

Learning Geography Promotes Learning Math: Results and Implications of Arizona's GeoMath Grade K-8 Program

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ABSTRACT

The *No Child Left Behind* (NCLB) legislation has resulted in declining classroom time dedicated to geography instruction, especially in grades K-8. To combat this problem, a National Geographic Society Grosvenor grant provided resources allowing 28 teachers authors to generate a package of more than 80 lessons that combine the teaching of geography and mathematics skills tested on Arizona's state mandated testing. When taught in 113 piloting classrooms that mirror Arizona's student demographics, GeoMath lessons generated statistically significant increases in performance in math skills and improved understanding of geography standards. In addition, a fourth of the K-8 piloting teachers surveyed felt that teaching GeoMath lessons increased in their level of comfort in teaching mathematics. Given the success of this GeoMath strategy, and a prior GeoLiteracy program, we advocate here a national agenda of articulating geography curriculum to high-stakes tested subjects of reading and math.

A long-time middle school teacher and now co-coordinator of the Arizona Geographic Alliance, Ekiss envisioned, organized and coordinated the entire project with teacher authors scattered across Arizona's diverse educational landscape. Trapido-Lurie worked with Eden and teacher authors to develop grade appropriate maps. Comeaux and Mings reviewed geography content and edited lessons. Davis handled behind-the-scenes logistics, and Douglass and Dorn organized the research, validated the geography content, and developed the CD. Hinde was an elementary educator for 18 years and is now an Assistant Professor of Elementary Education. Ramakrishna coordinated with the GeoMath program through his position as the director of ASUs GK-12 project "Down to Earth Science".

THE NEED

With passage and implementation of *No Child Left Behind* (NCLB), K-8 administrators and teachers no longer view accountability through reading and math testing as a passing fad or a temporary swing of the educational pendulum (Brennan et al. 2001; Olson 2004; Reborra 2004). The K-8 classroom is being remade daily under fear of declining or static test scores (Schroeder 2004). A number of organizations associated with "untested" subjects have sounded the alarm, exemplified by the National Council Social Studies (NCSS):

"What's easiest to cut are those programs that do not have a link to accountability," said Gayle Thieman, who oversees the Fund for the Advancement of Social Studies Education. Without pressure to improve social studies instruction, Ms. Thieman said, districts are likely to spend much of their professional-development and instructional-materials budgets elsewhere ... "When teachers and administrators are feeling the pressure from a testing system that emphasizes reading and math, the day will be restructured so there is less time available for other subjects," said Brian M. Stecher, a senior social scientist with the RAND Corp., an independent research organization based in Santa Monica, Calif. (Manzo 2002)

Educational think tanks (for example, Rentner 2004) express similar perspectives:

"What has happened is that standardized tests have been elevated to where they are the curriculum," said Ann Lieberman, a senior scholar at the Carnegie Foundation for the Advancement of Teaching, an education think tank based in Palo Alto, Calif. "What we are doing is narrowing the kinds of activities and learning opportunities for students rather than broadening and deepening them." (Olson 2000).

Proposition 301 legislation in Arizona mandates accountability metrics reflecting NCLB priorities, where salaries and bonuses of teachers and administrators (Go 2001) are often tied to student performance on language arts and mathematics tests alone (Nuevo 2004). Passage of Proposition 301 in combination with NCLB puts on the curriculum chopping block untested areas in Arizona's classrooms.

As is the case in many other states (Sloane and Kelly 2003), Arizona's high stakes test (Arizona's Instrument to Measure Standards or AIMS) is still experiencing a baptism under fire. Enduring pressures for its elimination and its modification, AIMS still thrives. Even districts that grudgingly held back in their articulation now rework their curriculum to fit with the testing of state standards, with such strategies as extra "AIMS math" or "AIMS reading"

preparation blocks. In a simple equation of $It = It_{ts} + It_{uts}$ (It , instruction time; It_{ts} , tested subject instruction time; It_{uts} , untested subject instruction time), any increase in It_{ts} must be balanced by a decrease in It_{uts} .

