. If the specific gravity of quartz is 2.67, what is its density in kg/m³?

Weighted average of the mineral densities. The weighting factor is abundance.

Densities from www.webmineral.com, and Deer, W.A., Howie, R.A., and Zussman, J., 1992, *The Rock-Forming Minerals*, Prentice Hall.

7

Multi-mineral igneous rock, 2: Granite from Stone Mountain, Georgia

Revise the spreadsheet of the previous slide to calculate the bulk density for Stone Mountain Granite (Wright, N.P., Mineralogical variation in the Stone Mountain Granite, *Geological Society of America Bulletin*, v 77, no 2, p 208).

	B	C	D
2	Stone Mountain Granite, Georgia		
3			
4	Mineral	Abundance	Mineral Density
5		(%)	(g/cm ³)
6	Quartz	35.80	2.65
7	Microcline	20.50	2.56
8	Oligoclase	29.90	2.65
9	Muscovite	13.30	2.82
10	Biotite	0.40	3.09
11	Epidote	0.10	3.45
12			
13	$\rho_b =$		2.66

All you need to do is change the mineral names and abundances, and add two more rows, because this rock contains six minerals instead of four. In other words, use your previous spreadsheet as a template.

As you learned in *Introduction to Geology*, the density of granite (continental crust) is less than the density of gabbro (oceanic crust).

So, how does a ton of granite compare to a ton of gabbro?

9

Multi-mineral sedimentary rock: What about porosity?

Notation
 n = porosity.
 V_p = volume of pores.
 V_b = bulk volume.
 V_g = volume of grains.
 ρ_b = bulk density.
 ρ_g = grain density.

Relationships

$$n = \frac{V_p}{V_b} = 1 - \frac{V_g}{V_b}$$

$$\rho_b = (1 - n)\rho_g + n\rho_{air} = (1 - n)\rho_g$$

Revise your spreadsheet from Slide 9 to incorporate porosity.

	B	C	D
2	Mineral	Abundance	Density
3		(%)	(g/cm ³)
4	quartz	37.70	2.65
5	microcline	0.70	2.56
6	plagioclase	45.40	2.65
7	mica	4.20	2.82
8	clay	12.00	2.65
9			
10	$\rho_g =$		2.67
11			
12	Porosity	23.80	0.00
13	grains	76.20	2.67
14	$\rho_b =$		2.03

Grain density is the weighted average of the densities of the constituent grains.


Bulk density of a sedimentary rock is the weighted average of the density of the grains (i.e., the grain density) and whatever is between the grains (i.e., air, unless saturated with water or some other fluid).

11


How large is a ton of rock?

Rethink your spreadsheet from Slide 10 to show the calculated cube edge lengths and sphere diameters in columns, so that the spreadsheet will be more compact. Include all the rocks covered in this module: ice, vein quartz, gabbro, granite, and arkose (with the mineral and pore percentages of the examples).


	B	C	D	E	F	G
2	SIZE OF CUBES and SPHERES					
3					Cube	Sphere
4		Weight	Density	Volume	Edge	Diameter
5		(tons)	(g/cm ³)	(cm ³)	(feet)	(feet)
6	Ice	1.00	0.917	9.88E+05	3.27	4.06
7	Quartz	1.00	2.65	3.42E+05	2.30	2.55
8	Gabbro	1.00	2.99	3.03E+05	2.20	2.74
9	Granite	1.00	2.66	3.41E+05	2.29	2.84
10	Arkose	1.00	2.03	4.47E+05	2.51	3.11




