VIRGINIA EARTH SCIENCE COLLABORATIVE ASTRONOMY COURSE FOR TEACHERS

E. M. MURPHY
Dept. of Astronomy, University of Virginia
Charlottesville, VA 22904

H. GELLER
Dept. of Physics and Astronomy, George Mason University,
Fairfax, VA 22030

M. BENTLEY
Science Education, University of Tennessee, Knoxville
Knoxville, TN 37996-4561

Abstract

We describe the development and implementation of a professional development course for teachers of grades 4-12 designed to increase their content knowledge in astronomy, space science, and the nature of science using interactive presentations, and hands-on and inquiry-based lessons. The course, *Space Science for Teachers,* encompasses the astronomy and nature of science components of the Virginia *Standards of Learning* for grades 4-12 [1]. In addition to increasing their content knowledge, teachers gain experience using innovative teaching technologies, such as an inflatable planetarium, planetarium computer software, and computer controlled telescopes. The courses included evening laboratory sessions where teachers learned the constellations, how to find specific celestial objects, and how to use a variety of small telescopes. Participants received three graduate credit hours in science after completing the course requirements. *Space Science for Teachers* was taught at the University of Virginia in Summer 2005 and 2006, at George Mason University in Summer 2006 and 2007, at the University of Virginia Southwest Center in Abingdon, Virginia in Fall 2006, and at the MathScience Innovation Center in Richmond during Summer 2005 and 2007. A total of 135 teachers participated in the courses.

Introduction

In the 2004-2005 and 2005-2006 school years, the shortage of ninth grade earth science teachers was the top critical teacher shortage area in the Commonwealth of Virginia [2]. In an effort to produce highly qualified earth science teachers and to improve teacher content knowledge about astronomy and the nature of science, the Virginia Earth Science Collaborative (VESC) developed and implemented a series of professional development courses in the content areas of astronomy and space science, meteorology, oceanography, and geology. Funding was provided by a Mathematics and Science Partnership (MSP) grant to the Virginia Earth Science

Collaborative (VESC) under the direction of Principal Investigator Dr. Julia Cothron, Executive Director of the MathScience Innovation Center. Classes were offered between Summer 2005 and Summer 2007. For the benefit of the science education community, we will discuss the format of the courses addressing astronomy and space science, hereafter called *Space Science for Teachers* (*SST*), including the significance of the program assessment tools utilized, participant comments, successes, failures, and recommendations for future programs.

Description of Course

Space Science for Teachers was designed to improve teachers' astronomy and space science content knowledge using activities and lessons that can be adopted in grades 4-12 classrooms. Teachers not only received instruction in the nature of science, but gained experience using instructional technology to teach the astronomy and space science content and received many resources for use in their classrooms. *Space Science for Teachers* consisted of approximately eighty hours of instruction which included lectures, discussions, hands-on activities, computer activities, and evening observing sessions. Most courses were conducted as eight to ten summer courses with one or two follow-up sessions during the following fall. One exception was the Fall 2006 course at UVA Southwest Center in Abingdon, Virginia that was conducted during the school year and delivered using a combination of on-line and face-to-face sessions, in order to reduce the traveling time for teacher participants.

Upon completing all course requirements, teachers earned three graduate credit hours in science from the respective higher education institutions. Local school divisions were required to provide $150 toward tuition. The remaining costs were covered by a Virginia Department of Education (VDOE) Mathematics and Science Partnership (MSP) grant to the Virginia Earth Science Collaborative (VESC). The grading rubrics and specific assignments were left to the discretion of the individual instructors. Final grades were based upon student performance on activities completed during the course, a final project, and the post-test results. The final project required teachers to prepare lesson plans with activities for teaching space science and astronomy in their classrooms, or in the classroom of a colleague for those who were not currently involved in teaching of the related subject matter.

Course Sections Offered

Space Science for Teachers was offered seven times as part of the VESC from Summer 2005 to Summer 2007 (see Table 1).

Table 1
Course Dates, Locations, Instructors, and Number of Participating Teachers

Acronym	Dates	Location	Instructors	Number of Teachers
S05A	June 20, 2005 to July 1, 2005	University of Virginia, Charlottesville	Edward Murphy, Randy Bell	24
S05B	August 1, 2005 to August 12, 2005	MathScience Innovation Center, Richmond	Edward Murphy, Ian Binns	29
S06A	June 21, 2006 to June 30, 2006	University of Virginia, Charlottesville	Edward Murphy, Randy Bell	28
S06B	August 7, 2006 to August 18, 2006	George Mason University, Fairfax	Harold Geller, Lee Ann Hennig	16
F06	September 21, 2006 to December 14, 2006	University of Virginia, Abingdon Center	Michael Bentley	10
S07A	August 6, 2007 to August 17, 2007	George Mason University, Fairfax	Harold Geller, Lee Ann Hennig	9
S07B	August 6 to August 17, 2007	MathScience Innovation Center, Richmond	Edward Murphy, Ian Binns	19

Typical Course Schedule

The course was designed to address all Virginia *Standards of Learning* (*SOL*) for space science and astronomy in grades 4-12 [1]. Table 2 provides a listing of the typical sequence of content topics including specific lessons and their correlation with the *SOL*.