Time on untested classroom subjects continues to decline in Arizona's elementary and middle school classrooms (Nuevo 2004; Olson 2004), despite solid evidence on the importance of multidisciplinary instruction in bolstering reading comprehension (National Reading Panel 2002). Although cross-disciplinary integration contains pitfalls if not carried out carefully (Hinde 2005), students in high-achieving classrooms work "on tasks that integrated several content areas (reading, writing, and social studies)" (Allington 2002, 745). Content-rich classrooms where the teacher integrates reading with other areas (Guthrie et al. 2000), for example geography (Metcalf et al. 2003) and science (Guzzetti et al. 1993), are increasing reading achievement. The general literature indicates that no single approach to reading and math education is effective, and "successful teachers tend to be those who are able to use a range of teaching strategies and who use a range of interaction styles" (Darling-Hammond 1999, 14).

This paper provides the first statistical insight that geography education improves student performance on tested elementary and middle school mathematics standards; this finding remains true across Arizona's K-8 classrooms regardless of ethnicity or income status. We present some background on math-geography integration, summarize the process of making and testing GeoMath, highlight our evaluation process and results, and end by advocating a national-level agenda integrating geography K-12 with the high stakes testing areas of mathematics and reading.

ARIZONA GEOMATH IS NOT FIRST

Professional geographers regularly integrate mathematics with geography (Gould 1975; Gatrell 1981). Classic links between history, geography and math pepper our curriculum (Makowski and Strong 1996) with a host of rich teaching material (Shaw 1998). GIS education continues to enrich authentic integration of math with science (Furner and Ramirez 1999). Mathematicians also appreciate linkages to geographic context in their discipline (Berggren 1997).

The primary grade literature on geography pedagogy similarly recognizes strong connections between geography and mathematics instruction (Dowd 1990; Patterson and Veters 1992; Palmer et al. 1993), even though elementary teachers may stray away from the less comfortable mathematical dimensions of multidisciplinary lessons (Gregg 2001). Geographic Information Science continues to grow, albeit slowly, in the K-12 curriculum and thoroughly embeds math with geography (Bednarz and Audet 1999; Bednarz and Baker 2003). National curriculum packages similarly ask students to engage in performance-based mathematics; student activities in ARGUS, ARGWorld (www.aag.org), and NASA Mission Geography (mission-geography.org) all involve a variety of math skills, both

explicitly and implicitly. Although gender-based (Self and Golledge 1994; Riding and Agrell 1997) and cultural (McEachron et al. 2003) differences occur in learning and skills, mathematics/geography linkages form interconnecting webs throughout current geography pedagogy. Individual states also integrate geography with mathematics, as exemplified by the South Carolina Geographic Alliance's (2003) IGSAM interactive Educational CD ROM for Windows systems, hosting such lessons as "When Will We Get There?" and "Be thankful for each thankful."

The lessons of GeoMath are unique in that they formalize the geography-math link through the lens of the high stakes test. GeoMath explicitly uses activity assessments that include items that mirror the style of Arizona's state mandated tests. Performance-based mathematics activities also exist in GeoMath, but the core unique aspect of the program rests in explicit practice on selected response test items.

THE PROCESS

GeoMath grew out of Arizona's K-8 GeoLiteracy CD lesson package (Hinde and Ekiss 2002), a parallel initiative to integrate geography and practice language arts skills tested on state mandated tests (Hinde 2005). A National Geographic Society Grosvenor grant formed the core of the support, cost-shared by a National Science Foundation GK-12 supplement, the Arizona Department of Education, and Arizona State University's (ASU) Geography Department. Our coordinating team:

