Spreadsheets for Numeracy

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Our Website says that we are a "network of individuals, institutions and corporations united by a common goal of quantitative literacy for all citizens." Further, our Website says that we "envision a society in which all citizens possess the power and habit of mind to search out quantitative information, critique it, reflect upon it, and apply it in their public, personal and professional lives."

What does such a society look like? Presumably we members of NNN think that our present society does not match that description now, and so we want to help it move to that new condition. How will we know when we get there?

I imagine that each of us has an indicator of a quantitatively literate society. For me, the test involves problem-solving. When confronted with information involving numbers, do people run from the information, tune out the numbers and "trust the engineers" (i.e., math phobia; math avoidance), or do they engage the numbers, manipulate them to answer questions that are relevant to their line of thought, and then have confidence in their answers to act on their conclusions?

Given the latter condition to be an indicator of quantitative literacy – i.e., taking the position that a QL person is willing and able to calculate in relevant context – then there is an obvious next question: How do people perform the calculations? What is the technological skill? Obviously slide rules are not the answer. Equally obvious: graphing calculators are not the answer either. If they were, the formal classroom would not be their exclusive habitat.

What is it that people turn to when they have to do something with numbers? I am reminded of a great line in a great article in the journal of the National Ground Water Association 20 years ago. The article made the point that appropriate finite-difference equations on a grid can be solved with standard electronic spreadsheets and, in the process, one can get great insight to the geometry of ground-water flow fields. Here is a slightly paraphrased version of the line (Olsthoorn, 1985, p. 381):

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

That was twenty years ago. The diversity of applications now is much greater. The great versatility of spreadsheets and the need to solve problems involving numbers

assure that the use of spreadsheets as the technology of choice for problem solving will continue to expand.

A model for evolution

We are witnessing evolution in QL problem solving (i.e., calculations for numeracy). In order to see what is going on in QL, we can view how our biological colleagues apply evolution paradigms to discussions of evolutionary changes that are occurring in educational arenas they are following. In particular, I was struck by the presentation at the annual meeting of the Geological Society of America last month by Rob Ross (2005), Educational Director of the Paleontological Research Institute (Museum of the Earth; http://www.priweb.org/museumoftheearth in a wrap-up discussion of the theme session, "Innovation, Evaluation and Best Practices in Informal Geoscience Education."

Ross et al. (2005) drew a parallel with the classic island model of evolutionary change presented by the population geneticist and evolutionary biologist Sewall Wright in the 1930s. According to this model (Fig. 1), evolutionary change in species is promoted when changes occur and stabilize in small, isolated "island populations" that then later disperse into other populations. That dispersal influences change in the other populations and, eventually, fosters change in the entire species.

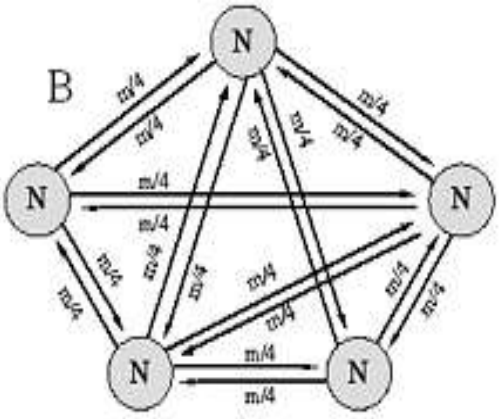

Figure 1. Gene flow between isolated populations: island model. For discussion and application see "Population Genetics of Plant Pathogens" on the APSnet Website (APSnet, 2005).

For his discussion of informal geoscience education, Ross labeled the vertices of the pentagon of islands (high school earth science, elementary school science, websites, museum exhibitry, and interpretive trips) and talked about dissemination and transfer of best practices between them. According to Ross et al (2005, p. 47),

> "Since current disciplinary boundaries tend to prevent gatherings of individuals of diverse expertise at professional meetings, efforts need to be made to invent means for greater cross-disciplinary communication."

Ross's application of the island model of evolutionary change describes what is happening with spreadsheets in education. There are disciplinary islands where changes are occurring. There are means developing now for cross-disciplinary gene flow.