Table 2
Typical Course Schedule

Day	*SOL* Addressed	Description of Lesson
1	4.7a, 6.8d, 6.8e	• Course Administration o Distribute and discuss syllabus o Discussion of course goals and expectations o Administer pre-test assessments o Course registration • Introduction to the Sky and Celestial Sphere o Diurnal motion o Celestial sphere activity o Introduction to planispheres and activity
2	ES.1e, ES.2b 4.7a, 6.8d, 6.8e	• Nature of Science I o What is science o Introduction to observation and inference • Introduction to the Constellations Using an Inflatable StarLab Planetarium • Introduction to *Starry Night*® Planetarium Program
3	4.7b, 6.8g, ES.4b 4.7b, 6.8e, ES.4b	• The Seasons • Phases of the Moon o Observing and drawing the phases of the Moon with *Starry Night*® o Psychomotor activity and "Simon Says" assessment
4	4.7b 4.7c, 4.7d, 6.8a, 6.8b, 6.8c, 6.8f, ES.4a, ES.4c	• Eclipses • The Solar System o Scale model solar system o Characteristics of the planets
5	6.8i, ES.4d 4.7c, 6.8f, ES.4c	• Space Exploration • Lunar Geology Inquiry Lesson • Build a Comet Activity
6	ES.2b, ES.4d 6.8h, ES.2d PS.9a, PS.9c	• Nature of Science II o The roles of observation and inference in science • The Tides o Tidal table activity o The boxer-short model of the tides • The Electromagnetic Spectrum

7	PS.9b	• Telescopes • Blackbodies • Spectroscopy o Spectroscope activity • Safe Solar Observing
8	4.7c, 6.8a, ES.4c ES.2b, ES.4d ES.14a, ES.14b	• The Sun • Nature of Science III o Scientific experiments, theories and laws
9	ES.14a, ES.14c ES.14c ES.14d	• The Stars and Their Births • Stellar Evolution • Black Holes, Neutron Stars • Galaxies

10	ES.14e	• The Big Bang
		• Course Administration
		  o Administer post-test assessment
		  o Hand out course evaluation forms
		  o Review post-test assessment

Fall Follow-up Sessions		• Presentations by Teachers of the Lesson Plans and Activities Developed for their Teaching • Presentations of Pre-Test and Post-Test Results from Their Implementation of the above Lesson Plans and Activities

The following sections provide examples of individual exemplary lessons taught during the course.

Example "Phases of the Moon" Activity

The "Phases of the Moon" lessons taught in the S05A, S05B, S06B, and S07A courses began with teachers using the *Starry Night®* software to observe and sketch the phase and orientation of the moon for a one-month period beginning on the date of the class. After using *Starry Night®* to explore the relation between the phases of the moon and the position of the Sun, the teachers participated in a psychomotor activity in which they developed a working model of the Sun-Earth-moon system. During the psychomotor activity, the participants are assessed using a "Simon says" activity in which the instructor calls out a phase of the moon ("Simon says first quarter") which teachers must correctly model. The speed and accuracy with which teachers can model the stated phase is used to judge their understanding of the concept. Written pre- and post-lesson assessments on the causes for the phases of the moon were used as a measure of their learning for the unit and as a model of how they could use similar activities and assessments in their own instruction.

Using a Personal Response System

In the S07A course conducted at GMU, the instructors utilized the iClicker personal response system (PRS) [3]. There were three main reasons for the use of a PRS in the course, independent of the research by Hake about their utility [4]. The classroom for both the S06B and S07A courses contained a computer at every participant's desk. During the S06B course, the instructors observed some teachers, especially those already familiar with the material, ignoring the presentation and working on other tasks on the computers in front of them. By using a PRS in the S07A course, the instructors were able to keep the participants' attention focused on the presentation by interspersing questions throughout the lesson.

Another advantage of the iClicker PRS was the ability to quickly discern if the participants comprehended the material presented. Usually, the participants were able to handle easily the questions presented. On some occasions, however, it was apparent that a number of the participants did not comprehend the material just reviewed. Finally, the use of the iClicker PRS was a demonstration of how teachers could use a PRS in their own classroom environment. Thus, in addition to addressing the space science content, the course modeled good pedagogical technique that teachers could use in their classrooms.