- recruited and trained 28 teacher authors from a mix of Arizona Geographic Alliance teacher consultants (TCs), National Board Certified teachers, and members of the National Council of Teachers of Mathematics (NCTM);
- encouraged authors to develop lessons that engage students in several of the basic mathematical proficiency strands (Kilpatrick and Swafford 2002) including number sense and operations, data analysis, geometry, algebra, probability and more;
- ensured that teacher authors came from a mix of rural and urban, economically well off and disadvantaged, and ethnically homogeneous and diverse schools;
- ensured that the lessons include environmental geography issues of conservation;
- established collaboration between ASU's cartographers, GK-12 graduate fellows, geography professors, and teachers authors to enrich geography content and to develop age-appropriate maps;
- following NASA Mission Geography's rich content, helped add state-of-the-art geographic knowledge, graphics, and animations from

- NASA and other U.S. government sources;
- edited lessons for uniformity of style;
- followed the What Works Clearinghouse - Design and Implementation Assessment Device (WWC-DIAD) (Valentine and Cooper 2003) to develop math assessment instruments to be given prior to the lesson and one month after a lesson is taught, tested the assessments instruments for validity with randomly selected control student groups of similar demographics that were not taught the GeoMath lessons;
- great efforts ensured that the 113 piloting classrooms included K-8 students, from regular public schools, alternative schools for at-risk children, and inner city and rural settings (Fig. 1); this socioeconomic requirement meets the randomized necessity of the WWC-DIAD (Whitehurst 2003);
- analyzed data from piloting classrooms to determine whether there was a loss or gain in mathematics learning compared to the control students taught the normal social studies and mathematics curriculum without the GeoMath intervention;
- aided authors in revising lessons to accommodate

piloting observations;

- developed a CD where teachers access lessons;
- enhanced meaningful communication skills among ASU "content" experts in geography, NSF funded GK-12 graduate fellows, teacher authors, piloting teachers, and administrators of the teacher volunteers;
- offered workshops by Arizona Geographic Alliance teacher consultants to self-perpetuate the curriculum package; and
- organized a website for lesson posting and review.

Arizona's GeoMath lessons (Table 1) follow the premise of GeoLiteracy, which the creativity and pedagogical professionalism of master teachers ensures teachable lessons that self-perpetuate because they work well. Instead of asking master teachers to tweak lessons created by content experts, we take the opposite strategy of 'beefing up' geography, math, and assessment instruments. This takes several iterations of communication between teacher authors and GK-12 graduate fellows, ASU geographers, assessment specialists, and the cartographers. A teacher may start with one idea that rests on unsound geographic data or reasoning and after several back-and-forth edits and discussions, the teacher will evolve a lesson based on

solid geographic research. A key, however, is that the lesson writing is driven by the K-8 teacher.

The format for the final package of lessons is a CD that requires only an Internet browser that comes with typical helper applications such as Adobe Acrobat to read pdf files. The browser links to lessons through state and national geography and math standards, as well as lesson titles and grade level. All of these "access" pages point the user towards a lesson "home page" (e.g., see www.alliance.la.asu.edu/geomath/general.html). Each lesson home page is designed to be as modular and accessible as possible. Links on the home page bring up files of teacher instructions, student activity sheets, keys, maps, extension activities, and sometimes student samples, images and animations. Additional features include: a wide array of unique GeoMath maps and Arizona Geographic Alliance outline maps; extra resources such as writing rubrics for lessons that integrate writing with math and geography; information on how to watch internet presentations of teachers explaining how to teach a few of the