An example in geoscience education

The island I am most familiar with of course is my use of spreadsheets to promote quantitative and mathematical literacy in the context of geoscience education. The purpose of my column "Computational Geology" in the *Journal of Geoscience Education* (*JGE*, http://www.nagt.org/nagt/jge/index.html), the journal of the National Association of Geoscience Teachers (NAGT), is to give background on a mathematical topic in geological context. The aim is to provide a resource for students and faculty who would like more detail than is possible in the geology classroom. As in the evolution of my own teaching (e.g., "Computational Geology" for upper-division geology majors), these *JGE* columns since 2002 make increasing use of spreadsheets to illustrate the mathematical content.

Some of the Computational Geology columns deal specifically with QL. For example, one column is on the mathematics of false positives, a classic QL topic, and develops a spreadsheet that calculates, not only the probabilities in the context of drug testing and cancer screening, but also the likelihood that some standard non-granite rocks in hand-sample geology teaching labs will be misclassified as "granite" by students (Vacher, 2003). Another QL column shows how spreadsheets can be used to create some graphs that spreadsheets were not designed to do (Vacher, 2005). One of these graphs is the triangular plot (standard fare in geology), the spreadsheet-construction of which gives practice in problem solving using the algebra of intersecting lines (Fig. 2). The point is,

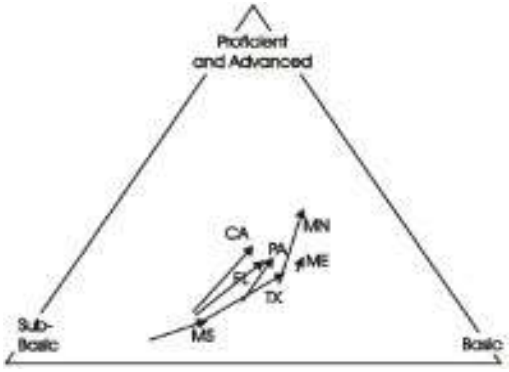

Figure 2. Triangular plot showing 1992-2003 improvement of Grade-8 mathematics results on the NAEP survey for California, Florida, Maine, Minnesota, Mississippi, Pennsylvania, and Texas (simplified version of graph in Wainer, 1992). Data from http://nces.ed.gov/nationsreportcard/. For spreadsheet that produces this graph see Vacher, 2005, Fig. 11). Triangular plots are used extensively in geology courses to display the composition of rocks and other materials composed of mixtures of three end members.

the evolution of exposition in the seven-year history of my column is a case history of how spreadsheets have been selected as the vehicle of choice to explain mathematics and QL in disciplinary context.

This evolution has resulted in a new NSF-funded project, S*preadsheets Across the Curriculum* (SSAC; NSF DUE 0442629) with co-PI Emily Lardner of the Washington Center for Improving the Quality of Undergraduate Education

http://www.evergreen.edu/washcenter/home.asp

The three-year project aims to develop self-contained Power-Point modules in which students develop Excel spreadsheets to solve problems in disciplinary context. We are in the first year of the project and will soon be taking applications for the second institute (Summer 2006, Olympia WA). For more about this project see

http://www.evergreen.edu/washcenter/project.asp?pid=75

Please return to the site in a couple of months to see (and maybe adapt) the completed modules from the first institute that was held in Olympia in July 2005.

The current SSAC project is a scale-up from an earlier proof-of-concept (POC) NSF project, *Spreadsheets for Geological-Mathematical Problem-Solving* (NSF DUE 0126500). The modules developed on that project are the conceptual templates for SSAC. In short, the modules are 15-20-slide, Power-Point presentations that students can work through as self-paced homework assignments. Each module poses a problem in context and gives the disciplinary and mathematical background for it. After the introductory material, the module steps the student through the construction of a spreadsheet that performs the calculations to solve the problem. The idea is that the students create their own spreadsheets, figuring out the cell equations along the way. Then, they use their spreadsheets to solve similar end-of-module assignments to hand in. The POC modules are posted on the SSAC Website (click on Geological-Mathematical Problem-Solving Modules).

Other examples in geoscience education

The Journal of Geoscience Education has published an increasing number of papers involving geological-mathematical exercises, problems or projects as geology has become more quantitative, and those papers have increasingly referred to the use of spreadsheets. For example, in the 1990s, the *JGE* published 212 articles involving geological mathematical problem-solving in some way (Vacher, 2000b). That total included 20 papers per year in the first three years of the decade, and 25 papers per year in the last three years. Three papers (5% of the papers that had some mathematical content) in those first three years involved spreadsheets, and 11 papers (15%) in the last three years involved spreadsheets (Fratesi and Vacher, 2005).

