KÉYAH MATH: PLACE-BASED, CULTURALLY-RESPONSIVE, TECHNOLOGY-INTENSIVE, QUANTITATIVE MODULES FOR INTRODUCTORY UNDERGRADUATE GEOSCIENCE

PROJECT DESCRIPTION

A. Goal and Objectives

The goal of this three-year project is to develop a series of versatile, place-based, culturally-responsive, and technology-intensive modules in mathematical geoscience for the enhancement of undergraduate geoscience courses for Native American students. Quantitative exercises such as the type proposed are typically not found in introductory geoscience textbooks, nor readily available commercially in ancillary materials.

Kéyah Math modules will integrate relevance and rigor. "Place-based" indicates that the modules will draw data-rich examples from the geology and environments of the Native American lands and adjoining regions of the Southwest United States. "Culturally-responsive" means that the modules will incorporate Native ideas and knowledge about Earth materials, processes, features, and history; include Indigenous terminology wherever possible; and address topics and issues of interest to Native American and other minority communities in the region. The central importance of these two components to our project is reflected in the name *Kéyah*, which is the Diné (Navajo) term for home lands and environment.

Quantitative exercises and supporting materials will be organized into twelve modules based on common topics presented in introductory undergraduate geoscience courses. Inquiry-based, data-rich mathematical applications will be incorporated into cross-platform software designed to do the calculations and to make the modules accessible to any student or teacher with a computer. The modules will be disseminated via the World-Wide Web, and on compact discs for students or faculty without Internet access. The versatility of, and easy access to, the modules will enable any number of them to be integrated into any basic course, regardless of a textbook or laboratory manual. The final product will:

- Bolster the interest and capabilities of all students in the geosciences through the use of scientific inquiry and current scientific data;

- Attract the interest of Native American students in particular, through the use of data and case studies taken from familiar, culturally-significant localities (*e.g.,* Ship Rock and the San Juan River basin on the Navajo Nation) and contemporary issues of significance to their communities (*e.g.,* water resources, climate change, soil erosion, coal mining);
- Improve the quantitative skills of Native American and other minority science students at an early stage in their undergraduate programs, better preparing them for professional careers in the geosciences; and
- Enhance the global infrastructure for geoscience education through universal web-based dissemination, and linkage to major digital clearinghouses such as the Digital Library for Earth System Education (DLESE).

To achieve a seamless interface with computer technology, this project will build on software tools (described below) designed in a current NSF-funded project, *A Versatile, Technology-Intensive Earth Math.*

B. Relevant Pedagogical Concerns

Mathematical Realism

The call to enhance the quantitative content of introductory undergraduate geoscience courses is not new (Shea, 1990). The Principal Investigator (Semken) of this proposed project teaches introductory courses in geology and in chemistry at a tribal community college, and notes the jarring, unrealistic inconsistency in quantitative content between the most popular textbooks in the two disciplines. Introductory chemistry textbooks (*e.g.,* Brown *et al.,* 2003), even so-called "conceptual" texts (*e.g.,* Snyder, 1997), are rich in mathematical concepts students need to fully understand key principles such as stoichiometry and energetics, and in quantitative exercises that enable them to master realistic chemical problems. While some introductory geoscience textbooks (*e.g.,* Plummer *et al*., 2001) have begun to incorporate simplified versions of equations for radiometric decay and groundwater movement, the pages of most popular editions (*e.g.,* Chernicoff and Whitney, 2002; Lutgens and Tarbuck, 2000; Monroe and Wicander, 2001) remain essentially devoid of mathematical expressions and quantitative end-of-chapter exercises. Despite frequent updates to keep these vibrant, graphics-rich books current with regard to research and discoveries, their portrayal of contemporary geoscience is unrealistically qualitative.

Having served as a reviewer of many introductory geoscience texts and laboratory manuals for a number of years, we see no evidence that publishers are interested in bucking this trend. It has been left to geoscience teachers themselves to develop and apply mathematical exercises for their courses. Educators interested in enhancing students' quantitative abilities within geoscience courses have recently outlined a number of specific mathematical principles and skills they have found to be most relevant and useful at the introductory level (*e.g.,* Macdonald *et al.*, 2000; Macdonald and Bailey, 2000; Vacher, 2000). We feel that the stage is clearly set for expanding these sound basic ideas into fully-annotated, versatile mathematical exercises for use by Native American programs as well as the broader geoscience-education community.