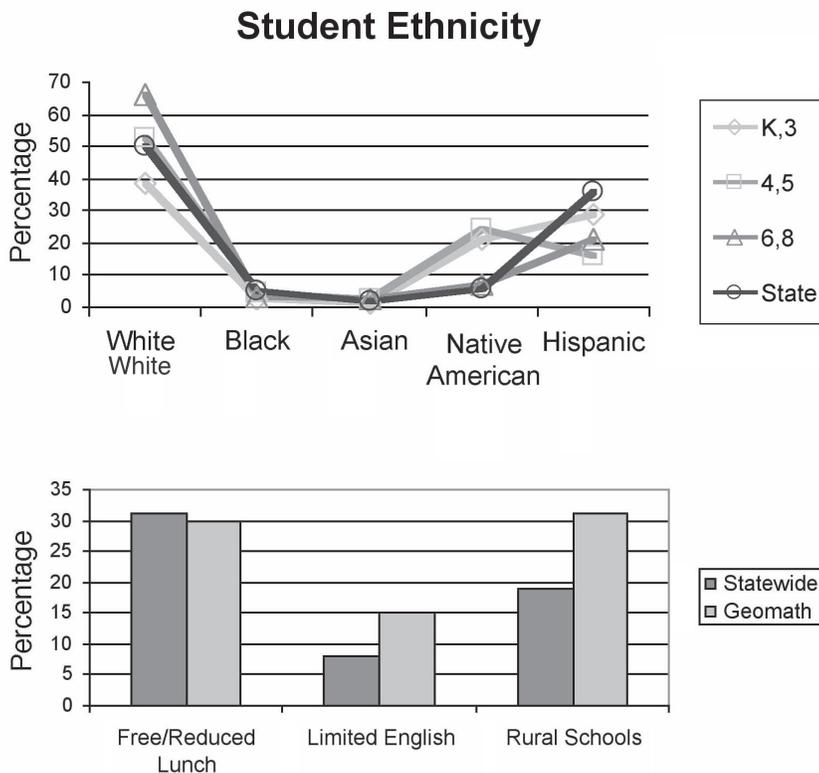


Figure 1. Characteristics of students in 113 piloting classrooms, compared with Arizona's school age population.

Table 1. Sample of the more than 80 GeoMath lessons. The bold lesson names and all lesson titles can be accessed with complete materials at <alliance.la.asu.edu/geomath/general.html>

Grade	Title	Description
K-1	Shape of My World: Mapping a Classroom	Students identify basic shapes in the classroom and make a map showing where major furniture and classroom features.
1-2	Counting islands: What is an island and how many do you see?	Students learn that the world is made up of many landforms, while practicing counting skills.
2-3	Racing around Arizona: Using an Arizona map to create a tour in Arizona	Students learn how to use an Arizona road map to locate places, plan travel, and calculate distances in the context of planning a bicycle race through the state.
2-3	Don't be such a drip: Water conservation	Students learn to draw conclusions from graphs, while they discover the importance of water conservation
3	Relying on the Desert: Plants used by Hohokam	Students learn how Hohokam people used natural resources to survive in a desert, while developing data analysis skills
4-5	Now you see them... now you don't: Movement in and out of Arizona	Students study the movement of people through data analysis of the census.
4-5	It's ours: How do we use this land?	Students learn about how European colonists and Native Americans viewed and used the environment through completing a Venn diagram and creating if/then statements.
4-5	Fun in the Sun?	Students learn sun safety, as they practice data analysis in the making of choropleth maps of melanoma rates.
4-5	Earthquakes in Ohio? U.S. Earthquake risk	Students learn how to make conjectures from occurrence and risk maps of earthquakes in the U.S.
4-5	Grand Canyon: A River Rafting Trip	On a Journey through the Grand Canyon, students practice finding elevations on a topographical map and determine measures of central tendency.
5-8	In the wake of Columbus: Decline of native peoples	Students learn of the catastrophic population decline among Native Americans associated with the Columbian contact, while practicing measurement and graphing skills.
6-8	Can You Hear Me Now? How a Country's Wealth Influences Communication	Students make and solve problems using scatterplots 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	HiLo: Places are much more than just elevations on a map	Students use cooperative strategies to learn important lessons about disagreements on the best use of natural resources in such places as the Dead Sea and Mt Everest, while also practicing skills in subtracting and ordering integers.
6-8	Marvelous Moroccan Mosaics: Patterns in Zillij	Students learn about the centuries-old craft of Zillij and use it to understand geometric shapes and tessellations
6-8	Journey to Africa: Rainfall or Drought	Students create box and whisker graphs to understand desertification
6-8	What's my piece of the pie?	Students learn about South America by creating circle graphs
6-8	Where did the lake go? The drying up of Lake Chad	Students explore the rate of change of Lake Chad, as they learn about interactions between people and environmental change.

lessons; how to order in-service workshops for a school or district; a slide show presentation on the entire package; and tools such as paper protractor, ruler, number line, and graph paper.

