VIRGINIA EARTH SCIENCE COLLABORATIVE: DEVELOPING HIGHLY QUALIFIED EARTH SCIENCE TEACHERS

J. COTHRON
MathScience Innovation Center
Richmond, VA 23223

Abstract

A collaborative of seven institutes of higher education and two non-profit organizations developed and implemented five earth science courses totaling eighteen credits that enabled secondary teachers to acquire an add-on earth science endorsement: *Geology I: Physical Geology* (4), *Geology II: Geology of Virginia* (4), *Oceanography* (4), *Astronomy* (*Space Science for Teachers*) (3), and *Meteorology* (3). These courses were collaboratively developed and included rigorous academic content, research-based instructional strategies, and intense field experiences. The thirty-three sections offered statewide served 499 participants. Three courses were offered to strengthen the skills of earth science teachers: *Teaching Earth Science Topics to Special Education Students* (3), *Integrating New Technologies in the Earth Sciences* (3), and *GeoVirginia: Creating Virtual Field Trips* (non-college credit). In these six sections, seventy-four people participated. Outcomes included an increased pool of endorsed earth science teachers and teachers with coursework in the earth sciences, a website with virtual field trips, and a statewide network. Partners included the College of William & Mary and its Virginia Institute of Marine Sciences, George Mason University, James Madison University, Longwood University, the MathScience Innovation Center (formerly the Mathematics & Science Center), Radford University, Science Museum of Virginia, University of Virginia Southwest Center, Virginia Commonwealth University, and eighty-three school divisions.

The Need

In Fall 2004, the Virginia Department of Education issued a Request For Proposals (RFP) to increase the number of endorsed earth science teachers in the Commonwealth, with funding to come from the Mathematics and Science Partnership (MSP) grant funded through the federal No Child Left Behind legislation of 2001 [1]. In Virginia, earth science is a high school course typically taught at the ninth grade level. In addition, many middle schools teach the subject as part of an acceleration option. At the time of the RFP, earth science teachers were the highest shortage area in the Commonwealth and student scores on the statewide, End-of-Course Earth Science Tests were the lowest among the sciences. In response to the RFP, a collaborative of institutions of higher education and non-profit organizations was formed to determine the need and to develop an appropriate proposal.

The three methodologies outlined below were used to assess the needs of the 134 divisions within the Commonwealth.

1) Educational Leaders —Personal conversations and small focus groups were held with educational leaders to determine general needs and to provide input on the development of the *Earth Science Needs Assessment Survey*.
2) Divisions — Each responding division completed the *Earth Science Needs Assessment Survey* and provided information on student achievement, endorsement status of teachers, financial support willing to provide, and greatest needs in earth science.
3) Teachers — On the *Teacher Survey*, potential participants provided information about the following: 1) certification and endorsement, 2) teaching assignment, 3) academic background, 4) self-perceptions of earth science knowledge and skills, 5) courses needed, 6) course delivery, and 7) open-ended questions related to the teaching of earth science. Survey items were based upon I.R. Weiss' *Status of Secondary School Earth Science Teaching* (a component of the 2000 National Survey of Science and Mathematics Education) [2].

Of the 134 Virginia divisions, seventy-one indicated they would participate. The remainder did not respond (41), did not want to participate (17), or were part of another grant (5).

The Need—Divisions' Report

The seventy-one divisions reported 565 earth science teachers, with 146 of them not fully endorsed. This represented 26.7% of the teaching force. Annually, divisions tended to employ 139 novice teachers with 49% of them not fully endorsed in earth science. Obtaining endorsed teachers was a major issue for middle schools that taught earth science as an acceleration option. The divisions projected 191 teacher participants, including unendorsed teachers and endorsed teachers, that wanted to improve their academic background or teaching skills in earth science. Within the seventy-one divisions, 182 middle and high schools taught earth science. Of these schools, fifty-six had fewer than 70% of their students passing the statewide, End-of-Course Earth Science Test, which is based upon Virginia's *Standards of Learning for K-12 Science* [3].

The Need—Teachers' Self-Report

Of the 324 teachers submitting surveys of intent to participate, 227 were endorsed in high school science subjects and ninety-seven were endorsed in middle school or special education. At the time of the RFP, *Virginia Licensure Regulations for School Personnel* provided an option for teachers endorsed in biology, chemistry, or physics to obtain an "add-on earth science endorsement" by taking eighteen semester credits in the earth sciences, including preparation in geology, oceanography, meteorology, and astronomy [4]. Other teachers, including those endorsed in middle school science or special education, had to meet the requirements of the full earth science endorsement which included a total of thirty-two hours of oceanography, meteorology, astronomy and geology (eighteen credits required). Generally, teachers preferred summer courses and weekend courses combined with websites.

Teachers rated their conceptual understanding and teaching skills on thirty-one dimensions using the following scale: 1 (not well qualified), 2 (adequately qualified), and 3 (very well qualified). On the six content dimensions included in the RFP, typical ratings were 1 and 2, with the order of confidence, least to greatest, in the following order: petrology and minerals, paleontology and historical geology, physical oceanography, astronomy, structural/tectonics, and meteorology. Teachers considered themselves "adequately qualified" to "very well qualified" to teach terms and facts, concepts, and process skills and to engage students in understanding the nature of science; this confidence may have been derived, in part, from their experience in teaching other scientific disciplines. Teachers typically considered themselves "not well qualified" to help students learn applications and to use technology including GIS, GPS, calculator- and computer-based labs, Internet collaborative projects, and computer simulations. Over 140 teachers expressed an interest in a course on effective strategies for integrating new technologies into the earth sciences. Another need, expressed on an open-ended question, was assistance with collaborative education, including improved content understanding for special education teachers and improved differentiation strategies for regular earth science teachers.

Project Goals and Funding

Based upon the needs assessment, the Virginia Earth Science Collaborative (VESC) developed four project goals:

1) Increase the pool of endorsed earth science teachers by offering the coursework needed for the add-on earth science endorsement in various geographic areas of Virginia;
2) Increase teachers' conceptual understanding of the earth sciences and their ability to deliver inquiry-oriented instruction by developing and offering earth science courses appropriate for teachers;
3) Increase the number of highly qualified earth science teachers by piloting courses in three identified areas of need—use of effective strategies including new technologies, improved collaborative teaching of earth science, and a targeted course for sixth grade teachers; and,

4) Establish a statewide collaborative that can be used to continuously lead and inform decisions and programs related to the teaching and learning of earth science.

A proposal based upon these goals was submitted to the Virginia Department of Education and funding of $920,848 was awarded for the period of March 2005 to September 2006. Based upon the success of the project, a second award of $351,649 was made between March 2006 and September 2007. Finally, a special award of $35,017 enabled development and funding of this Special Issue of *The Journal of Mathematics and Science: Collaborative Explorations*. A total of $1,307,514 in MSP funding was matched by $237, 000 from the VESC partners.