ICE




QUARTZ




GABBRO





GRANITE





ARKOSE











13

End of Module Assignments

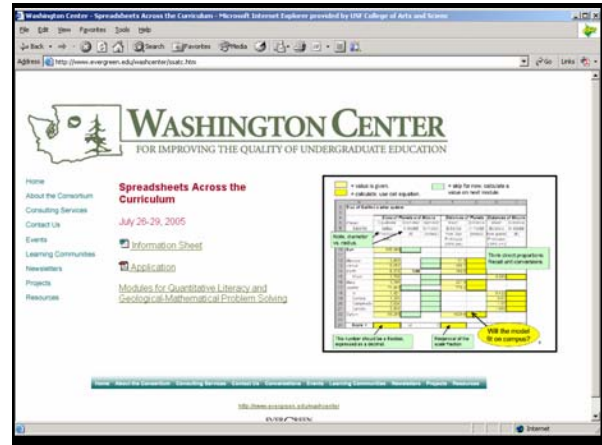
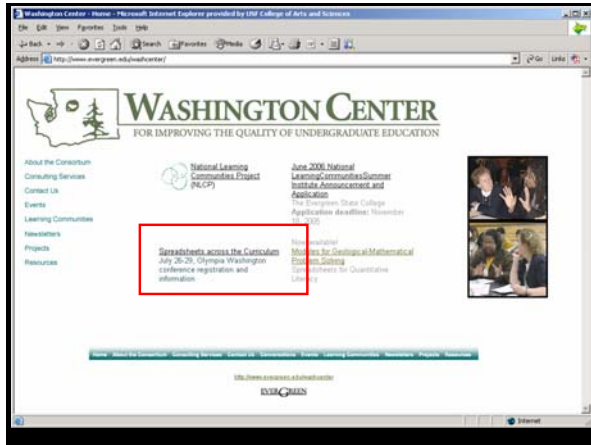
Assignment due 4 Sept 2003

- Turn in a hard copy of the spreadsheet in Slide 6 that shows the size of a cube and the size of a sphere of iron ore with density 5.5 g/cm³.
- Turn in a hard copy of the spreadsheet in Slide 4 that calculates the size of cubes and spheres of ice and quartz on the moon where $g = 0.167$ the value of g on Earth.
- Is the ratio of edge lengths (ice to quartz) the same as the ratio of sphere diameters? Why or why not?
- What are the unit weights of ice and quartz in kN/m³?

Assignment due 9 Sept 2003

- Turn in a hard copy of the spreadsheet in Slide 9 for a granite with the following composition: quartz 30%, microcline 45%, oligoclase 10%, and biotite 15%.
- Turn in a hard copy of the spreadsheet in Slide 11 for the same arkose, but containing water with density 1.01 g/cm³ instead of air.
- Turn in a hard copy of the spreadsheet in Slide 11 for the same arkose, but with an air-filled porosity that produces a bulk density of 2.50 g/cm³.
- Turn in a hard copy of the spreadsheet in Slide 13 that shows the size of a two tons of each of the rocks.
- What are the factors that control rock density (one short paragraph).

14




BROADER IMPACTS

QL is a Human Resources Development Issue


Human Resource Managers:
 Goal: To increase employee productivity.
 Mission: Increase employees' ability to produce.

Educators in academia:
 Goal: To increase student learning.
 Mission: Increase students' ability to learn.

The Case for Spreadsheets:
 → HR: Spreadsheets increase employees' ability to produce.
 → QL: Spreadsheets increase students' ability to learn.



In the Mind's Eye

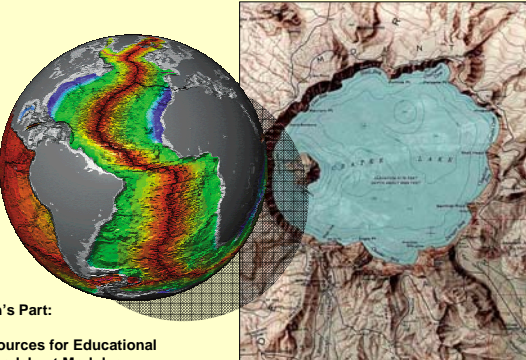


Polya

Spreadsheets make it happen.

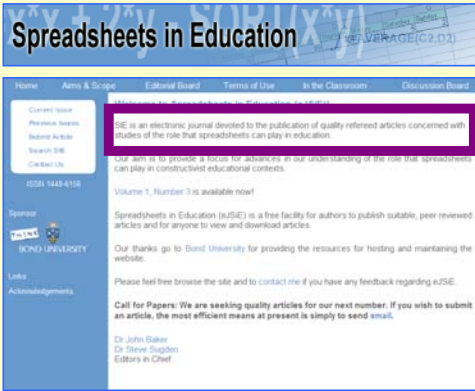
Not just enter-and-watch spreadsheets, but spreadsheets that students create to solve problems.

The more spreadsheets the better.



Beth's Part:
Resources for Educational Spreadsheet Modules Examples in the Geosciences

Images: NOAA, USGS



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Spreadsheets in Education (sJSE) is an electronic journal devoted to the publication of quality refereed articles concerned with studies of the role that spreadsheets can play in education.

Our aim is to provide a focus for advances in our understanding of the role that spreadsheets can play in constructivist educational contexts.

Volume 1, Number 3 is available now!