Cultural Relevance

Even when compared to other ethnic minorities, Native American students are seriously underrepresented in academic geoscience programs and in the geoscience profession, in spite of the central importance of Earth materials, landforms, and geological processes to many indigenous North American cultures, economies, and histories (Riggs and Semken, 2001). Many reasons for this are undoubtedly sociocultural or economic, such as a scarcity of qualified educators or inadequate infrastructure for teaching science in many Native community schools.

However, most experts in Native American science education (Aikenhead, 2001; Cajete, 1994, 1999; Deloria and Wildcat, 2001; Kawagley and Barnhardt, 1999; MacIvor, 1995; Mullens, 2001) have also cited the fact that science curricula and teaching materials, by ignoring millennia of indigenous interactions with the Earth and drawing most of their examples and case studies from unfamiliar localities, are perceived as irrelevant by Native students. For example, Alaska Native educator Oscar Kawagley and his colleague Ray Barnhardt note (1999):

"The curricula, teaching methodologies, and often the teacher training…are based on a world view that does not always recognize or appreciate indigenous notions of an interdependent universe and the importance of place in their societies."

The *Kéyah Math* project is a community-directed outgrowth of the practice of Indigenous (place-based, culturally-responsive) geoscience education at Diné College and other Tribal Colleges (Riggs and Semken, 2001). By integrating relevant local data and issues with mathematics and scientific inquiry, the *Kéyah Math* modules will enable Native and other Southwestern students to practice and learn contemporary geoscience in constructivist fashion: by building new knowledge on their own preexisting *sense of place*, a deep, empirical knowledge of the landforms, rocks, weather, and processes of change they observe every day of their lives.

Recommendations of the Greater Geoscience-Education Community

In 1996, the National Science Foundation published the "George Report," a comprehensive review of undergraduate education in all areas of science, technology, engineering, and mathematics (George *et al.*, 1996) that in turn inspired communities of educators in the various disciplines to conduct their own reviews. Later that same year, in response to the "George Report," the *Shaping the Future* conference on innovation in undergraduate Earth science education (Ireton *et al.*, 1997), also sponsored by NSF, was convened by the American Geophysical Union and the Keck Geology Consortium.

A panel at this conference addressed the question of increasing diversity, recruitment, and retention of students in the Earth and space sciences. The foremost recommendation of this Diversity Panel (which included the PI of this project), to college and university instructors, echoes the sentiments of Native educators discussed above:

- "Place Earth system science principles and problem-solving methods in the context of the local environment, which helps students connect the relevance of Earth system science to their lives…." (Ridgway *et al.*, 1997).

The place-based, culturally-responsive framework of the *Kéyah Math* modules is fully concordant with this recommendation.

The recent report, *Blueprint for Change* (Barstow *et al.,* 2002), the proceedings of a major recent NSF-funded workshop in geoscience education reform involving a diverse group of educators (including the PI of this project), also lists a number of recommendations for improving curricula and instructional materials. These, though formally addressed to the K-12 community, are equally relevant at the lower-division undergraduate level. The proposed *Kéyah Math* project responds directly to several of these recommendations, specifically that new curricula and instructional materials should:

- Engage students by means of "dynamic learning opportunities that are relevant to students' lives and communities;
- "Be inquiry-based;
- "Illustrate how Earth and space science reflects the contributions of and is relevant to diverse populations;
- "Provide a forum for the development of skills in math…." (Barstow *et al*., 2002)

C. Detailed Project Plan

Overview

In this three-year project, quantitative exercises and supporting materials will be organized into twelve modules based on common topics presented in introductory undergraduate geoscience courses. Inquiry-based, data-rich mathematical applications will be incorporated into cross-platform software designed to do the calculations and to make the modules accessible to any student or teacher with a computer. The modules will be disseminated via the World-Wide Web, and on compact discs. In addition to the materials described below, an on-line *Instructors' Guide* will be written and will include guidelines for classroom use, answers to problems and supplementary materials that can be used for student tests.

Kéyah Math Materials

The product to be developed will be designed after the model developed in the current NSF and FIPSE funded project, *A Versatile, Technology-Intensive Earth Math*, (NSF DUE-9952568 , FIPSE P116B001780; Zumoff and Schaufele, 2000). A preliminary version as of this writing can be viewed on the website earthmath.kennesaw.edu; in particular, note the adaptation to Navajo Nation schools by clicking on "Navajo Nation Studies". This adaptation was supported by the NSF-funded Navajo Nation Rural Systemic Initiative (ESR-9813616).