Implementation

Goal 1: Increase the Pool of Endorsed Earth Science Teachers — Before admission to classes, all teachers completed the *Teacher Survey*, which included their reason for participation. When necessary, these reasons were used to establish priorities for enrollment. Demographics on participants reflect the following priorities:

- Secondary science teacher completing an earth science or add-on earth science endorsement, with priority given to those currently teaching earth science (53% of participants);

- Middle or special education teacher taking eighteen credit hours toward the full earth science endorsement (16% of participants);

- Middle or special education teacher taking earth science courses to strengthen their background (13% of participants);

- Endorsed earth science teacher taking courses to strengthen their background, especially *Geology of Virginia* and courses which they may have taken in a non-laboratory setting (10% of participants); and,

- Other participants included pre-service or career switchers in degree programs and upper elementary teachers whose curriculum included earth science topics (8% of participants).

Because large numbers of elementary, middle, and special education teachers were applying to take the courses, these priorities were established in cooperation with the Virginia Department of Education. Although the primary purpose of the grant was to increase the number of endorsed earth science teachers, strengthening the academic background of teachers in the feeder curriculum was perceived as a critical way to improve the overall quality of the earth science curriculum. Initially, professors at the universities were hesitant to enroll teachers outside the target population, and their advice was asked regarding the best courses for students to take, with the recommendations being *Astronomy* (*Space Science for Teachers*), *Meteorology* and *Geology I: Physical Geology*. Of these courses, *Astronomy* and *Meteorology* had the greatest application to Virginia's upper elementary and middle school science curricula. Five courses were developed and delivered statewide (see Table 1).

Table 1
Participation in Courses for Add-on Earth Science Certification

Information	*Astronomy*	*Meteorology*	*Oceanography*	*Geology I: Physical Geology*	*Geology II: Geology of Virginia*	Total
Number of different locations taught	4	3	4	4	5	---
Number of course sections	7	6	6	5	9	33
Number of participants	134	115	79	64	107	499
Percentage (%) of participants	27	23	16	13	21	100
Participants' reasons for taking course (%)						
Secondary science teachers completing or adding an earth science endorsement (%)	38	52	71	66	50	53
Middle or special education teachers completing 18 credit hours (%)	13	18	13	22	17	16
Middle school or special education teachers strengthening background (%)	20	16	8	8	9	13
Endorsed earth science teachers strengthening background (%)	16	5	6	1	18	10
Other – pre-service teachers, elementary teachers, etc. (%)	13	9	2	3	6	8

Courses were taught at seven different locations within the state: Abingdon, Charlottesville, Fairfax, Harrisonburg, Radford, Richmond, and Williamsburg. The seven institutions of higher education delivering courses at the various locations were:

- College of William & Mary (Williamsburg and Richmond);
- George Mason University (Fairfax);
- James Madison University (Harrisonburg);
- Longwood University (off-site campus in Richmond area);
- Radford University (Radford);
- University of Virginia Southwest Center (Abingdon, Charlottesville, and Richmond); and,
- Virginia Commonwealth University (Richmond).

Thirty-three course sections were offered by these institutions: *Physical Geology* (5), *Geology of Virginia* (9), *Astronomy* (7), *Meteorology* (6), and *Oceanography* (6). In the sections, there were 499 participants (duplicated count), with the largest percentages enrolled in *Astronomy* (27%), *Meteorology* (23%), and *Geology of Virginia* (21%). Several factors contributed to the higher enrollment in these courses: the contents of *Astronomy* (*Space Science for Teachers*) and *Meteorology* are major components of the elementary and middle school curricula, *Geology I* and *II* and its applications to Virginia comprise over 50% ·of the earth science curriculum, and *Meteorology* was a web-based class. Enrollment was much smaller in *Oceanography* (16%) and *Physical Geology* (13%), with the classes taken primarily by teachers pursuing the earth science endorsement. For example, 88% of the *Physical Geology* participants and 84% of the *Oceanography* participants were secondary teachers pursuing the endorsement, or middle and special education teachers pursing eighteen hours toward the endorsement. In addition, many participants had taken physical geology as an undergraduate.

<u>Goal 2: Increase Teachers' Conceptual Understanding of the Earth Sciences</u> — In response to the RFP, five graduate courses specifically designed for teachers were targeted for development: *Astronomy* (*Space Science for Teachers*), *Meteorology*, *Oceanography*, *Geology I: Physical Geology* and *Geology II: Geology of Virginia*. With the exception of the geology sequence, courses could be taken in any order. Guidelines for development included addressing the areas of earth science required in the RFP, emphasizing inquiry and the nature of science, and providing extensive opportunities for teachers to engage in field studies. For example, *Oceanography* included a two- to three-day intense experience at the Virginia Institute of Marine Science

(VIMS) field station (Eastern Shore Laboratory), and *Geology of Virginia* included field experiences in the geologic provinces.

Five course development teams were formed to develop each of the designated courses, with each team led by a professor charged with appointing team members, scheduling meetings and discussions, compiling products for review and dissemination, and managing the course development budget. The composition of the various teams is provided below. As an initial step, each team developed general information about the course including the curriculum framework concepts, related Virginia *Standards of Learning* objectives, and examples of how inquiry and the nature of science would be addressed (see Table 2). Because the two geology courses were sequential and many professors were teaching both courses, the group met collectively to determine the scope and sequence of each course. Heather MacDonald, Professor at the College of William & Mary led the initial discussions with the assistance of Gerald Johnson and Brent Owens of the College of William & Mary, Rick Diecchio of George Mason University, Eric Pyle of James Madison University, Joyce Watson of the MathScience Innovation Center, and Jonathan Tso of Radford University.

- *Geology I: Physical Geology* — Eric Pyle provided leadership for course development with the assistance of Rick Diecchio, Joyce Watson, Jonathan Tso, and two professors at James Madison University, Roddy Amenta and Lynn Fichter.
- *Geology II: Geology of Virginia* — Heather MacDonald provided leadership for the team, which consisted of Gerald Johnson, Brent Owens, Rick Diecchio, Eric Pyle, Joyce Watson, and Jonathan Tso.
- *Astronomy (Space Science for Teachers)* — Edward Murphy, Assistant Professor at the University of Virginia led the team whose members included Harold Geller of George Mason University, Randy Bell of the University of Virginia, David Hagan of the Science Museum of Virginia, and Michael Bentley of the University of Virginia School of Continuing Education (Southwest Center).
- *Meteorology* — Juanita Jo Matkins, Associate Professor at the College of William & Mary led the team whose members included Eric Pyle of James Madison University, Jo Ann Mulvaney, Adjunct Professor at Virginia Commonwealth University, and Michael Bentley, Adjunct Professor at the University of Virginia School of Continuing Education.
- *Oceanography* — Kristen St. John, Associate Professor at James Madison University led a team comprised of Mark Krekeler of George Mason University, Vicki Clark of the Virginia Institute of Marine Science, Steve Oden, Adjunct Professor at Virginia Commonwealth University and educator at the MathScience Innovation Center, and Chris Lundberg, educator at the MathScience Innovation Center.