Spreadsheets in Education (sJSE) is a free facility for authors to publish suitable, peer reviewed articles and for anyone to view and download articles.


Our thanks go to Bond University for providing the resources for hosting and maintaining the website.

Please feel free to browse the site and to contact me if you have any feedback regarding sJSE.

Call for Papers: We are seeking quality articles for our next number. If you wish to submit an article, the most efficient means at present is simply to send email.

Dr John Baker
Dr Steve Suggden
Editors in Chief

www.sie.bond.edu.au



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Sergio Spreadsheet-Enhanced Problem Solving in Context as Modeling

John Baker & Steve Suggden Spreadsheets in Education: The First 25 Years

Gabriela Loufciuc

In the Classroom Resources

John Baker Illustrating the beats phenomenon with Excel: the construction of meaning through experimentation

Bernie O'Sullivan Spreadsheets, Graphing Calculators and the Line of Best Fit

Ed Staples The Euler Segment

www.sie.bond.edu.au

Geological education can be served by using spreadsheets:

- Spreadsheets allow educators to move away from instructivist teaching: they **promote more open-ended investigations, problem-oriented activities, and active learning** by students".
- Spreadsheets **"provide insights into the ... context** without necessitating attention to extraneous distractions".
- Spreadsheets, or more accurately, the building of spreadsheets, **promotes abstract reasoning** by the learner.
- Spreadsheets "are interactive; they **give immediate feedback** to changing data or formulae; they enable data, formulae and graphical output to be available on the screen at once; they give students a large measure of control and ownership over their learning".
- Spreadsheets **save time**. "The time gained can then be spent on investigating ... the so-called **what-if scenarios**. There is huge scope for investigation of dependence on parameters in almost any spreadsheet model....".



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Sabah Sadek & The Use of Spreadsheets for the Systemic Design of Flies

Beth Fretter & H L Vacher Spreadsheets in Geoscience Education: The Journal of Geoscience Education Through 2003

Karakli, Mohammed Al-Hussien, & Karen Kabanak Spreadsheet Simulation of Systems of Nonlinear Differential Equations

Book Review


Kieran F. Lim The Active Maker: Mathematical Modeling with Microsoft Excel by E. Neusarth & D. Arganbright (Brooks/Cole, Belmont (CA), 2004, ISBN 0-304-43095-0)

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Journal of Geoscience Education

From 1980 to 2004, there were 212 articles that included mathematics in some form. 38 of them included spreadsheet exercises.

Reference	Year	Journal	Mathematics	Spreadsheets
Adams, 1980	1980	Journal of Geoscience Education	X	
Adams, 1981	1981	Journal of Geoscience Education	X	
Adams, 1982	1982	Journal of Geoscience Education	X	
Adams, 1983	1983	Journal of Geoscience Education	X	
Adams, 1984	1984	Journal of Geoscience Education	X	
Adams, 1985	1985	Journal of Geoscience Education	X	
Adams, 1986	1986	Journal of Geoscience Education	X	
Adams, 1987	1987	Journal of Geoscience Education	X	
Adams, 1988	1988	Journal of Geoscience Education	X	
Adams, 1989	1989	Journal of Geoscience Education	X	
Adams, 1990	1990	Journal of Geoscience Education	X	
Adams, 1991	1991	Journal of Geoscience Education	X	
Adams, 1992	1992	Journal of Geoscience Education	X	
Adams, 1993	1993	Journal of Geoscience Education	X	
Adams, 1994	1994	Journal of Geoscience Education	X	
Adams, 1995	1995	Journal of Geoscience Education	X	
Adams, 1996	1996	Journal of Geoscience Education	X	
Adams, 1997	1997	Journal of Geoscience Education	X	
Adams, 1998	1998	Journal of Geoscience Education	X	
Adams, 1999	1999	Journal of Geoscience Education	X	
Adams, 2000	2000	Journal of Geoscience Education	X	
Adams, 2001	2001	Journal of Geoscience Education	X	
Adams, 2002	2002	Journal of Geoscience Education	X	
Adams, 2003	2003	Journal of Geoscience Education	X	
Adams, 2004	2004	Journal of Geoscience Education	X	



"We are biased, of course, but we are happy to argue that earth and space science offers hugely interesting **context**. As illustrated by these 38 papers, the range is tremendous. If mathematics educators are looking for examples, case histories, and ideas to adapt to their own uses, then check out the articles in the following annotated bibliography and watch for more as the IGE continues to publish spreadsheets in geoscience education."

