

Synopsis of 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, 77 were endorsed prior to the grant, 52 completed credentials through the grant, and 19 obtained 18-credits toward the endorsement. Within the 154 non-endorsed participants, there were 27 individuals who stated on the initial survey that they were currently teaching earth science (unendorsed) and 38 who stated that they were a secondary science teacher planning to add the endorsement. An analysis of course work revealed the following distribution of coursework by these 65 individuals:

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

Given the commitment needed to take 3 or more courses, one can reasonably hypothesize that an additional 16 people will complete the endorsement through coursework offered outside the grant. For those taking only 1 or 2 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 6 college-credits needed for certificate renewal and having no intent 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 pretest-posttest 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 I.

Astronomy. The instructors chose to use the nationally developed *Astronomy Diagnostic Test* (ADT) in 6 of the 7 sections, with one instructor who taught an on-line course using his own instrument [1,2,3]. The ADT Version 2.0 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 ADT 2.0 was administered as a pre-test to 5,346 students and as a post-test to 3,842 students in 97 classes at various universities, four-year, and two-year colleges in 30 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 21 correct. Data on participants' achievement in Astronomy courses are summarized in Table I.

As shown in Table I, the ADT was administered as a pre-post test in 6 of the 7 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

Table IV: 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	18.00
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	NA	NA	NA	NA
	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-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.

teachers were college graduates (some were science majors) and not undergraduates as in the national norm group. With the exception of Section 6, all sections showed a greater gain score than the norm group (14.90%). In this section, 66% of the participants were middle or elementary teachers strengthening their background.

Meteorology. The instructors teaching the meteorology course developed the assessment by choosing items from the American Meteorological Society *Online Weather Studies* [4,5] materials that reflected both the content covered in the course and the high school *Standards of Learning* items testing meteorological knowledge and understanding. There were 18 multiple-choice items and 3 short-answer items (each worth 4).

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 I). With the exception of Section 3, which had a gain of 8%, all scores were clustered between a 17.00% and 19.60% gain. No obvious demographic differences exist to explain the lower achievement.

Oceanography. Because there was not 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 25 short-answer and multiple-choice items. For the 2006 and 2007 courses, the Oceanography pretest-posttest 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 10 Essential Knowledge and Skills (EKS) for oceanography from Pages 15-16 of the Earth Science Standards of Learning Sample Scope and Sequence [6]. While nearly all of the content addressed in the 2005 assessment instrument was the same in 2006, the assessment instrument was modified to be 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 I). Both the pre-test and post-test scores showed a range of about 30% 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 1 and 2) to summers 2006 and 2007. The unusually high increase in Section 1 partly reflects 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 3 of the 5 sections taught at one university.

In addition, 84% of the participants were middle or senior high teachers seeking an endorsement.

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 Inventory* [7], a multiple-choice assessment instrument with 73 multiple-choice items validated for Earth Science courses. The course leader developed the test and circulated to the instructors of the other sections for review. In January 2006, the Physical Geology team met with the External Evaluator and discussed ways to improve questions on the pre-post content test and to expand the range of questions so that there was not a “ceiling effect.” The course leader revised the instrument for use in future sections of *Physical Geology*. The final version of the instrument consisted of 20 multiple-choice and 3 short-answer items.

Physical Geology participants showed a mean increase of 15.61% points with scores increasing from a mean pre-score of 67.12% to a mean post-score of 83.73%. 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. Eight-eight percent of the participants were middle or senior high teachers seeking an endorsement. The development team perceived that Version 1 was “too easy” and that the items selected from the Geosciences Test were ambiguous. Modifications were made in Version 1 to address these concerns.

Geology of Virginia. During the fall of 2005, a pilot section of the Geology of Virginia was taught to 8 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 30-item exam that incorporated 18 multiple-choice items, 7 matching items, and 5 multiple-answer application items (often involving the interpretation of geological diagrams). The total number of points on this exam was 70.

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, 6 to 9 participants, the performance of a single individual greatly impacted 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 instruments including content tests and surveys were used. Dr. George Bass assisted with design and analysis of these measures.

Integrating New Technologies in the Earth Sciences. For this combination web-based and face-to-face course, a pre-post questionnaire was administered in which participants rated their expertise in five content domains: a) Remote sensing and image processing, b) Real-time and real-world data, c) Computer simulations and 3D modeling, d) Global positioning systems and geographic information systems, and e) 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-D 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 21 participants, 2 received a WF and 2 received an F. When the course was repeated a second time, the pre-post data were similar. Again, participants tended to do well (8 A’s, 2B’s) or not perform (3F’s), with failing students not completing assignments despite extensions.

Teaching Earth Science Topics to Special Education Students. The instructors used a 20-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 13 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 including 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.

GeoVirginia: Creating Virtual Field Trips. This professional development course was taught to 12 teachers in the summer of 2007 over 6 consecutive days with 2 follow-up sessions. The class had 3 instructional goals: to reinforce and broaden teachers’

knowledge of geology in Virginia and their ability to teach it, to train the teachers to use a number of technology tools to record a field trip for public posting on a website, and 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 [9].