This model has four components:

- the *Text*;
- the *Tool Chest*;
- *Review Topics*; and
- the *Journal*.

The four components will be arranged to appear on the computer screen with the *Text* appearing in a larger frame with a smaller frame to the left, referred to as the *Left Menu*, listing links to the Review Topics and *Tool Chest*. The *Journal* is kept separately on the local word processor.

Twelve modules will be written in this format integrating mathematical methods with basic concepts from introductory college geoscience courses. Each module will be a Southwestern place-based case study in geology that requires quantitative skills for analysis and solution (*e.g.,* geochronology of volcanic rocks; discharge and downcutting in the San Juan River system).

The *Text*, written in HTML, will present the problem to be analyzed, outline field trips where appropriate, ask questions, and provide links to relevant information and geological and mathematical concepts. To have access to the text, students will only need a Java enabled Web browser.

The *Left Menu* will include the *Review Topics* and *Tool Chest*. The *Review Topics* include a list of links to expository review material in mathematics, geology, and Indigenous knowledge. This is provided for students to refresh their memories regarding topics, formulas, or definitions in these subjects.

The *Tool Chest* will consist of links to three different types of applets: Computation Applets, Experimentation Applets, and Instructional Applets. The Computation Applets perform the mathematical operations needed for the module; the Experimentation Applets give the student a chance to experiment with possible solutions or models; and the Instructional Applets will provide animated demonstrations of mathematical and natural principles and phenomena.

The *Journal* is a place for students to record their work and take notes; this can be printed and turned in to the Instructor. Any text editor such as Microsoft Word, Notepad, *etc*, can be used. Students will be able to transfer the work done with the applets to the *Journal* via the clipboard.

Inquiry-Based Format

Each module will be written in a guided inquiry-based format that is based directly on the Diné Educational Philosophy (DEP), a practical problem-solving and planning process that was derived by traditional Navajos from empirical observations of natural processes (Navajo Community College, 1992; Semken and Morgan, 1997). This philosophy has been passed down from Navajo elders and medicinemen, and is an integral part of the academic process at Diné College, the Tribal College of the Navajo people.

The DEP consists of four stages that correspond to the four cardinal directions, and the daily cycle of traditional Diné life, which in turn mirrors the passage of the sun across the sky. The first stage corresponds to the east and the white dawn, the ceremonial time, and is termed *Nitsáhákees*, or "thinking." The second stage, *Nahat'á*, "planning and learning," corresponds to the south and the blue sky of midday, when Diné people work at their livelihoods. The third stage, corresponding to the west and the yellow dusk, is *Iiná*, "application." The fourth stage, *Siihasin*, "reflection, assessment, maintenance," corresponds to the north and the black night sky, and is associated with thoughtful respect for the natural environment. This cycle is considered continuous, in that the results of *Siihasin* lead naturally back into *Nitsáhákees* and new thoughts or activities.

Not only is the DEP incorporated into curriculum design and teaching at Diné College; it is a fundamental process in all traditional Navajo lives and in Navajo Nation governance. Similar cyclical ways of learning and planning are present in other Native American cultures. We have also used this model for observing and interpreting geological processes of change in the local environment (Semken and Morgan, 1997).

We have adapted this traditional Diné pedagogy into a four-step inquiry learning cycle that is fundamentally identical to "textbook" scientific inquiry (*e.g.,* Trefil and Hazen, 2000, figure 1.2) and conceptual learning cycles such as that of Lawson (1994). Our Diné-based format for the *Kéyah Math* modules is:

- *Nitsáhákees*: presentation of a problem;
- *Nahat'á*: acquisition of relevant information and skills;
- *Iiná*: application of information and skills to the problem; and

- *Siihasin*: investigation of the solution.

In the *Nitsáhákees* stage, students will be presented with a problem and asked questions to generate discussion and student thought. At this stage they think about and discuss the implications of the problem and, with guidance from the instructor, visualize a solution. The questions can be presented by the instructor for group discussion or accessed from the Web or CD with individual responses written to the *Journal*. (See below for a complete description of this, and other features of the software to be developed.)

This first stage naturally leads to the second, *Nahat'á*, in which students gather pertinent data and scientific information, and review or learn mathematical skills and concepts which are needed to analyze the problem. Information can be accessed from several sources: field trips, the Web via links to appropriate sites; data provided on the CD (including *Review Topics*); or from printed sources.