Table 2
Overview of Courses for Earth Science Endorsement

Geology I: Physical Geology **(4 credits)** Curriculum Framework Concepts: Identification and use of minerals, rock cycle processes, (weathering, erosion, deposition, metamorphism, melting, crystallization) and products (igneous, metamorphic, sedimentary rock identification), plate tectonic processes (subduction, rifting, continental collision) and their relationship to the rock cycle, influence of surficial process on soil development and local geomorphology, age of Earth, basic stratigraphic principles and relative time. Related SOL: ES 1c; ES 3; ES 5; ES 6; ES 8 b, c; ES 9 a, b, c, d; ES 10 a, b, c. Examples of Inquiry Skills & Nature of Science. Classification of minerals and rocks, interpretation of rock cycle diagram, development of concept maps relating rock cycle and plate tectonics, interpretation of topographic maps.
Geology II: Geology of Virginia **(4 credits)** Pre-requisite: Geology I: Physical Geology Curriculum Framework Concepts: Relationship between plate tectonic processes and geologic hazards (earthquakes, volcanic eruptions), structure geology (faults, folds), paleomagnetism and the geologic time scale, fossil identification and use, geologic history and the resulting physiographic provinces and resources of Virginia. Related SOL: ES 1 b, c, e: ES 2: ES 3, ES 7 c, d, e; ES 8, ES 9 f; ES 10. Examples of Inquiry Skills & Nature of Science. Local and regional field studies of Virginia's physiographic provinces and resources, fossil identification, interpretation of geologic maps, development of field guides by teachers for teachers.
Oceanography **(4 credits)** Curriculum Framework Concepts: Tectonic evolution of the ocean basins, physiography of the sea floor, heat capacity of the ocean and influence on maritime climates, waves, tides, influence of winds on surface currents, upwelling, relationships between sea level change and climate and tectonics changes, influence of temperature and salinity on density and deep water circulation, coastal geology, marine ecosystems, controls on marine sedimentation, microfossils and ancient oceans, marine resources. Related SOL: ES 1; ES 2; ES 3; ES 4b; Es 7 a, d, e; ES 8 b, c; ES 10 a; ES 11; ES 13 d. Examples of Inquiry Skills & Nature of Science. Intense field experiences at VIMS Field Station including shipboard physical, chemical, and biological analyses of saltwater ecosystems, marine depositional environments, currents and tides, long shore transport, barrier island dynamics, and fisheries.
Meteorology **(3 credits)** Curriculum Framework Concepts: Earth's heat budget and global wind patterns, weather vs. climate, radiation, convection, cloud formation, the hydrologic cycle, vertical structure of the atmosphere, orographic effects on weather, severe weather, the influence of life (microbial, human) and geologic processes on atmospheric composition and temperature through geologic time, comparison of the atmospheres of Earth, Mars, and Venus. Related SOL: ES.1, ES.3 a, b, c, d; ES 9 d; ES.11 c, ES.12 a, b, c, d, e; ES 13 a, b, c, d. Examples of Inquiry Skills & Nature of Science. Through the use of Internet-accessed, real-time and near real-time data, hands-on activities, lab experiences and field experience, the course will focus on inquiry-based learning and the applications of experimental design in meteorology. The course will feature an examination of current understandings of climate change and how these understandings reveal the nature of the scientific enterprise and scientific knowledge.

***Astronomy* (3 credits)**
Curriculum Framework Concepts: Position and motion of Earth in space, sun-Earth-moon relationships and the resulting seasons, tides, and eclipses; characterization of solar system bodies (sun, planets, meteors, and asteroids), formation and evolution of the universe (big bang theory) and solar system (solar nebular theory), life cycle of stars, nature of space exploration and study (ground-based observations vs. space-based observations), major contributions of the space program.
Related SOL: ES 1; ES 2; ES 3; ES 4; ES 14.
Examples of Inquiry Skills & Nature of Science. Computer-based labs and simulations, such as *Starry Night®*, planetarium work, night sky observations.

Goal 3: Increase the Number of Highly Qualified Earth Science Teachers — As previously described, teachers recommended three major ways to improve their capabilities in the earth sciences and to improve student achievement. First, 146 teachers requested a course on effective strategies utilizing the following: ***good*** hands-on labs (not paper-and-pencil worksheets); effective computer software and simulations; and, the use of global positioning systems, geographic information systems, imaging software, and calculator-based labs. A recurring theme was the use of materials that helped students see the relevance of earth science in their community. To meet this need, *Integrating New Technologies in the Earth Sciences* was developed and piloted in Fall 2005 in the Richmond area; development included a web-based collaborative student project relevant to Virginia. Drew Keller, an educator at the MathScience Innovation Center, led development of this course, which built upon the Center's expertise in GIS, GPS, and web-based instruction. Jackie McDonough, Adjunct Professor at Virginia Commonwealth University, six outstanding earth science educators, and three members of the Virginia Department of Mineral Resources assisted with course design. The course was a blend of face-to-face and web instruction through *Moodle*™, a web-based instructional system used by the Center. The 3-credit graduate course was offered through Virginia Commonwealth University's School of Education, and was offered a second time in Spring 2006.

Second, numerous divisions and teachers from high needs schools expressed a need for more effective collaboration involving special needs students. Comments were that special education teachers needed a greater understanding of earth science concepts and that the regular classroom teacher needed a greater understanding of appropriate differentiation strategies for various special education students, slow learners, and poor readers. To meet this need, *Effective Collaboration in the Earth Science Classroom* was developed and piloted in Summer 2006 at Longwood University's off-campus site in Powhatan County, which is located west of Richmond. Teachers from schools with less than a 70% pass rate Earth Science *SOL* Test were given priority for enrollment. Enza McCauley (Science Education) and Peggy Tarpley (Special Education) combined their expertise to develop the course, which was offered as a 3-credit graduate course through Longwood University's School of Education.

Third, sixth grade teachers expressed a need for a general earth science course focusing on the major concepts included in the sixth grade curriculum. When advertised in Spring 2006, the course was insufficiently enrolled. An informal survey of participants who had originally expressed an interest revealed that many had enrolled in *Astronomy* or *Meteorology* and preferred to take these in-depth courses, rather than a general survey. For this reason, course development was cancelled.