In other words, we don't have to force QL upon geologists:

If geology, then calculus

Understanding geology can lead to an understanding of rates of change and other mathematical concepts.

Groundwater Flow
I will show you how any hydrologist can build groundwater models using the same piece of general software that one may use to do the bookkeeping for the golf club.

- Olsthoorn


A map of the water table in the vicinity of a pumping well exhibiting a "cone of depression".

	A	B	C	D	E	F	G
1	10.00	10.00	10.00	10.00	10.00	10.00	10.00
2	10.00	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	10.00
3	10.00	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	10.00
4	10.00	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	10.00
5	10.00	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	10.00
6	10.00	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	=R1L+H/D*4	10.00
7	10.00	10.00	10.00	10.00	10.00	10.00	10.00




Geomorphology
How does the profile across a glacial valley change over time?


Three hypotheses:
 $E = C$
 $E = AU^2$
 $E = Bd$

Section	U	C^2	10^4AU^2	Bd	E	F
1	2	18	256	84	80	77
2	3	36	675	84	121	115
3	4	54	1216	84	164	160
4	5	75	1875	84	210	210
5	6	108	2700	84	258	258
6	7	147	3675	84	308	308
7	8	192	4800	84	360	360
8	9	243	6075	84	414	414
9	10	300	7500	84	470	470
10	11	363	9075	84	528	528
11	12	432	10800	84	588	588
12	13	507	12675	84	650	650
13	14	588	14700	84	714	714
14	15	675	16875	84	780	780
15	16	768	19200	84	848	848
16	17	867	21675	84	918	918
17	18	972	24300	84	990	990
18	19	1083	27075	84	1064	1064
19	20	1200	30000	84	1140	1140
20	21	1323	33075	84	1218	1218
21	22	1452	36300	84	1300	1300
22	23	1587	39675	84	1384	1384
23	24	1728	43200	84	1470	1470
24	25	1875	46875	84	1560	1560
25	26	2028	51600	84	1652	1652
26	27	2187	56475	84	1746	1746
27	28	2352	61500	84	1842	1842
28	29	2523	66675	84	1940	1940
29	30	2700	72000	84	2040	2040
30	31	2883	77575	84	2142	2142
31	32	3072	83400	84	2246	2246
32	33	3267	89475	84	2352	2352
33	34	3468	95800	84	2460	2460
34	35	3675	102375	84	2570	2570
35	36	3888	109200	84	2682	2682
36	37	4107	116275	84	2796	2796
37	38	4332	123600	84	2912	2912
38	39	4563	131175	84	3030	3030
39	40	4800	139000	84	3150	3150
40	41	5043	147075	84	3272	3272
41	42	5292	155400	84	3396	3396
42	43	5547	163975	84	3522	3522
43	44	5808	172800	84	3650	3650
44	45	6075	181875	84	3780	3780
45	46	6348	191200	84	3912	3912
46	47	6627	200775	84	4046	4046
47	48	6912	210600	84	4182	4182
48	49	7203	220675	84	4320	4320
49	50	7500	231000	84	4460	4460
50	51	7803	241575	84	4602	4602
51	52	8112	252400	84	4746	4746
52	53	8427	263475	84	4892	4892
53	54	8748	274800	84	5040	5040
54	55	9075	286375	84	5190	5190
55	56	9408	298200	84	5342	5342
56	57	9747	310275	84	5496	5496
57	58	10092	322600	84	5652	5652
58	59	10443	335175	84	5810	5810
59	60	10800	348000	84	5970	5970
60	61	11163	361175	84	6132	6132
61	62	11532	374600	84	6296	6296
62	63	11907	388275	84	6462	6462
63	64	12288	402200	84	6630	6630
64	65	12675	416375	84	6800	6800
65	66	13068	430800	84	6972	6972
66	67	13467	445475	84	7146	7146
67	68	13872	460400	84	7322	7322
68	69	14283	475575	84	7500	7500
69	70	14698	490900	84	7680	7680
70	71	15117	506375	84	7862	7862
71	72	15540	522000	84	8046	8046
72	73	15967	537775	84	8232	8232
73	74	16398	553700	84	8420	8420
74	75	16833	569775	84	8610	8610
75	76	17271	585900	84	8802	8802
76	77	17712	602175	84	8996	8996
77	78	18156	618600	84	9192	9192
78	79	18603	635175	84	9390	9390
79	80	19053	651900	84	9590	9590
