

Mathematics Learning and Geography Education

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In 2002, Arizona teachers saw geography being increasingly marginalized as reading, writing and math requirements grew. For example, 22.5 % of Arizona 8th graders were required to score at the proficient level or higher on state mathematics tests in 2004-05, up from 7 % in the 2003-04 academic year.¹ Facing the loss of geography teaching time due to the pressures of a testing system that emphasized mathematics, reading and writing,² teachers of the Arizona Geographic Alliance (AzGA) agreed at their 2002 Annual Conference of Teacher Consultants on the need to develop a *GeoMath* curriculum package linking the teaching and learning of geography and mathematics in grades K-8.³

The *GeoMath* program was built on the finding that geography inherently integrates mathematics with many areas of its study,⁴ not just the mapping sciences⁵ This is borne out by analysis of the voluntary national standards for geography.⁶ All essential elements of these standards explore number sense, as do many leading geography lesson packages such as *Mission Geography*,⁷ *Activities and Readings in the Geography of the United States* (ARGUS), and *Activities and Readings of the Geography of the World* (ARGWorld). Similarly, mathematics innovators consistently seek authentic examples to enrich conceptual understanding.⁸

A natural question is why a full curriculum package had not been developed to exploit a mathematics-geography linkage. The answer likely includes a number of obstacles such as: (1) convincing elementary educators that key mathematics skills can be learned using elements other than the mathematics textbook; (2) convincing administrators that mathematics scores can be improved by using cross-curricular materials in addition to core mathematics instruction; (3) pressures on teachers to teach only those mathematical concepts and skills directly tested on mandated assessments; and (4) the open secret that those attracted to elementary school teaching are the most likely to be poorly trained in mathematics, often translating into a phobia of mathematics for their students.⁹

GeoMath Materials

The *GeoMath* project produced a CD-based lesson package of more than eighty lessons with student assessments with math items that mirror the style of the required high stakes test.¹⁰ All of the twenty-eight lesson authors (a mix of AzGA teacher consultants, National Board Certified Teachers, and members of the National Council of Teachers of Mathematics) integrated geography lessons with tested mathematics skills based on state standards, many of which reflect the six essential elements of the National Geography Standards. Table 1 provides a sampling of the teacher-produced lessons.

Users access the *GeoMath* program through any Internet browser and a PDF reader such as Adobe Acrobat. Figure 1 illustrates the first

Table 1. Sampling of the more than eighty *GeoMath* lessons

Grade	Title	Description
K-1	<i>Shape of My World: Mapping a Classroom</i>	Students identify basic shapes in the classroom and make a map showing the location of major furniture and classroom features.
2-3	<i>Don't Be Such a Drip: Water conservation</i>	Students draw conclusions from graphs, while they discover the importance of water conservation
3	<i>Relying on the Desert: Plants used by Hohokam</i>	Students learn how Hohokam people used natural resources to survive in a desert, while developing data analysis skills
4-5	<i>Now You See Them... Now You Don't: Movement In and Out of Arizona</i>	Students study the movement of people through data analysis of the census.
4-5	<i>Grand Canyon: A River Rafting Trip</i>	On a journey through the Grand Canyon, students practice finding elevations on a topographical map and determine measures of central tendency.
5-8	<i>In the wake of Columbus: Decline of Native Peoples</i>	Students learn of the catastrophic population decline among Native Americans associated with the Columbian contact, while practicing measurement and graphing skills.
6-8	<i>Can You Hear Me Now? How a Country's Wealth Influences Communication</i>	Students make and solve problems using scatter plots created by using data from a variety of countries. These data will help students explore relationships between different countries and how their citizens get information using popular culture items such as, TVs, cell phones, and the Internet.
6-8	<i>Marvelous Moroccan Mosaics: Patterns in Zillij</i>	Students learn about the centuries-old craft of Zillij and use it to understand geometric shapes and tessellations
6-8	<i>Where Did the Lake Go? The Drying Up of Lake Chad</i>	Students explore the rate of change of the water level of Lake Chad, as they learn about interactions between people and environmental change