Finally, a non-college credit course was developed by the MathScience Innovation Center to enable earth science teachers, and their students, to develop and implement virtual field trips to various geologic sites within their community. As part of *Integrating New Technologies in the Earth Sciences*, creation of virtual field trips was introduced; however, the resulting products were of poor quality and the instructor recommended that a separate course be developed. Three members of the MathScience Innovation staff combined their expertise to develop a new course, *GeoVirginia: Creating Virtual Field Trips*, which was offered for forty-five, non-college credits. While John Sylvester provided leadership in developing the content management system and initial course, Joyce Watson provided expertise in earth science and Echol Marshall provided expertise in videography and development of a web-based course. The course was piloted in Summer 2007 and offered a second time in Fall 2007.

Five sections of the pilot courses were offered with seventy-four teachers enrolled (see Table 3). Although the pilot courses were offered in the Richmond area, the fact that two of the courses were web-based enabled statewide participation. Participants in *Integrating New Technologies in the Earth Sciences* attended two face-to-face sessions on Saturday and completed the remaining work via the website. In the first offering of *GeoVirginia*, participants attended a two-day, face-to-face session and then spent a month completing projects, with ongoing follow-up provided via the web (*Moodle*™) or individual sessions with instructors. In the second offering of *GeoVirginia*, only one Saturday face-to-face session was held, with the remaining work occurring via the Center's videoconferencing system (*Elluminate*Live!), *Moodle*™, or individual videoconferences.

Table 3
Participation in Special Topics Earth Science Courses

Information	*Integrating New Technologies*	*Effective Collaboration*	*GeoVirginia: Virtual Field Trips*	Total
Number of different locations taught	1	1	1	
Number of course sections	2	1	2	5
Number of participants	35	13	26	74
Percentage of participants (%)	47	18	35	100
Participants' reasons for taking course (%)				
Secondary science teachers completing or adding an earth science endorsement (%)	43	0	23	19
Middle or special education teachers completing 18 credit hours (%)	6	0	8	6
Middle school or special education teachers strengthening background (%)	0	54	4	10
Endorsed earth science teachers strengthening background (%)	31	15	65	50
Other – pre-service teachers, elementary teachers, technology specialists, etc. (%)	20	31	0	15

In the pilot classes, the majority of participants were enrolled in *Integrating New Technologies in the Earth Sciences* (47%). Although the target audience was endorsed earth science teachers, they comprised only 31% of the population. Even though it did not count toward the endorsement, some middle and secondary teachers enrolled to immediately improve their ability to use technology with their students (49%). Unexpectedly, technology resource teachers also enrolled (20%).

Again, although the target audience for *GeoVirginia: Creating Virtual Field Trips* was endorsed earth science teachers, they comprised only 65% of the population. Because examples of virtual field trips were posted on the website, students in the Summer 2007 *Geology of Virginia* classes learned about the site and wanted to immediately begin making products. These motivated teachers made up 31% of the class and created virtual field trips based upon their summer experiences.

Enrollment in *Effective Collaboration in the Earth Science Classroom* was disappointing. Beginning with an over-subscribed class of thirty-five students in the spring, the class dropped to thirteen participants by the August 2006 class. The class consisted primarily of special education and elementary teachers, with few endorsed earth science teachers electing to participate. During the time that the course was developed and implemented, the Virginia Department of Education was refining requirements for content coursework by special education teachers. Initially, many teachers saw the course as a way to meet the state requirements and enrolled; however, as school divisions developed local options for meeting the requirement, they dropped out, with many being no-shows on the first day of class.

Goal 4: Establish a Statewide Collaborative — The collaborative of seven institutes of higher education and two non-profit organizations involved in the Virginia Earth Science Collaborative (VESC) included major institutions from all geographic areas of Virginia. All participants had representatives on the staff and board of the Virginia Mathematics and Science Coalition. In addition, various subsets of the institutions had partnered previously on National Science Foundation (NSF) and Mathematics and Science Partnership (MSP) grants that focused on teacher preparation and licensure, an inter-institutional master's degree for middle school mathematics and science teachers, and various programs related to licensure and the Statewide Master's Degrees Program for K-8 Mathematics Specialists. Because none of these grants had fostered development of strong partnerships in the sciences, the partners viewed establishment of a statewide network in the sciences as a major objective.

Goal 4: Steering Committee — The Virginia Earth Science Collaborative Steering Committee provided overall leadership and guidance for the grant. Led by Project Director Dr. Julia Cothron, the committee consisted of twenty-six active members, including twelve professors from arts and sciences, six professors from schools of education, five educators from the K-12 community, and three members from higher education administration and museums. To facilitate implementation, a site leader was appointed for each of the major institutions: College of William & Mary, George Mason University, James Madison University, MathScience Innovation Center, Radford University, and the University of Virginia Southwest Center. Each site leader was responsible for achieving site objectives for course development and implementation, developing liaisons with area schools, interacting with the external evaluator, and administering the subcontract budget. The project director and site directors interacted regularly through teleconferences and electronic mail.

During the first eighteen months of the grant, the group met four times. The grant was funded in March 2005, with Steering Committee meetings occurring in March and June 2005. Because members were most concerned about course implementation in Summer 2005, the two initial meetings focused on course development, assessment, teacher recruitment and registration, and information about the variety of resources available through the Virginia Department of Education, including the *Standards of Learning for K-12 Science*, test blueprints, and released test items [3,5,6]. In January 2006, the Committee met to discuss concerns that had emerged during the first year of the grant, to develop appropriate modifications for future coursework, and to develop a sequence of courses for the second phase of the grant, from September 2006 to September 2007. Major concerns included developing quality tools for assessing participants' achievement of course objectives, developing effective ways to support classroom implementation, and improving recruitment in specific areas of the state. Because these concerns varied among institutions, various subgroups of the Steering Committee assumed responsibility for addressing them. In September 2006, the Steering Committee met as part of the "Spotlight on Earth Science" conference and began the transition to an Earth Science Committee under the leadership of the Virginia Mathematics and Science Coalition. During the last year, the grant leadership interacted through teleconferences and e-mail, and the various course development leaders met face-to-face or electronically with team members. In addition, a web-based *Moodle*™ site was established for ongoing posting of materials and dialogue among members.

Goal 4: Coalition Committee — In October 2006, the Virginia Mathematics and Science Coalition approved establishment of an Earth Science Committee to provide leadership on issues related to teacher licensure and training, state standards and their assessment, and other policy issues. Dr. Eric Pyle of James Madison University and Dr. Edward Murphy of the University of Virginia agreed to co-chair this committee; both of these individuals were site leaders for the Virginia Earth Science Collaborative. Under their leadership, an active committee was established and regular reports provided at the Coalition's meetings, which occur three to four times annually.

Goal 4: Website — In Spring 2005, a project website was launched to provide information about the goals and objectives of the grant, requirements for the full and add-on earth science endorsements, course development, teacher eligibility, course schedules and registration. As needed, this site was updated throughout the grant. In Summer 2007, the site was expanded to include electronic articles about courses offered throughout Virginia. In Fall 2007, the site was modified to include a section entitled "GeoVirginia" which includes virtual field trips to various sites across Virginia.