STATISTICAL EVALUATION AND THE WWC-DIAD

Despite the practical exigencies that demand the development of programs such as GeoMath and the earlier GeoLiteracy, the authors believe that authentic and performance-based assessment remains a far superior means of determining student learning. But because "accountability" by selected-response testing is political reality in Arizona, the GeoMath program focuses on selected-response items that mirror state mandated testing.

Control Test and Construct Validity

NCLB's What Works Clearinghouse and Design and Implementation Assessment Device (WWC-DIAD) requires that research evaluates interventions using randomized control trials (Cooper and Valentine 2003; Whitehurst 2003; Bhattacharjee 2005). Since GeoMath seeks to stem the overall erosion of social studies in K-8 classrooms in today's accountability era (Manzo 2002; Olson 2004; Reborra 2004; Rentner 2004; Schroeder 2004) proper testing in this context remains essential.

The first step is to validate the test items used in pre- and post-testing of mathematics skills. Not only do the items have to reflect Arizona's AIMS test that embeds elements of the national Stanford 9 test, test items must have construct validity in a control group that mirrors the economic and racial profile of the GeoMath piloting group as a whole (cf. Fig. 1). Using valid test items, out of 10 questions administered in grades 3, 4, 5 and 20 questions for grades 6-8, performance between pre- and post-testing was statistically indistinguishable (Fig. 2). In other words, students who were taught the normal curriculum of social studies and math without GeoMath lessons did not improve in the tested math skills.

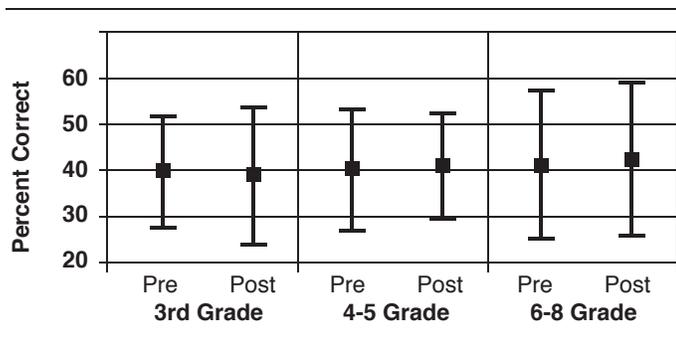


Figure 2. No statistically distinguishable improvement occurred in math skills where control groups were taught the regular social studies curriculum, but not GeoMath materials. Bars and central symbol represents one standard deviation and the mean, respectively.

RESULTS ON MATH ACHIEVEMENT WITH GEOMATH STUDENTS

We compared student performance on the pre-test, given before teaching of the GeoMath lesson, with student performance on the post-test given one month after teaching the lesson. The size of the inversion group of piloting teachers represents 3008 students. The research team did not select the piloting teachers. Instead, a state-wide recruitment of volunteers were accepted or rejected for study participation based on whether or not they met the grant-constrained parameters of reflecting the socio-economic profile of the state as a whole (Fig. 1). Figure 4 summarizes the findings of a statistically significant linear regression. A pair-wise t-test similarly reveals statistical significance at $p < 0.001$ where math skills improved as a result of teaching math in the context of an authentic geography lesson.

These results are especially encouraging given that GeoMath piloting students were slightly more disadvantaged in English skills and derive more heavily from rural settings (Fig. 1). We speculate that the performance difference between control (Fig. 2) and GeoMath (Fig. 3) groups might be from meaningful connections made in GeoMath lessons between particular math skills and authentic geographic context. In other words, GeoMath lessons may have provided a "change of pace" of authentic context that helped increase student interest and hence retention of skills.