Guest Lecturers

In both the S07A course and the S06B course conducted at GMU, instructors made use of guest speakers. The best guest speakers are those whom have already been observed by the instructors to be passionate about their work and provide relevant information to participants. An added benefit is when the guest speaker can also provide resources for the teachers which can be utilized in their respective classroom environments. The instructors have often been asked by K-12 teachers as to how to find guest speakers. Aside from faculty at the institutions of higher education, one excellent resource for guest speakers in astronomy is the "Solar System Ambassadors Program" run by NASA's Jet Propulsion Laboratory (JPL) [5]. The JPL website also displays a directory of the ambassadors available in every state of the nation. Greg Redfern, a NASA JPL Solar System Ambassador, was a guest speaker in the GMU courses. NASA also maintains a "Speakers Bureau" which sends out speakers from NASA field offices around the country [6].

Final Projects

In the S05A, S05B, S06A, and S07B courses, the final project was an activity roundup. Past experience had taught the instructors that it is very difficult to get teachers to complete assignments in a timely manner after the end of the course. Therefore, the summer course instructors developed the "activity roundup" as a major assignment for teachers to complete during the two weeks of the course. Teachers worked in groups of four or five to come up with a set of twelve to fifteen hands-on activities that addressed all the astronomy and space science components of the Virginia *Standards of Learning*. Each teacher was responsible for compiling, describing, and evaluating three activities. The activities were gathered from the Internet, textbooks, resource materials distributed to the teachers, resource materials provided by the instructors, and resource materials that teachers brought to the course. Activities from all the teachers were gathered onto a CD for some of the courses and distributed to the entire class. Thus, each teacher received a CD with seventy-five to ninety hands-on activities for addressing the Virginia *Standards of Learning*.

Description of Field and Laboratory Experiences

In addition to the daily classroom lessons, the teachers were required to attend at least one evening observing session that introduced them to the night sky, gave them practice identifying the constellations, introduced them to using a small telescope, and allowed them to practice finding objects in the night sky. The evening sessions were weather dependent. Some examples of evening activities are described.

<u>Constellation Activity</u> —During the S05A, and S06B courses, a number of evening sessions were offered at the Leander McCormick Observatory at the University of Virginia. The first evening lesson focused on finding and identifying the constellations in the night sky using a worksheet and peer instruction. It began with a review of the celestial sphere and the use of a planisphere. The instructors distributed the *Edmund Mag 5 Star Atlas* and showed the participants how to use it to find objects in the night sky [7]. The class proceeded outdoors where the instructors discussed outdoor evening observing sessions, dark adaptation, and safety with green laser pointers.

The teachers were divided into (approximately) five groups of five teachers each. Each group was assigned two constellations which they had to find in the night sky using their planisphere or *Edmund Mag 5 Star Atlas*. The instructors circulated among the groups and assisted them in finding their assigned constellations. They also shared stories about one or both of their constellations. Once all the groups were able to identify their two constellations, the teachers were then rearranged into new groups of approximately five teachers. These new groups had one teacher from each of the previous five groups. Each teacher taught his or her two constellations to the new partners. At the end of the session, the teachers had learned to identify ten constellations and practiced teaching two constellations.

Each group was then assigned a worksheet that reviewed basic concepts of the celestial sphere and constellations, and required teachers to apply their classroom knowledge to the actual sky (e.g., measuring angular distances in the sky, locating the celestial poles and equator). If sufficient time remained, the teachers used a pair of binoculars to find objects in the night sky using the *Edmund Mag 5 Star Atlas*.

Evening Observing Session — During the S06B and S07A courses at George Mason University, participants were able to view the night sky using the University's 12-inch Meade Schmidt-Cassegrain telescope. Participants were able to view the moon, Jupiter and its moons, the Ring Nebula, M-57, and star clusters in Cygnus. Three evening observation sessions were conducted during the Fall 2006 course at UVA Southwest Center (Abingdon, Virginia). Teachers used planispheres and the *Edmund Mag 5 Star Atlas* to locate celestial objects, and had the use of an 8-inch Meade Schmidt-Cassegrain telescope, as well as binoculars.

Telescope Activity — The second evening lesson in the S05A and S06B courses focused on using a small telescope to find objects in the night sky. The session began with a discussion of the different types of telescopes and the advantages and disadvantages of each type, a discussion of telescope accessories, and the techniques of finding objects in the night sky. The University of Virginia Department of Astronomy offered eight, 8-inch Schmidt-Cassegrain telescopes for the teachers to use. While there was still daylight, the instructors demonstrated how to set up and use one of the 8-inch telescopes.

Just before dark, the teachers were assigned to groups and loaned a telescope. They were responsible for setting up the telescope, using it to find at least five objects in the night sky, and then taking it down. The five objects typically included the moon, one or two planets, one or two stars, and at least one deep sky object (nebula, galaxy, or star cluster). Each of the objects was progressively harder to find. The instructors circulated among the groups, answered questions, and helped them find their assigned targets.