set of choices for viewing lessons. Teachers typically select lessons by grade level but an administrator who evaluates the suitability of this package would probably start with Arizona mathematics standards (Figure 2) and then seek specific lessons that match a particular mathematics strand (Figure 3). No matter the motivation of the user, be it mathematics or geography, all pathways lead to the lesson home page (e.g. Figure 4) that contains links to all material needed to teach that lesson. One of the richest aspects of the *GeoMath* CD is the inclusion of maps designed via creative synergism between the lesson authors and Arizona State University's cartography program led by Barbara Trapido-Lurie.¹¹ Each of the maps went through several changes based on repeated feedback between teachers and the cartographic team.

The following key roles were required to create the *GeoMath* CD:

- a manager who oversaw the project and kept lesson authors on deadline;
- a cartography coordinator;
- an editor who compiled revisions and materials (this person can change, but only one person should compile at any time);
- an editor who checked the lesson materials for conformity before and after piloting;
- a coordinator who organized construction of the CD;
- an editor who collected continuous CD updates.

The single largest challenge for such cross-disciplinary programs as *GeoMath* comes when states inevitably change their standards. Since the

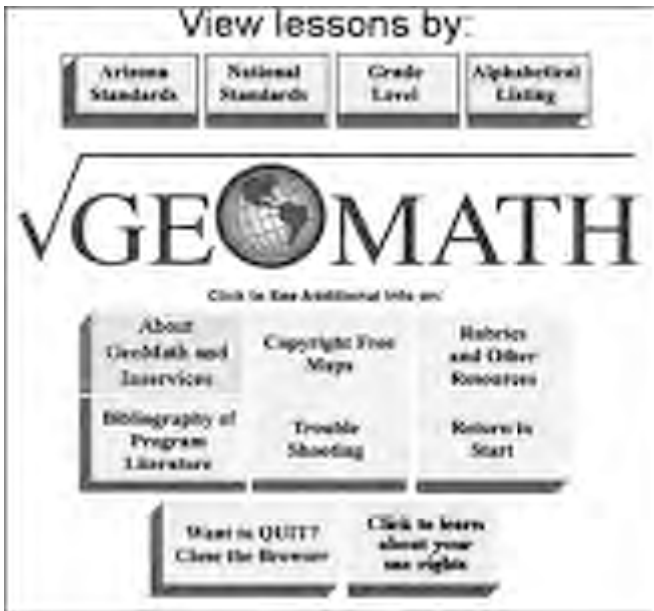


Figure 1. *GeoMath* CD home page. Users first encounter a series of choices on how to access the lesson activities and how to obtain information on additional features, such as more than 100 maps and a listing of any library books that might be needed to teach the lesson.

inception of the program Arizona state mathematics standards have changed twice, along with a new geography strand of the social studies standard. The common core will require another set of revisions. Hence, AzGA regularly revises these lessons and activities to articulate to slightly revised performance objectives.

Evaluation of *GeoMath*

Our preliminary evaluation began with 113 teachers in grades K-8 teaching a *GeoMath* lesson. Two strategies were employed to assess student achievement of mathematics and geography concepts. First we asked the piloting teachers to assess the percent of their students who achieved 80% on the geography and mathematics performance objectives. Figure 5 reveals that about half the piloting classrooms had 80% or more of their students mastering the geography standards, while only one-fifth of the classrooms were unable to reach a mastery level in half the students.

Our second assessment strategy focused solely on mathematics and asked piloting teachers to give a pretest and then the same test again thirty days after teaching the lesson. An overview of our find-