Impact

Project quality and impact were judged through a combination of quantitative and qualitative procedures focused on each project goal. Dr. George Bass, Associate Professor at the College of William & Mary, was the project's external evaluator.

Goal 1: Increase the Pool of Endorsed Earth Science Teachers — A total of 303 different teachers participated in the grant. Of these, seventy-seven were endorsed prior to the grant, fifty-two completed credentials through the grant, and nineteen obtained eighteen credits toward the endorsement. Within the 154 non-endorsed participants, there were twenty-seven individuals who stated on the initial survey that they were currently teaching earth science (non-endorsed) and thirty-eight who stated that they were a secondary science teacher planning to add the endorsement. An analysis of course enrollment revealed the distribution of these sixty-five individuals (see Table 4).

Table 4
Distribution of Course Enrollment

Number of courses taken	1	2	3	4	5
Number of people	34	15	11	4	1

Given the commitment needed to take three or more courses, one can reasonably hypothesize that an additional sixteen teachers will complete the endorsement through coursework offered outside the grant. For those taking only one or two courses, possible explanations include leaving the profession (especially for first-year earth science teachers), finding a position in their area of endorsement, taking additional coursework for the endorsement outside the grant, or using the grant to obtain the six college credits needed for certificate renewal and having no intention of completing the endorsement within the specified period.

Goal 2: Increase Teachers' Conceptual Understanding of the Earth Sciences — The evaluation of the courses focused on the impact of the course experience on the participants' learning. Instructors agreed to administer the pre-test/post-test measure of the course subject matter. The course development team was responsible for the selection or construction of a suitable paper-and-pencil test on appropriate course content. A synopsis of pre-/post-data for the various courses is summarized in Table 5.

Table 5
Pre-/Post-Data on Participants' Learning

Course	Instrument	Number Participants	Mean Pre-Test (%)	Mean Post-Test (%)	Difference (%)
Astronomy - 1	*Astronomy Diagnostic Test*	24	55.80	71.40	15.60
Astronomy - 2	*Astronomy Diagnostic Test*	29	44.80	64.50	19.70
Astronomy - 3	*Astronomy Diagnostic Test*	28	61.00	81.00	20.00
Astronomy - 4	*Astronomy Diagnostic Test*	17	54.00	71.00	17.00
Astronomy - 5	*Astronomy Diagnostic Test*	19	47.40	66.40	19.00
Astronomy - 6	*Astronomy Diagnostic Test*	9	48.20	59.80	11.60
Astronomy - 7	Individual Instructor	NA	NA	NA	Gain
	Astronomy Means	126	56.6	71.9	15.3
Meteorology - 1	Items from AMS Test	34	35.00	53.00	18.00
Meteorology - 2	Items from AMS Test	25	78.00	86.00	8.00
Meteorology - 3	Items from AMS Test	10	43.00	51.00	8.00
Meteorology - 4	Items from AMS Test	19	61.50	81.10	19.60
Meteorology - 5	Items from AMS Test	8	74.00	91.00	17.00
Meteorology - 6	Items from AMS Test	14	41.00	58.60	17.60
	Meteorology Means	110	53.70	68.60	14.90
Oceanography - 1	Team Made – Version 1	14	29.60	91.20	61.60
Oceanography - 2	Team Made – Version 1	11	44.00	76.50	32.50
Oceanography - 3	Team Made – Version 2	20	45.00	63.00	18.00
Oceanography - 4	Team Made – Version 2	9	44.00	88.00	44.00
Oceanography - 5	Team Made – Version 2	12	58.50	91.50	33.00
Oceanography - 6	Individual Instructor	NA	NA	NA	Gain
	Oceanography Means	66	43.86	79.82	35.96
Physical Geology -1	GCI + Team Made – Version 1	22	64.59	75.04	10.45
Physical Geology -2	GCI + Team Made – Version 1	8	55.00	93.00	38.00
Physical Geology -3	GCI + Team Made – Version 1	12	72.50	80.50	8.00
Physical Geology -4	GCI + Team Made – Version 2	6	60.00	98.00	38.00
Physical Geology- 5	GCI + Team Made – Version 2	16	75.30	84.10	8.80
	Physical Geology Means	64	67.12	82.73	15.61
Geology VA - 1	Instructor – Preliminary Items	8	43.00	69.00	26.00
Geology VA - 2	Team Made	9	48.00	76.00	28.00
Geology VA - 3	Team Made	6	60.00	75.00	15.00
Geology VA - 4	Team Made	15	45.00	66.00	21.00
Geology VA - 5	Team Made	16	59.00	95.00	36.00
Geology VA - 6	Team Made	14	51.00	80.00	29.00
Geology VA - 7	Team Made	19	52.20	84.90	32.70
Geology VA - 8	Team Made	9	46.60	70.50	23.90
Geology VA - 9	Individual Instructor	N/A	N/A	N/A	N/A
	Geology of Virginia Means	96	50.83	78.78	27.95

Note 1: AMS = American Meteorological Society and GCI = Geoscience Concept Inventory.

Note 2: For *Astronomy* (*Space Science for Teachers*)-7, N = 10, Pre = 72.9%, Post = 79.3%, Gain = 6.40%.

Note 3: For *Oceanography*-6, N= 16, Pre = 60.10%, Post = 98.70%, Gain = 38.70%.

Note 4: For *Geology of Virginia*-9, N= 12, data not available.

Goal 2: *Astronomy* — The instructors chose to use the nationally developed *Astronomy Diagnostic Test* (*ADTv2.0*) in six of the seven sections; one instructor who taught an on-line course used his own instrument [7-9]. The *ADTv2.0* is a 21-item, multiple-choice test developed by the Collaboration for Astronomy Education Research in 1999. During 2000 and 2001, the Astronomy Diagnostic Test National project investigated the validity and reliability of the test. The *ADTv2.0* was administered as a pre-test to 5,346 students and as a post-test to 3,842 students in ninety-seven classes at various universities, and at four-year and two-year colleges in thirty states. Student results showed an average pre-test score of 32.4% and an average post-test score of 47.3% out of the maximum perfect score of all twenty-one correct. Data on participants' achievement in the *Astronomy* courses are summarized in Table 5.

As shown in Table 5, the *ADT* was administered as a pre-/post-test in six of the seven sections taught. In each of these sections, as well as the one in which the instructor administered a different test, positive achievement gains occurred. Across sections, the mean percentage correct increased from 56.6% to 71.9% for a gain of 15.3%. The mean pre-test scores ranged from 44.80% to 61.0%, with all exceeding the undergraduate pre-score of 32.4%. All sections also exhibited a higher post-score than the undergraduate-level students (47.3%). Some differences in performance could be expected because all teachers were college graduates (some were science majors) and not undergraduates as in the national norm group. With the exception of section six, all sections showed a greater gain score than the norm group (14.90%). In this section, 66% of the participants were elementary or middle school teachers strengthening their background.