Teacher Assessed Performance on Geography and Math Achievement

The entire national accountability movement does not accept the judgment of teachers over "what works" in their classrooms. Instead, the only acceptable interventions are

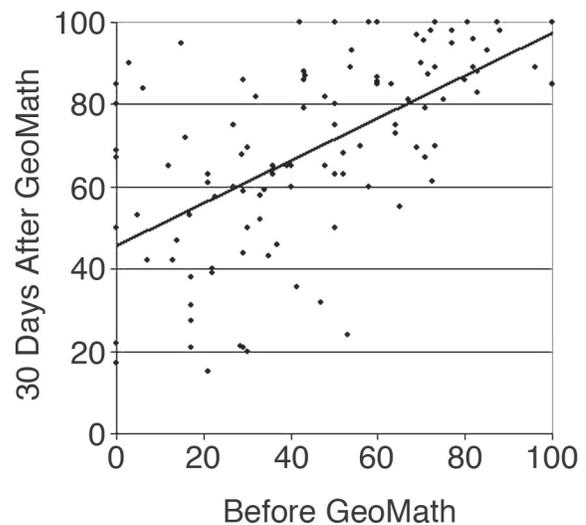


Figure 3. Math achievement gain in 113 classrooms, where the line represents the linear regression with an R^2 value of 0.34, statistically significant at $p < 0.001$.

those requiring randomized control trials (Bhattacharjee 2005). The principles of the GeoMath and GeoLiteracy programs run counter to the principles of the national accountability movement that internally distrusts our nation’s education professionals. Arizona’s GeoLiteracy and GeoMath programs were suggested by teachers, created by teachers, and refined by teachers with assistance at the university level.

Although our assessment component fully complies with the WWC-DIAD in the math assessment, we drew the line with regard to geography. How could we take a program that was crafted by teachers and then turn around and devalue their professional judgment over what works inside their classrooms? For the geography assessment, we assumed that these consummate professionals know how to teach and evaluate their students using the assessment instruments that were developed for lessons. Thus, we simply asked teachers what percentage of their students mastered the geography performance objectives assessed through a mix of performance-based and selected-response assessments built into the structure of the lesson (Fig. 4). Mastery was defined explicitly in the grading key as a score of 80 percent or better.

Qualitative survey of teacher attitudes

Throughout the process, we surveyed author teachers and piloting teachers regarding their attitudes on the project, on geography, and on math. Given the national problem of elementary teacher dislike of mathematics, we were curious about the hypothesis that K-8 teachers might increase their level of comfort in mathematics instruction. So we asked piloting teachers their level of comfort before and after teaching a GeoMath lesson, scored as: Very Uncomfortable = 1; Uncomfortable = 2; Comfortable = 3; and Very Comfortable = 4.

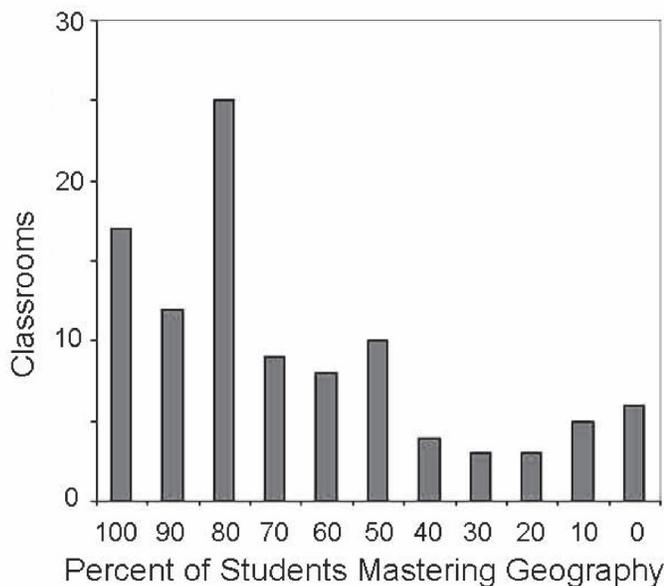


Figure 4. Teacher evaluation of geography performance

While almost three-fourths of the piloting responses revealed no change in math comfort, considerable improvement took place in teacher attitude (Fig. 5). As exemplified in this initial investigation of attitude change, future potential appears to exist in helping improve attitudes towards math education through K-8 social studies lessons.