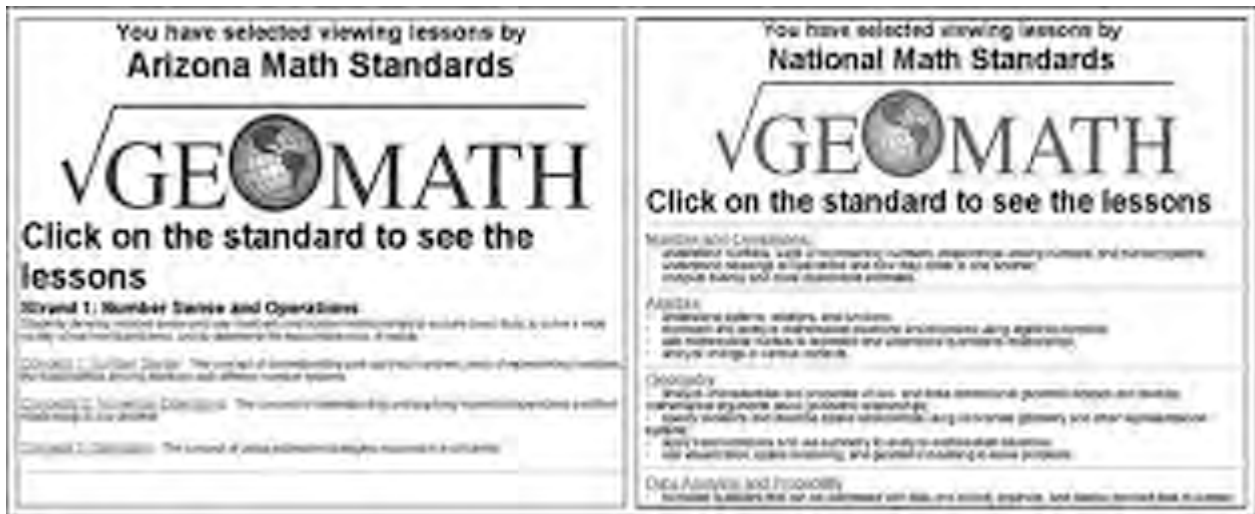


Figure 2. “Arizona Standards” and “National Standards” Web pages on the *GeoMath* CD. Assume that you clicked “Arizona Standards” or “National Standard on Figure 1.” You would encounter the pages above. If you then selected the top choice, to view number sense lessons, you would be taken to Figure 3.

Strand 1: Number Sense and Operations Concept 1: Number Sense				Arizona Geography Standard 3SS-E5 Describe natural and human characteristics of places and use this knowledge to define regions, their relationships with other regions, and their patterns of change			
Grade Level	Title	Description	Duration	Grade Level	Title	Description	Duration
K	Where is Gizmo's Home?	In this fun, hands-on activity, students use a map to help locate a lost pet. Students develop and use vocabulary related to spatial relationships.	1-2 class periods	AA	Cyclops and the Future of China's Ecosystems: Using Mathematics to Look at the Future	Students estimate the number of disposable chopsticks that can be obtained from one cubic meter of wood, and from that information determine the cubic meters of wood that China would use in a year under varying consumption of reuse.	1 class period
0.1	Country Islands: What is an Island and How Many Do You See?	The world is made of many landforms. In order to understand a place, children should know the kinds of landforms that can be found.	1-2 class periods	00	Jerusalem: A City of Conflict	Students will calculate percentages of the different religious populations in Jerusalem.	1 class period
3	Why Were They Built? Dams in Arizona	Students will learn how dams have modified natural resources. They will also place the dates of construction of Arizona's dams in order from earliest to most recent.	1 class period	00	Microbus: Moroccan Patterns in Tiles	Students learn about the centuries-old craft and use it geometric shapes to make tessellations.	2 class periods
4.5	Hazardous Trails: Discovering Routes through Arizona to California	Students learn of the routes early explorers blazed in their travels through the Arizona territory. Along the way, students also learn about the Gila River and practice calculating distance.	2 class periods	00	Judge of the Planet: Calculating Sun Angles	Students use a formula to calculate sun angles, the key to knowing why Earth's seasons change and the key to knowing how to orient shading to save energy.	2 class periods
4.5	Fun in the Sun?	Students learn sun safety awareness in their community. They create a choropleth map of the United States that illustrates the estimates of melanoma rates by state.	2 class periods	00	A Hibernian in My Own Backyard: A Geographic Field Study	Students learn about the theme of region while tracing the changes in a tree over a period of time.	3-4 class periods
				00	Round and Round We Go: World Traveler	Students use printed material and informative websites to measure mileage and learn about some new and interesting places around the world.	1 class period
				00	Trade - The Great Balance Act	Students will learn how our trade with Japan reflects imports, exports, and a trade deficit.	1 class period