Goal 2: *Meteorology* — The instructors teaching the meteorology course developed the assessment by choosing items from the American Meteorological Society's *Online Weather Studies* program materials that reflected both the content covered in the course and the high school *Standards of Learning* items testing meteorological knowledge and understanding [10,11]. There were eighteen multiple-choice items and three short-answer items (each worth four).

For the 110 participants completing the pre-/post-tests, there was a 14.9% mean achievement gain, from a mean pre-test of 53.7% to a mean post-test of 68.6% (see Table 5). With the exceptions of sections two and three, which had a gain of 8% each, all scores were clustered between a 17.00% and 19.60% gain. No obvious demographic differences exist to explain the lower achievement.

Goal 2: *Oceanography* — Because there was not a nationally developed, standardized instrument assessing basic oceanography knowledge, the instructors were forced to construct their own instrument during the first set of courses in 2005. After sharing items and sample items among themselves, a preliminary version was constructed consisting of twenty-five, short-answer and multiple-choice items. For the 2006 and 2007 courses, the *Oceanography* pre-test/post-test was revised to reflect lessons learned in 2005. The revised assessment instrument was based on the foundational concepts of oceanography that the instructional team collaboratively identified. These concepts all related to the content learning goals of the course as identified in the course syllabus and to the ten Essential Knowledge and Skills (EKS) for oceanography from the *Science Standards of Learning Sample Scope and Sequence—Earth Science* [12]. While nearly all of the content addressed in the 2005 assessment instrument was the same in 2006, the assessment instrument was modified to contain entirely multiple-choice items for the 2006 and 2007 courses. Although the instructors believed that the short-answer questions used in 2005 provided more information on student understanding of the oceanography concepts, they recognized that there was instructor variability when grading these items. To retain some of the benefits of written short answers, participants were asked to justify their selected answer in the pre-assessment. These justifications helped instructors identify incoming misconceptions of content.

Across the five *Oceanography* sections reported, the mean increase was a high 35.96% (see Table 5). Both the pre-test and post-test scores showed a range of about thirty percentage points, with pre-test scores ranging from 29.60% to 58.50% and post-test scores from 63.0% to 91.50%. As previously noted, modifications were made in the test format from Summer 2005 (sections one and two) to Summer 2006 and 2007. The unusually high increase in section one partly reflects that the instrument development process for the pre-test served more as a "pilot" of the instrument than a valid pre-test. Of all the courses, *Oceanography* had the most consistent instruction team, with three of the five sections taught at one university. In addition, 84% of the participants were middle school or senior high school teachers seeking an endorsement.

Goal 2: *Physical Geology* — The course development team chose to design their own content test using their own constructed items and items selected from the "Geoscience Concept Test," a multiple-choice assessment instrument with seventy-three, multiple-choice items validated for earth science courses [13]. The course leader developed the test and circulated it to the instructors of the other sections for review. In January 2006, the *Physical Geology* team met with Dr. George Bass, External Evaluator, and discussed ways to improve questions on the pre-/post-content tests and to expand the range of questions so that "ceiling effect" did not occur. The course leader revised the instrument for use in future sections of *Physical Geology*. The final version of the instrument consisted of twenty multiple-choice and three short-answer items.

Physical Geology participants showed a mean increase of 15.61 percentage points, with scores increasing from a mean pre-score of 67.12% to a mean post-score of 82.73%. Pre-test scores tended to be high and reflected the fact that many participants were already teaching earth science and had learned geologic concepts through the teaching process. Eighty-eight percent of the participants were middle school or senior high school teachers seeking an endorsement. The development team perceived that the first version was "too easy," and that the items selected from the Geoscience Concept Test were ambiguous. Modifications were made in the first version to address these concerns.

Goal 2: *Geology of Virginia* — During Fall 2005, a pilot section of *Geology of Virginia* was taught to eight teachers. The two instructors chose to design their own content test using their own constructed items to assess both students' background knowledge in geology and students' knowledge of the geology of Virginia. Approximately 80% of the pre-test/post-test focused on the geology of Virginia and 20% focused on background knowledge. Based on that experience, the team of instructors for the 2006 and 2007 courses redesigned the assessment test. They created a thirty-item exam that incorporated eighteen multiple-choice items, seven matching items, and five multiple-answer application items (often involving the interpretation of geological diagrams). The total number of points on this exam was seventy.

Beginning with a mean pre-test score of 50.83%, participants showed an impressive 27.95% gain, to end with a post-test mean of 78.78%. Achievement gains ranged from 15.00% to 36.00%. Because some of the sections were very small, six to nine participants, the performance of a single individual greatly impacted the scores. Given that it was the second course in a sequence, this course also had a high percentage of endorsed teachers strengthening their background (18%) and of secondary teachers seeking an endorsement (67%).

Goal 3: Increase the Number of Highly Qualified Earth Science Teachers — To assess participants' learning, a variety of pre-/post-administered instruments including content tests and surveys were used. Dr. George Bass assisted with the design and analysis of these measures.

Goal 3: *Integrating New Technologies in the Earth Sciences* — For this combination web-based and face-to-face course, a pre-/post-administered questionnaire was given in which participants rated their expertise in five content domains: 1) remote sensing and image processing; 2) real-time and real-world data; 3) computer simulations and 3-dimensional modeling; 4) global positioning systems and geographic information systems; and, 5) graphing calculators and probes. Using a 5-point Likert Scale (0 = "None" and 4 = "Expert"), they rated themselves as having "little knowledge" (1.16) before the course and "some knowledge" (2.17) after the course. Increases were greatest in the areas of remote sensing and imaging, computer simulations and 3-dimensional modeling, and global positioning and geographic information systems. Less change was shown in the area of graphing calculators and probes, where many schools had done in-service, and in real-time and real-world data, where many earth science teachers already had access to meteorological and oceanographic data. When asked about their skill in using the various technologies, the ratings were slightly different, with participants rating themselves as having "some knowledge" at the beginning and "much knowledge" at the end. Skill increase was greatest in the area of GPS and GIS, followed closely by use of real-time and real-world data. When asked about strengths of the course, participants mentioned the range of resources and websites, learning about technology that they did not realize was available, interacting with colleagues, and the modular format of the class. Suggestions for improvement included more face-to-face time for sharing and more dialogue through the web. As in most web-based courses, the drop rate was higher than in a face-to-face course. Of the original twenty-one participants, two received a WF and two received an F. When the course was repeated a second time, the pre-/post-data were similar. Again, participants tended to do well (eight A's, two B's) or not perform (three F's), with failing students not completing assignments despite extensions.