During the *Iiná* (third) stage, students are guided through steps to apply the mathematical concepts to solve the problem. The *Tool Chest* will provide students with the mathematical tools and geology concepts needed to analyze the problem. (Some instructors may prefer that their students compute by hand, or use handheld calculators.) Students will then enter their answers and explanations into the *Journal* using an existing text editor.

In stage four, *Siihasin*, students are asked to examine the implications of the solution and review the mathematical and geological concepts used.

The appropriateness of this traditional Navajo method for teaching mathematical geoscience is reinforced by the fact that it is also evoked by several Western paradigms for problem solving, including the AMATYC Standards for two-year-college mathematics (AMATYC, 1995) and the four-step "How to Solve It" heuristic of Polya (1957).

Software

Java applets developed for the *Earth Math* Project by Dr. Philippe Laval will be used in the *Kéyah Math* modules. Other applets that demonstrate geological principles will be developed and added as appropriate. It is highly desirable to have self-contained platform-independent materials such as these. This delivery system will make the modules accessible to any student or teacher with a computer, and does not require the purchase of costly software. Moreover, it is not appropriate to use software that requires extensive instruction for student use. The applets can be run from within the web browser, or Java applications on the CD, and will allow students to do mathematics interactively. Mathematics performed by the applets can be transferred to the student's *Journal* via the clipboard.

The applets, accessed from the *Left Menu*, perform the following tasks:

- fit data with regression functions;
- graph functions of one variable, trace and label points on the graph;
- solve single equations numerically; solve systems of equations;
- perform arithmetical operations;
- evaluate functions; and
- perform simple symbolic and numeric differentiation and integration.

Content: Integrating Geoscience, Culture, Place, and Mathematics

A central theme of Diné ethnogeology, which is the empirical knowledge of Earth features and processes obtained by Diné people from careful observations and reasoning over many centuries, is the dynamic interaction between *Nohosdzáán* (Earth) and *Yádilhil* (Sky) that has shaped the Colorado Plateau landscape and maintained its habitability for all its indigenous life forms (Navajo Community College, 1992; Semken and Morgan, 1997). In the Indigenous Geology curriculum at Diné College, *Nohosdzáán* is equated with the solid-Earth system and *Yádilhil* with the fluid-Earth system; each system has a set of dynamic processes such as volcanism, crustal deformation, weathering and erosion, and sedimentation. The introductory-geology syllabus is organized as a cyclical twelve-topic passage through Earth (plate tectonics, rock cycle, igneous rocks, mountain-building, metamorphic rocks, seismicity), then Earth-Sky interactions (weathering and erosion, sedimentary rocks, landscape evolution), and finally through Sky (groundwater and rivers, desert climate, impact processes). Each topic is illustrated with laboratory or field studies of nearby Colorado Plateau and Southern Rocky Mountains localities.

We propose to use a similar twelve-topic, place-based Earth-Sky cycle to organize the *Kéyah Math* modules. A preliminary, abbreviated list of possible modules to be developed is given in the table below. The basic quantitative skills that will be written into the modules are taken from the study by Macdonald and Bailey (2000): estimating, measuring, determining rates, graphing, modeling, and geochronology (exponential decay). We have added the use of contour (topographic) maps.

The modules are not intended to exhaustively match the list of topics presented in an introductory-geology course, but rather as practical applications of basic mathematics to geoscience problems that can be used to supplement a wide range of topics. It is important to note that although we have organized these modules concordantly with Diné ethnogeology, they can be used in any sequence an instructor desires. It will also be possible for an instructor to use his or her own place-based data with the software.

KM Module	**Place or Theme**	**Mathematical Skill(s)**	**Activity**
Diné bikéyah I: mapping the landscape in three dimensions	Local USGS 1:100,000 topographic map (Farmington, NM quad)	Measuring Determining scale Contour mapping	Locate landmarks using latitude/longitude and PLS; calculate distances using map scale; calculate landform slopes and stream gradients using contours
Tsé na'alkaah: interpreting rocks by texture and composition	Sedimentary, igneous, and metamorphic rocks from the Colorado Plateau and Southern Rockies (hand specimens, specimen images, thin-section images	Estimating Measuring Determining density	Measure and compare grain sizes; estimate mineral percentages; calculate and compare rock densities (among specimens and with average crustal and mantle densities)
Tsé dildoní: The ages of Southwestern volcanoes	Ship Rock, Jemez Mountains, and El Malpais volcanics, NM	Geochronology (exponential decay)	Calculate rock ages given data from actual K-Ar and Ar-Ar studies
Leejin: geology and environmental significance of coal on the Colorado Plateau	Cretaceous Western Interior coalfields in the southern Colorado Plateau	Measuring Graphing Determining rates	Determine heat and trace element content of peats and Plateau coals and coal provenance; discuss implications for electricity production and air pollution
Tó biyaazh: the availability of groundwater resources	Shallow alluvial and deep sandstone aquifers in the San Juan Basin, NM	Determining rates	Determine rates of groundwater flow in regional aquifers
Tooh (San Juan River) I: the legacy of glaciers in a desert river valley	Quaternary terraces along the San Juan River and tributaries, NM and	Contour mapping Determining rates	Determine spacing and elevation of river terraces from topo map;