In all, there are 38 papers in the *JGE* that note the use of spreadsheets in geoscience education through 2003 (Fratesi and Vacher, 2005). The range of topics is broad, including for example, the abundance of elements in the Earth's crust (Dutch, 1991); the directional properties of inclined strata (Vacher, 2000a); the shape of valleys scoured by mountain glaciers (Harbor and Keattch (1995); and the location of our solar

system within the Milky Way galaxy (Shea, 1993). There is also a broad range in the extent of involvement of spreadsheets. A few articles describe entire courses and the use of spreadsheets in those courses. Some papers present exercises that are built completely upon the use of a spreadsheet. Most of the papers include an example spreadsheet with some description.

Website geoscience-education publications are growing exponentially. Of particular significance is the Digital Library of Earth Science Education (DLESE) (http://www.dlese.org/dds/index.jsp), which contains the collection entitled *Teaching Quantitative Skills in the Earth Sciences* http://serc.carleton.edu/quantskills. This collection is organized under headings such as "Teaching Techniques and Tips," "Activities for Class and Lab", and "Student Resources." "Teaching Techniques and Tips" includes both geoscience-specific and mathematics-specific resources as well as discussion topics. Activities for Class and Lab include 85 items and a search engine. Searching on spreadsheets produces 31 items.

Teaching Quantitative Skills in the Earth Sciences is one of several products of the Science Education Resource Center (SERC) (http://serc.carleton.edu/serc/about.html) an office of Carleton College in MN. SERC, one of the leaders in geoscience education, has special expertise in community organization, workshop leadership, digital libraries and Website development. It aims to improve undergraduate science education through projects that focus on supporting faculty.

One of those projects is *Starting Point* (NSF DUE 0226243; PIs, Cathy Manduca [SERC], Mary Savina [Carleton] and Dorothy Merritts [Franklin and Marshall], an online resource that integrates information about pedagogy with a collection of teaching resources to support a virtual community of geoscience educators involved in introductory geology courses

http://serc.carleton.edu/introgeo/index.html

One of the major collections is *Mathematics and Statistical Models*

http://serc.carleton.edu/introgeo/mathstatmodels/index.html

within which is a useful collection of geoscience activities involving Excel

http://serc.carleton.edu/introgeo/mathstatmodels/geo_excel.html

Level I activities assume no prior familiarity with Excel. Level II activities assume experience of the type included in Level I activities. The *Mathematics and Statistical Models* resource also includes a Website collecting a variety of Excel how-to sites focusing on elementary modeling

http://serc.carleton.edu/introgeo/mathstatmodels/xlhowto.html

The big project now in professional development for geoscience faculty is the *Cutting Edge*, a five-year National Dissemination project, consisting of workshops and Website (NSF DUE-0127310; PIs, Heather MacDonald [William and Mary], Cathy Manduca [SERC], Dave Mogk [Montana State], Barbara Tewskbury [Hamilton College])

http://serc.carleton.edu/NAGTWorkshops/programdescription.html

This immensely influential workshop program has included six or more workshops a year for early career educators (faculty, graduate students and post-doctoral fellows): a course design workshop; three "emerging theme" workshops; and workshops at professional meetings.

One of the 2005 *Cutting Edge* workshops was *Teaching Hydrogeology in the 21st Century*. One of the Websites associated with the workshop is a collection of activities – *Classroom, Laboratory and Field Exercises in Hydrogeology*

http://serc.carleton.edu/NAGTWorkshops/hydrogeo/activities.html

The Website includes 42 activities and a search engine. Searching on "Spreadsheets" produces 13 activities.

The hydrogeology workshop included eight 75-minute "Long Demonstrations"

http://serc.carleton.edu/NAGTWorkshops/hydrogeo/presentations.html

Three of these presentations have titles signaling the relevance of spreadsheets to teaching hydrogeology: "The Woburn groundwater flow and transport model – a Spreadsheet tool for teaching the general concepts of modeling" by Scott Bair (Ohio State); "Using Excel to ease the math phobia encountered in teaching hydrology," by Terry Lahm (Capital University), and "Using Exccel for aquifer test" by Yongli Gao (East Tennessee State).