Figure 3. The fourth level down in the decision tree on the *GeoMath* CD (first is Figure 1, second is choosing math or geography at the state or national level, third is Figure 2) brings you to a listing of specific lessons, listed by math or geography standard. Clicking on any of the title brings the user to a lesson home page such as the one found in Figure 4 (below)

ings is provided in Figure 6. Student averages showed improvement across all grade levels in mathematics performance one month after the lesson was taught, and only 13 out of 113 classrooms saw a decline in mathematics scores. This improvement was demonstrated to be statistically significant and is contrasted with a small comparison group sample that did not use *GeoMath* materials for its mathematics instruction and obtained no significant differences in student mathematics achievement.

While the majority of teachers did not change their elementary teacher attitudes toward mathematics instruction, almost 25% of the 113 piloting teachers reported an increased level of comfort toward reaching mathematics skills after piloting a *GeoMath* lesson. A rich arena for future research rests in the teacher realization that mathematics can be fun when it is tied to curriculum that they enjoy teaching (geography). There also exists a feeling of control over an intimidating subject when teachers step beyond the mathematics textbook.



Figure 4. Lesson “home pages” on the *GeoMath* CD. Each lesson has its own "home page" that provides links to print out all materials needed to teach the lesson. Each of the links brings up a PDF file. Early elementary lessons tend to contain just the teacher instructions and perhaps student worksheets and examples, while middle school lessons tend to be richer in geography content and contain more material options for the teacher.

Conclusion

In an effort to incorporate geography instruction into academic subjects with mandatory assessments under No Child Left Behind, the Teacher Consultants of the Arizona Geographic Alliance developed a plan to convince administrators of the value of geography in preparing for the high-stakes mathematics testing by creating a package of GeoMath lessons. The lessons have assessments that prepare students for the mathematics test and also help them learn geography. They were piloted in more than a hundred K-8 classrooms across Ariz-

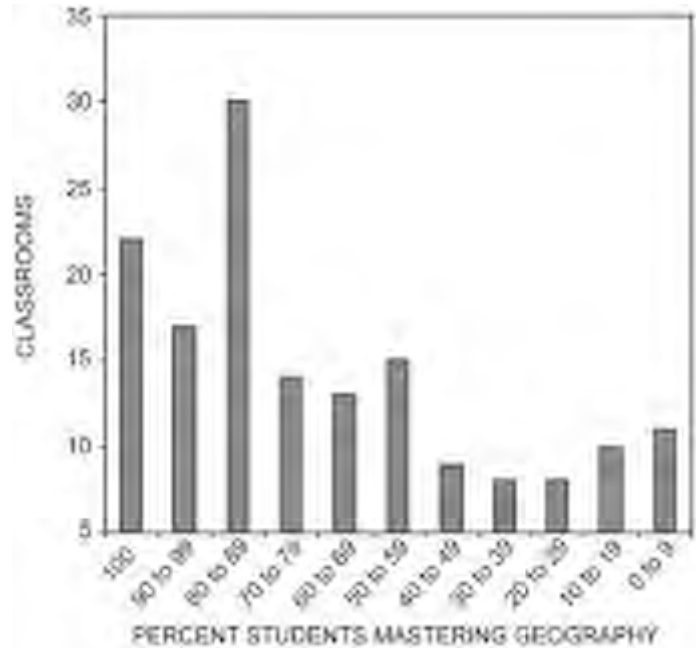


Figure 5. Percent of students by math classroom that mastered geography material as defined by a score of 80% or higher on assessments of geography achievement.