	CO		given ages, calculate rates of downcutting
Tooh (San Juan River) II: historic floods prior to damming	San Juan River valley in vicinity of Shiprock, NM	Graphing Contour mapping	Obtain discharge and river stages from USGS data on WWW; reconstruct flood damage in Shiprock
Séí: historical climate changes and growth of sand dunes on the Colorado Plateau	Aeolian dunes at various sites on the Navajo Nation and environs	Graphing Determining rates Modeling	Determine climatic conditions under which dunes form and expand; discuss historical and current impact of drought and soil erosion
Diné bikéyah II: the age of the present landscape	Landforms and surfaces on the Colorado Plateau (terraces, young lava flows, alluvial fans, *etc.*)	Geochronology (exponential decay)	Calculate ages of regional surfaces and landforms given data from actual Cl-36 dating studies
Impact landforms in the Southwest	Meteor Crater, AZ; Upheaval Dome, UT; Beclabito Dome, NM; late-K Yucatan impact crater	Estimating Determining rates Modeling	Determine impact energy and impactor size at Meteor Crater; compare other possible local impact sites, and Yucatan late-K impact

Project Timetable

Year One (May 2003 through April 2004)

- Consultation among Investigators and Faculty Consultants
- Module Development
  - Data collection, including regional summer field work and consultation with scientists working in the region
  - Modification of applet software
  - Consultation on Native linguistic and cultural matters
- Preliminary web site development on Diné College server

Year Two (May 2004 through April 2005)

- Summer workshop for faculty of approximately 10 test sites (collaborating regional colleges and universities)
- Piloting of *Kéyah Math* modules at Diné College and test sites
- Revision of modules based on results from pilot tests
- Continued web site development
- Development of evaluation instrument and preliminary formative assessment by external evaluator

Year Three (May 2005 through April 2006)

- Continued formative evaluation of project
- Dissemination
  - Major summer workshop for approximately 20 colleges and universities
  - Publications in relevant journals and advertising in newsjournals and at conferences
- Introduction of modules at Tribal and Southwestern colleges
- Summative project assessment and final reporting
- Drafting and submission of new Dissemination Project proposal

D. Evaluation Plan

Dr. Pam Drummond will serve as the external evaluator for this project. She has experience assessing the effectiveness of curricula using quantitative modeling in courses, driven by relevant issues, for undergraduate students. This evaluation will address the extent to which the project's *Kéyah Math* modules affect changes in students' knowledge of and opinions about geoscience. Multiple sources of information, requiring both quantitative and qualitative methods, enhance the results of an assessment. Therefore, a portion of this particular study will use instruments having multiple-choice responses with a large number of students. This component will offer an extensive examination of student gains in both cognition and disposition resulting from use of the modules. In addition to this extensive investigation, a smaller number of students will participate in an interview. This intensive portion of the study will explore beliefs about and appreciation of geoscience. Thus, this evaluation is a variation of a pre-test post-test design that uses both quantitative and qualitative methods. It will contain five stages as delineated in the following table.

Stage One	Identify Learning Outcomes
Stage Two	Design Assessment Instruments
Stage Three	Collect Data
Stage Four	Analyze Results

Stage Five	Provide Summative Evaluation and Final Report

E. Dissemination

Dissemination will begin in Year 2 of the project. After initial development and establishment of the modules and web site, a training and content-expansion workshop will be held at the beginning of Year 2 for a set of 8 to 10 two-year colleges in the Southwest who have agreed to serve as test sites. (Letters of collaboration from these institutions can be found in the Supplementary Documents section.) At this initial workshop, faculty at the testing institutions will receive training in module functions and how to incorporate their own data and case studies into the modules.