No doubt, the participants in the workshop, together with others teaching hydrogeology around the country, are excitedly awaiting publication of the new book by Bair and Lahm, *Practical Problems in Groundwater Hydrology*. The milestone book is due out from Prentice Hall on New Year's Eve, 2005. *Practical Problems* takes a case-study approach, developing hydrogeological concepts in the context of well-documented, real-world examples that have good story lines. According to the information supplied by the publisher, the book features interactive learning with Excel-based problems which provide students immediate graphical and quantitative feedback as they apply the concepts to complete the exercises.

It is worth repeating: quantitative literacy and math phobia are polar opposites. The title of Lahm's presentation at the *Cutting Edge* hydrogeology workshop– "Using EXCEL to ease the math phobia encountered in teaching hydrogeology" – shows that QL is an issue in the effective teaching of hydrogeology, a quantitative field. Bair and Lahm are demonstrating that spreadsheets are not only the technology of choice, but also that spreadsheets effectively develop the problem-solving habit of mind that is required to learn this quantitative subject and practice it as a professional. At the recent GSA annual meeting, Lahm (2005) made the following points in a presentation on the same subject, namely spreadsheets, hydrogeology, and overcoming math phobia:

> "Teaching quantitative aspects of hydrogeology can represents a challenge for faculty, especially when students exhibit an aversion to mathematics.... (Q)uantitative concepts are central to the understanding of basic principles of groundwater flow and behavior in the environment....We have developed a series of groundwater case studies that employ Excel to teach ... quantitative aspects of hydrogeology. The case study approach builds student interest in the problem and provides a context....By using Excel, students can visualize natural processes more clearly and develop a higher level of understanding...."

Beyond geology

In this note, I have described what is happening in spreadsheets for QL on the island on which I live. I have also described a few things going on in the geological archipelago that I see in short ventures forth from my home island. What is going on in other islands? I would like to know. More to the point, the spread of QL will benefit if we all knew.

It should be noted that there are some Internet resources that are helping spreadsheets in education to disperse and take root on a variety of islands. For example, the Website maintained by Erich Neuwirth, *Spreasheets, Science, Mathematics and Statistics Education* (http://sunsite.univie.ac.at/Spreadsite/#recbooks) is a multiplex collection that "tries to collect some information about spreadsheets with an emphasis in mathematics and statistics." Its subtitle is appropriate: "Quite a lot of what you always wanted to know." The same can be said for the book *The Active Modeler – Mathematical Modeling with Microsoft Excel* by Erich Neuwirth and Deane Arganbright (Brooks/Cole, 2004). Co-author Deane Arganbright, it should be noted, is the Dean of spreadsheets in education in the US. His book *Mathematical Applications of Electronic Spreadsheets* (McGraw-Hill, 1985) is a classic. Think about it: 1985! How's that for being ahead of the curve!

The really big news for the evolution and eventual radiation of spreadsheets in education is a new, international, online journal that is called, appropriately enough, *Spreadsheets in Education* (eJSiE) (www.sie.bond.eu.au). This new journal – coming out of Bond University in Australia – is "devoted to the publication of quality refereed articles concerned with studies of the role that spreadsheets can play in education," It "is a free facility for authors to publish suitable peer-reviewed articles and for anyone to view and download articles" (from the home page). The inaugural issue included an extensive review – with 205 references – of how spreadsheets have been used in education – mostly in mathematics and statistics, but also physical sciences, computer science, and economics and operations research (Baker and Sugden, 2003).

The first issue of the second volume has just gone online. Included is a masterful resource paper by Arganbright (2005) on spreadsheet techniques that will enliven any presentation involving graphs – in other words, any presentation that subscribes to the goals of QL, no matter in what island it may occur.

The four published issues of *Spreadsheets in Education* are heavily weighted with contributions from mathematics and statistics. Co-editors John Baker and Steve Sugden are eager for papers and classroom resources in additional fields. I can think of no better way to facilitate the spread of the QL gene pool across the islands of education than for members of NNN who use spreadsheets in their various home disciplines to contribute to this new online journal.

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