For a pre-post assessment, the instructors constructed an instrument in which about 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 asked each teacher to respond to queries on course structure, teaching expertise, and content relevance using a five-point Likert scale (0 to 4). 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 such as 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 78 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, 11 detail pages were created, each with a unique and fresh perspective on a particular site of Virginia geologic interest. All 12 teachers left with the intention to create a new and different field trip web page with their students during the 2007-08 term.

In the fall of 2007, a second course with 14 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, *lluminate Live*. As compared with the first class, participants showed a greater increase on both the content (.79) and the technology skills (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. Course 2 participants projected that they would share materials with 95 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 3 years of the grant, 83 local education agencies, 178 schools, 7 institutes of higher education, and 2 non-profits participated. Professors from arts and sciences (25) and Schools of Education (9) interacted with experienced K-12 educators (24) to develop and deliver the 5 core courses and 3 pilot courses

Spotlight on Earth Science Conference. Under the leadership of Eric Pyle, Associate Professor at James Madison University, a conference was held on September 18-19, 2006 with approximately 100 participants. On the first day, instructors from the Tidewater and VESC MSP grants presented sessions on geology, oceanography, 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.

Coalition Committee. In October 2006, Professors Eric Pyle and Ed Murphy reported the recommendations from the *Spotlight on Earth Science Conference* to the Virginia Mathematics & 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 (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, Advanced Placement and dual enrollment courses. Several VESC institutions are actively exploring implementation of a statewide master's degree that includes coursework in the earth sciences.

Web Site. Since its inception in the spring of 2005, the Coalition's web site (<http://VirginiaEarthScience.info>) has had 57,617 visitor sessions, with the sessions representing 13,948 unique IP addresses. 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 17 electronic articles describing their experiences in developing and implementing courses. One component of the site, *GeoVirginia*, enables people from across the state to develop, post and access virtual field trips.

Discussion & Recommendations

Increase Pool of Endorsed Earth Science Teachers. The Collaborative offered 33 sections of the 5 earth science courses required for the add-on endorsement at 7 different locations around the state. Through these offerings, 52 teachers completed the coursework for the endorsement, 19 teachers obtained 18-credits toward the endorsement, and 16 teachers completed 3 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 4 courses, one in each area of earth science [8]. Throughout the grant, strong enrollment occurred in courses offered in Central Virginia (Richmond and Charlottesville). Enrollment was smaller in Northern Virginia, Harrisonburg, and Radford and several course cancellations occurred in these areas. In Southwestern Virginia, the University of Virginia's School of Continuing Education was successful in getting a cohort of teachers to complete requirements over a 5-semester period.

The request for a proposal required that teachers commit to completing the 18-credits for the add-on endorsement in 18 months, and the grant was developed for 2 full-day multiweek institutes to be taken each summer and 1 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 1 full-day multiweek institute each summer, typically the first two weeks in August. In the 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 held for the pilot courses. Such models will also enable teachers in more rural parts of the state to access courses.

Increase Teachers' Conceptual Understanding of the Earth Sciences. The Collaborative developed 5 graduate courses that would enable participants to obtain an Add-On Earth Science Endorsement: *Astronomy*, *Oceanography*, *Meteorology*, *Physical Geology* and *Geology of Virginia*. The 499 teachers participating in the 33 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, enabling instructors to learn and improve future offerings. For *Astronomy* and *Meteorology*, participants showed strong achievement gains of 15.3% in *Astronomy* and 14.9% in *Meteorology*. These courses were developed and taught by strong teams of instructors who had the most varied population from class to class. For example, 13% of astronomy and 9% of meteorology participants were elementary 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 in the summer of 2005, course cancellations because of insufficient enrollment, and changing instructional teams. Different teams taught each of the 5 sections, with 3 of them not including the

original course developers. Throughout the grant all course instructors struggled to improve the quality of the pre-post assessment and improved instruments are needed. In addition, more standard methods of administering instruments and including in participants' 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 3 weeks and that opportunities for post-course implementation support be strengthened. Even though *Meteorology* was successful as an on-line course with 3 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 2-week institute in *Astronomy* was the most successful for the adult learner, with a major reason being that teachers attended for 10 days (80 hours), even though the requirement was 45 hours, and they had ample opportunity within this time frame to work individually and in small groups to apply their new-found 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.

Increase the Number of Highly Qualified Earth Science Teachers. The Collaborative developed 3 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 (13) 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.

The course on 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* 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 included 3 virtual field trips created by the MathScience Innovation staff, 23 virtual field trips created by participants in the *GeoVirginia* course, and 10 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.

Establish a Statewide Collaborative. The Collaborative was successful in developing a statewide partnership and institutionalizing the partnership as an Earth Science Committee under the Mathematics & 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, 52 teachers met requirements for the Add-On Earth Science Endorsement, 19 teachers completed 18-credits toward the full endorsement, and 16 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 [10,11].

Through the Collaborative, 5 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 course that strengthened their understanding of Virginia's Geology, astronomy, and 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 [12].

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 & Science Coalition. Recommendations for improvement include a) offering course throughout the academic year, not just the summer, and increasing the number of classes that are a blend of web-based and face-to-face instruction, b) lengthening 4-credit summer institutes from 2 to 3 weeks, and c) 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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