After this workshop, preliminary in-class evaluation at the test sites, and continued revision during Year 2, wider dissemination will begin in Year 3. A major two-day workshop for some 15 to 20 schools will be held in Shiprock. This will be directed toward two-year and four-year institutions in the Southwest, where principal initial usage of the materials is expected.

Also in Year 3, the *Kéyah Math* website will be submitted for review by and linkage to the *Digital Library for Earth System Education* (DLESE; www.dlese.org), so that these modules can be included among the many exemplary web-based Earth-system science materials that DLESE makes available to the global educational community. The *Kéyah Math* web site will be a strong component of the dissemination plan.

Additional dissemination in Year 3 will include publications in journals such as the *Journal of Geoscience Education* and *The American Mathematical Monthly*; presentations at annual meetings of the Geological Society of America, American Geophysical Union, American Indian Higher Education Consortium (AIHEC), American Indian Science and Engineering Society (AISES), and Society for Chicanos and Native Americans in Science (SACNAS); and advertisement of the *Kéyah Math* web site in appropriate professional publications. During Year 3, a major proposal will be submitted to NSF for expansion of the project to develop similar materials in the same format for use at all Tribal Colleges. This follow-up project will involve localizing geological studies as well as integrating the languages and cultural knowledge of a wider group of Native American communities.

F. Results from Prior NSF Support

Semken: Advanced Technologies: Simulations for Learning about Interactions in Complex Environments, and *VR Excursions.*

NSF DUE-9555211, a Course and Curriculum Development grant to Northern Arizona University with subcontract to Diné College, S.C. Semken was Co-Principal Investigator. The grant was for $16,000 annually for three years, 01 April 1996 to 31 March 1999.

This project centered on the development and dissemination of a set of real-world simulations in environmental geology using multimedia technology. The simulations were organized into three modules: (1) the environmental geology of landfills, (2) the proposed Yucca Mountain, Nevada, high-level radioactive-waste repository, and (3) the environmental significance of mining Cretaceous Western Interior coals and coal-fired power generation in the San Juan Basin, New Mexico. S.C. Semken was the technical lead on the third module and also provided some content for the other two, in collaboration with geoscience educators at Northern Arizona University, and technical advisors from the local mining firm, electric utility, and Tribal and Federal environmental regulatory agencies.

The project was completed successfully (Kelly *et al.,* 1998) and culminated in the 1999 publication of a commercial multimedia CD-ROM and laboratory manual, *VR* (Virtual Reality) *Excursions: Exploring Earth's Environment*, by Prentice-Hall (Kelly *et al.,* 1999). This product is still on the market and still in regular use by colleges and universities and some secondary schools.

Schaufele and Zumoff: EarthMath Phase Three: Calculus and Statistics for a New Century.

NSF DUE-9653135; the grant was for a total of $220,800 from FY 1994 through FY 1997. C. Schaufele and N. Zumoff were Principal Investigators.

Using modeling and real world data as motivation, materials appropriate for business calculus and introductory statistics courses were developed, tested, and evaluated. Materials are designed to improve the mathematical knowledge and skills of entering college students outside of science, mathematics, and engineering. Elementary concepts from statistics and calculus are used to construct and analyze algebraic functions that model real data. A complete set of modules was written, piloted and class tested and comprise a stand-alone core course or a replacement for business calculus. Modules have also been piloted in elementary statistics. The courses were piloted at both Kennesaw State University, Phoenix College and Portland State. These materials have been published by Kendall-Hunt as a textbook, *Earth Studies* (Zumoff *et al.*, 2000).

In the spirit of the Earth Algebra and Earth Math projects, previously funded by both the Fund for the Improvement of Post-Secondary Education (FIPSE) and the NSF, the course incorporates the principles of the NCTM and AMATYC *Standards.* Assessment evidence indicates that experience with the Earth Math Studies does enhance problem solving and decision making competence and opinions about mathematics were stronger. Both treatment and control groups exhibited significant improvement and there was no statistically significant difference between the two groups in Applied Calculus. The scores of the statistics Treatment group were significantly higher than those of the Control Group. It should be noted here that the Applied Calculus Treatment group was also using innovative reform material while the Statistics Treatment group used a traditional text.

Materials were evaluated according to eight curriculum standards considered germane to the Earth Math Studies: the four process standards and four content standards. A comparison of the individual components for each standard with the Studies revealed that these materials were highly congruent with the Standards. Further analysis showed the students in the Treatment courses were much more likely to work together in small groups in class and to work on projects as well.