AN OPEN AGENDA FOR CONNECTING GEOGRAPHY TO NO CHILD LEFT BEHIND

Imagine if a business leader’s success was tied to the performance of employees who only sometimes came to work, when they came to work they were not prepared properly at home to succeed in the work place, and this business leader could not fire such poorly prepared employees. Such is our “accountability” system in K-12 education. This reality forces hard decisions upon K-12 geographic educators who do not have the benefit of a high-stakes geography test.

The Arizona and Michigan geographic alliances are now undertaking—supported by a Grosvenor Grant of the National Geographic Society Education Foundation—a similar, but much more extensive research test of the efficacy of geography lessons to improve scores in high-stakes reading tests in grades 3-8. Preliminary analyses reveal that geography instruction makes statistically significant improvements in reading comprehension. We believe that the time may have come for a national program of connecting geography in a systematic way to reading, writing, and mathematics. This section explains our vision of such a national articulation between geography and

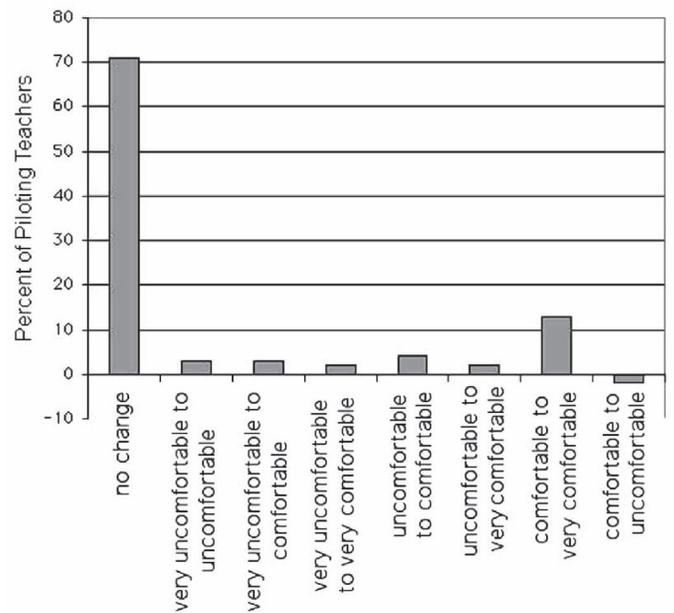


Figure 5. Teacher attitudes changed towards math through the teaching of geography.

high-stakes testing (Heubert and Hauser 1999) in language arts, mathematics, and science. The mission of articulating geography curriculum to high stakes testing would logically involve the following five general steps.

Step 1: Programming of a server must be done in a manner that the teacher sees everything in terms of their own state's standards and their own state's high stakes test. A teacher from Texas, for example, must be able to obtain materials that fit Texas' standards and test. Our group includes a programmer who is the visionary on how to maximize the efficiency of lesson activity dissemination in a way that teachers feel lessons are locally applicable.

Step 2: Lesson improvement is ongoing. Although we are very proud of Arizona's teachers and the job they did in creating GeoMath and GeoLiteracy lessons, not all of the lessons are as clever, crisp, or tight as they might be. There must be a stage whereby teachers from other geographic alliances and organizations contribute activities, which are then piloted and tested for efficacy in teaching math and reading nationwide. These new lessons must maintain the strategy of "crisp" activities in that they are as short as possible, with more detailed options linked as extensions. They need to be reviewed, but not authored, by geography and assessment professionals. They need to include maps designed in collaboration with teachers, and the lesson pieces need to remain as modular as possible; thus facilitating adaptation by experienced teachers wishing to develop the lesson within their overall curriculum.