Goal 3: *Teaching Earth Science Topics to Special Education Students* — The instructors used a twenty-item exam for the pre-test and post-test. This exam consisted of twenty, 4-option multiple-choice items on earth science knowledge and understanding. Half of the items required the student to interpret a drawing, diagram, or table of earth science concepts and principles. Beginning with a mean pre-test score of 70%, the thirteen participants showed a gain of 9% to end, with a mean post-test score of 79%. Because the overall class average on the pre-test was reasonably high—70% with one teacher achieving a perfect 100%—participants entered this course with good background knowledge of basic earth science concepts and did not have much opportunity for growth. For future offerings of this course, the difficulty level of the test needs to be increased and items need to be added that assess participants' understanding of how to differentiate and modify earth science instruction for students with disabilities. In the pilot course, differentiation skills were demonstrated through products that included lesson plans based upon trade books and various areas of earth science. Other recommendations for improvement included increased time for teaching science content, and requiring a pair of earth science and special education teachers from a school to attend.

Goal 3: *GeoVirginia: Creating Virtual Field Trips* — This professional development course was taught to twelve teachers in Summer 2007 over six consecutive days with two follow-up sessions. The class had three instructional goals: 1) to reinforce and broaden teachers' knowledge of geology in Virginia and their ability to teach it; 2) to train the teachers to use a number of technology tools to record a field trip for public posting on a website; and, 3) to train teachers to plan, conduct, and record data from geology field trips. The class culminated with a final product in which each teacher created a virtual field trip for posting on the "GeoVirginia" component of the Virginia Earth Science Collaborative website [14].

For a pre-/post-assessment, the instructors constructed an instrument in which approximately 33% of the questions focused on the teachers' knowledge and use of field trips, and 66% focused on technological skills. Each question offered a Likert scale response from "None" (scored as 0) to "Expert" (scored as 4). Regarding their expertise with field trips, participants rated themselves at the lower end of the "much knowledge" category at the beginning of the course (2.17) and at the higher end of the category at the conclusion of the course (2.71). More growth was shown on technology skills, with ratings increasing from "some knowledge" (1.69) to "much knowledge" (2.52).

The post-assessment form also included a robust course evaluation survey. Seven questions required that each teacher respond to queries on course structure, teaching expertise, and content relevance using a 5-point Likert Scale (0 = "None" and 4 = "Expert"). All responses averaged 3.87, with the highest response, an average of 3.93, given for the question, "value of instructional materials provided." These materials included geology teaching tools: electronic reference materials, maps, rock samples, and technology-enabling tools, such as digital cameras and high-capacity memory sticks.

Each teacher was asked to project a likely number of students and peer-teachers with whom he or she expected to share the newfound knowledge and materials. The teachers projected that they would share materials with seventy-eight peer teachers and 1,109 students. Although one teacher failed to create a web page that fully employed all the instructional strategies taught in the class, eleven detailed pages were created, each with a unique and fresh perspective on a particular site of Virginia geologic interest. All twelve teachers left with the intention to create a new and different field trip web page with their students during the 2007-08 term.

In Fall 2007, a second course with fourteen participants was taught. To facilitate statewide participation during the school year, the distance-learning component was increased. Participants attended one Saturday face-to-face session, completed coursework on *Moodle*™, and interacted with instructors through the videoconferencing system, *Elluminate*Live! As compared with the first class, participants showed a greater increase on both the content (.79) and the technology skill (1.13) components of the pre-/post-tests and better quality virtual field trips. Potential factors were the more direct focus on technology and additional support through the videoconferencing system. Participants of the second course projected that they would share materials with ninety-five peer teachers and 855 students.

Goal 4: Establish a Statewide Collaborative — The Collaborative was successful in achieving its major goal—creation of a statewide network in the earth sciences. During the three years of the grant, eighty-three local education agencies, 178 schools, seven institutes of higher education, and two non-profit organizations participated. Professors from the arts and sciences (25) and schools of education (9) interacted with experienced K-12 educators (24) to develop and deliver the five core courses and three pilot courses.

Goal 4: "Spotlight on Earth Science" Symposium— Under the leadership of Dr. Eric Pyle, Associate Professor at James Madison University, a symposium was held on September 18-19, 2006 with approximately one hundred participants. On the first day, instructors from the Tidewater (ITEST) and VESC MSP grants presented sessions on the *Geology*, *Astronomy*, *Meteorology*, and *Oceanography* courses taught through the two MSP grants. Presentations were also made on special courses including the technology and special education courses. On the second day, participants discussed needs in the areas of teacher education, best practices, and curriculum.

Goal 4: Coalition Committee — In October 2006, Professors Eric Pyle and Edward Murphy reported the recommendations from the "Spotlight on Earth Science" symposium to the Virginia Mathematics and Science Coalition. A formal Earth Science Committee, co-chaired by these professors, was established by the Coalition to address issues related to teacher licensure and training, state standards and their assessment, and other policy issues. Since its formation, the Committee has been instrumental in clarifying licensure requirements for the add-on earth science endorsement and is organizing to address state standards for earth science when they are available for public review in 2009. Courses developed by the VESC are included in two MSP proposals submitted by the Coalition for 2008 funding, with one focusing on elementary teachers and the second focusing on teachers of Pre-Advanced Placement (Pre-AP), Advanced Placement (AP), and dual enrollment courses. Several VESC institutions are actively exploring implementation of a statewide master's degree that includes coursework in the earth sciences.

Goal 4: Website — Since its inception in Spring 2005, the Collaborative's website has had 57,617 visitor sessions, with the sessions representing 13,948 unique IP addresses [15]. The site is a repository of information on the project including information about partners, course development and implementation, and assessment of impact. In addition, professors and educators have authored seventeen electronic articles describing their experiences in developing and implementing courses. One component of the site, "GeoVirginia," enables people from across Virginia to develop, post, and access virtual field trips [14].

Discussion and Recommendations

Goal 1: Increase Pool of Endorsed Earth Science Teachers — The Collaborative offered thirty-three sections of the five earth science courses required for the add-on endorsement at seven different locations around Virginia. Through these offerings, fifty-two teachers completed the coursework for the endorsement, nineteen teachers obtained eighteen credits toward the endorsement, and sixteen teachers completed three or more courses with the expectation of completing the endorsement outside the grant. Completion of the endorsement requirements was made easier by changes in licensure requirements whereby individuals with a degree in the environmental sciences could add the endorsement with four courses, one in each area of earth science [16]. Throughout the grant, strong enrollment occurred in courses offered in central Virginia (Richmond and Charlottesville). Enrollment was lower in Northern Virginia, Harrisonburg, and Radford, and several course cancellations occurred in these areas. In southwestern Virginia, the University of Virginia Southwest Center (Abingdon, Virginia) was successful in getting a cohort of teachers to complete requirements over a five-semester period.

The RFP required that teachers commit to completing the eighteen credits for the add-on endorsement in eighteen months, and the grant was developed for two, all-day, multiweek institutes to be taken each summer and one web-based course during the academic year. This rapid pace proved impossible for teachers in many urban and rural areas to sustain because of large summer school programs in which they were expected to teach. These teachers could participate in only one all-day, multiweek institute each summer, typically the first two weeks in August. In future, alternative course delivery models are needed, including "after school" coursework during the summer and academic year and combinations of web and face-to-face sessions, as were held for the pilot courses. Such models will also enable teachers in more rural parts of Virginia to access courses.