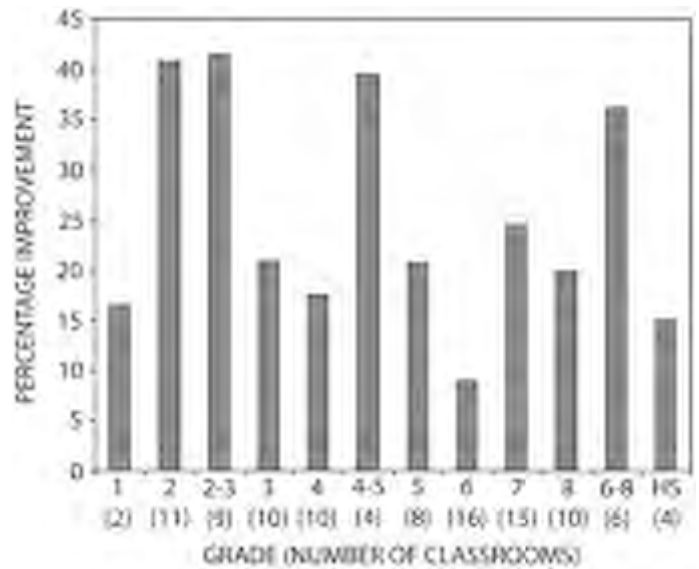


Figure 6. Average improvement in math achievement from pre-test to post-test for the intervention group that received instruction using *GeoMath* materials. These results are statistically significant ($R^2 = 0.34$, $p < 0.001$).

ona that mirrored the socio-economic status of the Arizona student body. Preliminary evaluation data suggest that *GeoMath* lessons improve understanding of geography while increasing performance in mathematics skills, as well as increasing the mathematics comfort level of 25% of the elementary school teachers who piloted the lessons.

In addition, experience with *GeoMath* suggests that good elementary teachers enjoy the creative process and that *GeoMath* lessons exemplify a means to exert that creativity in mathematics coursework. Creative, cross-disciplinary instruction may help mitigate the documented phobia of mathematics by elementary teachers which often results in fear of mathematics by their students.¹² A program like GeoMath has the potential to foster an improvement in elementary teacher attitudes toward mathematics in addition to promoting specific student achievement.

Notes.

¹Olson, L. 2004. "Taking Root," *Education Week on the Web*, December 8 Edition 24(15). Available from www.edweek.org (last accessed October 15, 2010).

²Manzo, K.K. 2002. "Concentration on reading, math troubles social studies educators," *Education Week on the Web*, April 5 Edition 21(23). Available from www.edweek.org (last accessed October 15, 2010).

³The Arizona Geographic Alliance obtained support for the *GeoMath* project from the National Geographic Society's Education Foundation Grosvenor Grant program, matched by such sources as the Arizona State Department of Education, Arizona State University's Geography Department, and a

supplement to a National Science Foundation GK-12 grant (DGE 0086465).

⁴Gould, P. 1975. Mathematics in geography: Conceptual revolution or new tool. *International Social Science Journal* 27:303-27.

⁵Bednarz, S.W., and T. R. Baker. 2003. Research on GIS in Education. *Journal of Geography special issue* 102(6):231-91. Furner, J.M., and M. Ramirez. 1999. Making connections: using GIS to integrate mathematics and science. *TechTrends* 43(4):34-39; Kerski, J.J. 2010. Bridging geography and mathematics. *Perspectives* (NCGE): 14-15.

⁶Geography Education Standards Project. 1994. *Geography for life: National standards in Geography K-12*. Washington D.C.: National Geographic Society.

⁷Bednarz, S.W. 2011. *Mission Geography Homepage*; available from <http://missiongeography.org> (last accessed April 18, 2011).

⁸Kilpatrick, J., and J. Swafford, eds. 2002. *Helping children learn mathematics*. Washington D.C.: National Research Council.

⁹Stipek, D.J., K.B Givin, J.M. Salmon, and V.L. MacGyvers. 2001. "Teachers' beliefs and practices related to mathematics instruction," *Teaching and Teacher Education* 17:213-26.

¹⁰These lessons are also available on the Internet at alliance.la.asu.edu/geomath/general.html.

¹¹All lessons and the specially designed *GeoMath* maps can be seen at the public website of the Arizona Geographic Alliance <http://alliance.la.asu.edu/azga> and click on "GeoMath" in the far right menu. (Last accessed October 15, 2010).

¹²Stipek et al. 2001. *op. cit.*