80	81	19506	668775	84	9792	9792
81	82	19962	685800	84	9996	9996
82	83	20421	702975	84	10202	10202
83	84	20883	720300	84	10410	10410
84	85	21348	737775	84	10620	10620
85	86	21816	755400	84	10832	10832
86	87	22287	773175	84	11046	11046
87	88	22760	791100	84	11262	11262
88	89	23235	809175	84	11480	11480
89	90	23712	827400	84	11700	11700
90	91	24191	845775	84	11922	11922
91	92	24672	864300	84	12146	12146
92	93	25155	882975	84	12372	12372
93	94	25640	901800	84	12600	12600
94	95	26127	920775	84	12830	12830
95	96	26616	940000	84	13062	13062
96	97	27107	959375	84	13296	13296
97	98	27600	978900	84	13532	13532
98	99	28094	998575	84	13770	13770
99	100	28590	1018400	84	14010	14010
100	101	29087	1038375	84	14252	14252
101	102	29586	1058500	84	14496	14496
102	103	30087	1078775	84	14742	14742
103	104	30589	1099200	84	14990	14990
104	105	31092	1119775	84	15240	15240
105	106	31596	1140500	84	15492	15492
106	107	32101	1161375	84	15746	15746
107	108	32607	1182400	84	16002	16002
108	109	33114	1203575	84	16260	16260
109	110	33622	1224900	84	16520	16520
110	111	34131	1246375	84	16782	16782
111	112	34641	1268000	84	17046	17046
112	113	35152	1289775	84	17312	17312
113	114	35664	1311700	84	17580	17580
114	115	36177	1333775	84	17850	17850
115	116	36691	1355900	84	18122	18122
116	117	37206	1378175	84	18396	18396
117	118	37722	1400600	84	18672	18672
118	119	38239	1423175	84	18950	18950
119	120	38757	1445900	84	19230	19230
120	121	39276	1468775	84	19512	19512
121	122	39796	1491800	84	19796	19796
122	123	40317	1514975	84	20082	20082
123	124	40839	1538300	84	20370	20370
124	125	41362	1561775	84	20660	20660
125	126	41886	1585400	84	20952	20952
126	127	42411	1609175	84	21246	21246
127	128	42937	1633100	84	21542	21542
128	129	43464	1657175	84	21840	21840
129	130	43992	1681400	84	22140	22140
130	131	44521	1705775	84	22442	22442
131	132	45051	1730300	84	22746	22746
132	133	45582	1754975	84	23052	23052
133	134	46114	1779800	84	23360	23360
134	135	46647	1804775	84	23670	23670
135	136	47181	1829900	84	23982	23982
136	137	47716	1855175	84	24296	24296
137	138	48252	1880600	84	24612	24612
138	139	48789	1906175	84	24930	24930
139	140	49327	1931900	84	25250	25250
140	141	49866	1957775	84	25572	25572
141	142	50406	1983800	84	25896	25896
142	143	50947	2009975	84	26222	26222
143	144	51489	2036300	84	26550	26550
144	145	52032	2062775	84	26880	26880
145	146	52576	2089400	84	27212	27212
146	147	53121	2116175	84	27546	27546
147	148	53667	2143100	84	27882	27882
148	149	54214	2170175	84	28220	28220
149	150	54762	2197400	84	28560	28560
150	151	55311	2224775	84	28902	28902
151	152	55861	2252300	84	29246	29246
152	153	56412	2280075	84	29592	29592
153	154	56964	2308000	84	29940	29940
154	155	57517	2336175	84	30290	30290
155	156	58071	2364500	84	30642	30642
156	157	58626	2393075	84	31000	31000
157	158	59182	2421800	84	31360	31360
158	159	59739	2450675	84	31722	31722
159	160	60297	2479700	84	32086	32086
160	161	60856	2508875	84	32452	32452
161	162	61416	2538200	84	32820	32820
162	163	61977	2567675	84	33190	33190
163	164	62539	2597300	84	33562	33562
164	165	63102	2627075	84	33936	33936
165	166	63666	2657000	84	34312	34312
166	167	64231	2687075	84		

 Jet Propulsion Laboratory
California Institute of Technology

Example modules:

-  Cosmic chemistry:
Calculating isotope ratios
-  Heat: an agent of change:
Heat effects on metals
-  A thematic travel unit:
Eccentricity of planetary orbits



Even Shakespeare was familiar with conditional formulas . . .