Goal 2: Increase Teachers' Conceptual Understanding of the Earth Sciences — The Collaborative developed five graduate courses that would enable participants to obtain an add-on earth science endorsement: *Astronomy* (*Space Science for Teachers*), *Oceanography*, *Meteorology*, *Physical Geology* and *Geology of Virginia*. The 499 teachers participating in the thirty-three sections offered statewide demonstrated an increase in conceptual understanding of the course topics. The achievement gains were greatest in *Geology of Virginia* (27.95%) and *Oceanography* (35.96%) where over 90% of the participants were secondary science teachers, strong collaborative work had occurred among the course developers, and multiple sections were taught which enabled instructors to learn and improve future offerings. For *Astronomy* and *Meteorology*, participants showed strong achievement gains of 15.3% and 14.9%, respectively. These courses were developed and taught by strong teams of instructors who had the most varied populations from class to class. For example, 13% of *Astronomy* and 9% of *Meteorology* participants were elementary school teachers. In addition, both *Astronomy* (20%) and *Meteorology* (16%) had a high percentage of middle school teachers who were taking the class to strengthen their background. Although *Physical Geology* participants also showed comparable gains of 15.61%, this course was impacted by being the first course offered (Summer 2005), by course cancellations because of insufficient enrollment, and by changing instructional teams. Different teams taught each of the five sections, with three of them not including the original course developers. Throughout the grant, all course instructors struggled to improve the quality of the pre-/post-assessments, and improved instruments are needed. In addition, more standard methods of administering instruments and including the appropriate ones in participants' final grades are needed. All instructors agreed that the instruments did not reflect the rich learning experiences provided students, including the lab and field experiences that were assessed by end-of-course projects.

Also, all instructors agreed that the rapid pace of course offerings did not maximize the opportunity for teachers to learn. For the 4-credit courses—*Oceanography*, *Physical Geology*, and *Geology of Virginia*—instructors recommended that the multiweek institutes be a minimum of three weeks and that opportunities for post-course implementation support be strengthened. Even though *Meteorology* was successful as an on-line course with three face-to-face sessions, the instructors recommended additional face-to-face sessions because the teachers struggled with some concepts on-line that could have been explained easily with classroom demonstrations and labs. Overall, the two-week institute in *Astronomy* was the most successful for the adult learner, the major reason being that teachers attended for ten days (eighty hours), even though the requirement was only forty-five hours. They had ample opportunity within this time frame to work individually and in small groups to apply their newfound learning and skills to their teaching responsibilities. In the future, new delivery systems for all courses are needed, including combinations of virtual and face-to-face sessions that retain the rich inquiry and field components.

Goal 3: Increase the Number of Highly Qualified Earth Science Teachers — The Collaborative developed three pilot courses that enabled teachers to learn about successful collaboration between special education and earth science teachers, integration of new technologies in the earth sciences, and implementation of real and virtual field trips that expand the learners' understanding of Virginia geology. Although the special education course had a small number of participants (thirteen), it was a successful pilot; recommendations for increased effectiveness include more time for teaching earth science content and enrolling only teams of special education and earth science teachers.

Integrating New Technologies in the Earth Sciences proved a successful model for using web-based learning (*Moodle*™) and face-to-face sessions to reach a statewide audience. Unfortunately, the primary course developer and instructor left the state before dissemination to other institutions, and transfer of materials from the MathScience Innovation Center to other institutions will be more difficult. The course's primary contribution will probably be modeling effective use of face-to-face and web instruction to meet a statewide audience.

The *GeoVirginia: Creating Virtual Field Trips* course has proven successful in enabling teachers to gather information about local geology and present it through a virtual field trip format. When this article was written, the *Google*™-based site, "GeoVirginia," included three virtual field trips created by the MathScience Innovation Center staff, twenty-three virtual field trips created by participants in *GeoVirginia*, and ten products created by teachers in the geology classes. Because implementation in classrooms is just beginning, the impact of students using and developing virtual field trips is yet to be determined. The MathScience Innovation Center is committed to supporting implementation of other field trips by participating teachers and their students, and will continue to disseminate information about the project through statewide conferences.

Goal 4: Establish a Statewide Collaborative — The Collaborative was successful in developing a statewide partnership and institutionalizing the partnership as an Earth Science Committee under the Virginia Mathematics and Science Coalition. New science partnerships that build upon relationships established during the project have emerged, including statewide initiatives for elementary teachers, teachers of advanced high school courses, and potential master's degrees in the earth sciences. As with all externally funded projects, the challenge will be to maintain the programs through local resources.

Conclusion

The Virginia Earth Science Collaborative sought to increase the number of endorsed earth science teachers, increase teachers' conceptual understanding of the earth sciences, increase the number of highly qualified earth science teachers, and establish a statewide collaborative. Through the grant, fifty-two teachers met requirements for the add-on earth science endorsement, nineteen teachers completed eighteen credits toward the full endorsement, and sixteen teachers completed 75% or more of the requirements for the add-on endorsement. In 2004-05, earth science was the number one critical teaching shortage area in Virginia; by 2007-08, it did not make the Top Ten List [17, 18].

Through the Collaborative, five core courses required for the endorsement were developed, as well as courses to strengthen teachers' ability to differentiate instruction for special education learners, integrate modern technologies into the earth sciences, and increase teachers' understanding of Virginia's geology and its integration into the curriculum through virtual field trips. The 573 students in the classes showed increased understanding of targeted earth science concepts as measured by pre-/post-tests and surveys. Through the classes, many elementary and middle school teachers strengthened their understanding of meteorology and astronomy concepts. In addition, endorsed earth science teachers gravitated toward courses that strengthened their understanding of Virginia's geology, astronomy, and the use of newer technologies, such as GPS and GIS. Most important, during this interval, the statewide percentage of students passing the End-of-Course Earth Science assessment increased from 80% in 2004-05 to 84% in 2006-07 [19].

The Collaborative was successful in building a statewide network to provide leadership in the earth sciences, with future work now institutionalized through an Earth Science Committee under the Virginia Mathematics and Science Coalition. Recommendations for improvement include the following: 1) offering courses throughout the academic year, not just in the summer, and increasing the number of classes that are a blend of web-based and face-to-face instruction; 2) lengthening 4-credit summer institutes from two weeks to three weeks; and, 3) strengthening the pre-/post-assessments and standardizing procedures for administration. Next steps include integrating these earth science courses into new programs for elementary teachers and teachers of AP environmental science, developing statewide master's degrees that include earth science coursework, and continuing to work on policy issues related to state standards and their assessment and teacher licensure. ■

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