Step 3: Articulation to Science, the 3Rs and Geography. Physical geography combines biological science (e.g., biogeography), physical science (e.g., Wien's Law, Stefan Boltzman, physics of glaciers and streams, chemistry of rock weathering, and atmospheric pollution), and earth science (e.g., geomorphology, hydrology, soils, climate and weather). Rather than develop an entirely different "GeoScience/Physical Geography" program to work with the upcoming NCLB-requirement of science testing, we feel it is better to link science education in physical geography to either language arts or mathematics, depending upon the nature of the lesson. In this way, activities maintain the richest authentic integration of physical geography (science) tested content, and skill building in language arts and math.

Step 4: Online materials for teacher training for all teachers in all places. The Arizona geographic alliance has experimented with on-line streaming presentations of GeoLiteracy and GeoMath lessons by teachers. These presentations are used in pre-service teacher preparation and to supplement workshops to in-service teachers. Feedback from students and teachers reveal that on-line access to lesson-specific training makes the entire program more effective. The general axiom remains true: teachers only truly trust other teachers on whether an activity actually works. The on-line materials could grow gradually in variety, but we are convinced that a national GeoArticulation program

must include free on-line video presentations that could be used in all teacher trainings, whether they are used in colleges of education, geographic alliance workshops, or as a refresher the night before a lesson is taught.

Step 5: Self-perpetuation is vital. There must be some small ongoing funding mechanism to monitor the delivery website. This would be a coordinating center that would best be supported by an endowment or by a departmental/college commitment to maintenance of the curriculum package. Copyrights of all new-posted materials must be assigned to the coordinating authority. New lessons would be added to accommodate major world events such as a new political alignment or a new economic treaty, and lessons would be updated with such items as maps of the changing European Union. Self-perpetuation would also involve updating changes of state standards and testing style. And, thus, we return to the first step. The site must be programmed using a relational database that allows a piece to be updated (e.g., standard, assessment, map) and a teacher to see that update simultaneously as a part of a lesson that articulates to their state's testing regime.

CONCLUSION

The GeoMath curriculum package of the Arizona Geographic Alliances teaches geography standards and practices math skills tested in Arizona's high stakes test. Randomized control trials and subjective teacher evaluations support the statistically-significant finding that teaching geography improves performance on math skills. Similarly, practicing math skills in a geography lesson also helps learn geography performance objectives. In a quarter of the piloting classrooms, K-8 teacher comfort level in mathematics instruction increased as a consequence of GeoMath lessons.

We asked two natural questions prior to embarking on this two-year GeoMath program: what happens when the pendulum swings away from high-stakes testing, because of tremendous downsides (Rentner 2004) of this incredibly stressful educational strategy? Would the entire effort of GeoMath be wasted? At the end of two-years we can see no downside, whatsoever, to combining geography learning with practicing math skills—especially in the elementary arena where the school year could last 365 days a year and a long list of untested state standards might still remain untaught. In a "best case" scenario, the assessment paradigm changes to authentic, rich performance-based assessments that are far superior pedagogical tools to selected response. If a switch to superior assessment instruments takes place, it would be a simple procedure to modify each "lesson home page." Links could be made to performance-based assessment.

Even if we had the funding to support our vision of a national articulation of geography to high-stakes testing of math and reading, we would not advocate that this program appear overnight. Quick fixes promoted at the national level rarely last beyond the administrator who bought into the national program or notebook/CD on a

shelf, unless these programs find local taproots planted by local teachers. Just as the lessons are modular, the program should grow as each piece is tested and refined. However, we believe it is urgent that we start a national articulation to math and reading just as soon as possible if we wish to maintain or expand geography instruction in grades K-8.

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