Distance Learning

The Fall 2006 course in Abingdon, Virginia (F06) was taught in a hybrid fashion: seven face-to-face meetings alternating weeks with on-line meetings through the "Virtual Classroom" chat feature of *Blackboard®*. Other vehicles for course delivery were weekly e-mails of "instructor's notes," weekly threads on the "Discussion Board" (a password-protected, on-line message forum), and twice-weekly chat sessions via the course *Blackboard*® site. The instructor regularly provided documents (handouts) and other resources, such as *PowerPoint* presentations, graphics, images and animations in the *Blackboard*® "Course Materials" folder. Each week, there were one or two threads posted to *Blackboard*'s® Discussion Board and students were able to post their own threads as well. Students were required to respond to two posts by their classmates for each thread. Using *Blackboard*'s® Virtual Classroom feature, students gathered on-line twice during weeks with no face-to-face class, once per week in an assigned small group, and once for a whole-class meeting. Students also interacted with the instructor and their peers by e-mail. Three of the ten students had never used an on-line course interface previously.

Example Follow-up Session

In both the S07A course and the S06B course conducted at GMU, follow-up sessions were conducted on weekends in the fall semesters immediately following the summer courses. During the first follow-up session, participants had about ten minutes to present a lesson plan that they developed, and which they would be using in an actual classroom environment. Their presentations included the following: the concept they were going to cover in the lesson plan; the approach they were taking to do a pre-testing of the students regarding the concept; a demonstration of how they were conducting the active learning in the classroom environment; the approach taken in the conduct of a post-test to verify student learning; and, a summary of how the lesson plan fit into the overall teaching strategy within the curriculum. Participants were then allowed about five minutes to take questions and suggestions from the other participants for improvements to the lesson plans.

During the second follow-up session, participants were given about ten minutes to present the results of the implementation of the lesson plan that they developed and utilized in a classroom environment. In addition to a presentation, teachers prepared a written report detailing the following aspects: the results of the pre-tests given to the students; a summary of all activities included in the implementation of the lesson plan; a description of how the lesson plan was implemented in the specified classroom environment; the results of the post-tests given to the students; a list of lessons learned from the implementation of the lesson plan; a description of how the lesson plan could be modified for enhanced student learning; other evidence of student or teacher learning from the implementation; and, a description of future plans for implementing the lesson plan. Course participants then had about five minutes for questions and comments from their peers.

Participant Demographics

Courses were open to grades 4-12 teachers; however, priority was given to secondary earth science teachers working toward an endorsement to teach earth science. Applications to enroll in *Space Science for Teachers* were handled through the VESC website. Statistics of teacher participants by grade level and subject area were also calculated. Approximately 36% of the participating teachers were middle school teachers and 64% were high school teachers. Roughly 90% of the participants were science teachers in either middle school or high school. About 6% of the teachers were special education teachers. Table 3 lists the geographic distribution of teachers by Superintendents' Region.

Table 3
Distribution of Participants by Superintendent's Region

	1	2	3	4	5	6	7	8	Total
Percentage	35%	2%	7%	27%	13%	8%	5%	3%	100%

Table 4 lists the reasons that teachers participated in the course as reported by the teachers on surveys completed prior to course admission. The three primary reasons for taking the course were the following: 1) complete requirements for certification in earth science by unendorsed teacher; 2) complete requirements for add-on earth science endorsement by teacher endorsed in another science; and, 3) update background of earth science certified teacher.

Table 4
Reason for Course Participation

Category	Percentage
1 – Unendorsed teacher currently teaching earth science that will complete requirements by September 2007	20%
2 – Teacher endorsed in biology, chemistry, or physics that will complete the add-on earth science endorsement by September 2007 (also includes some individuals with other endorsements that will complete full endorsement)	23%
3 – Middle school science or special education teacher committed to beginning requirements for the earth science endorsement (can complete 18 of 32 hours through this grant)	12%
4 – Special education teacher that works collaboratively with students in high school earth science	4%
5 – Middle school or special education teacher that teaches earth science topics as part of the middle school curriculum	14%
6 – Endorsed earth science teacher taking coursework to update background	22%
7 – Other (includes those with incomplete surveys at time of report)	5%

Course Materials

One objective of the course was to teach the material in a hands-on and inquiry-based manner in an effort to demonstrate good pedagogy. A critical component of this strategy is to ensure that teachers have access to, and experience using, hands-on resource materials. Funding from the VESC grant was used to purchase the items in Table 5 for each teacher, budget permitting.

Table 5
Teacher Resources Distributed to Participants

Item	Publisher/Source	More Information
Textbook: *Foundations of Astronomy*, by Michael Seeds, 8th Edition	Thomson/Brooks Cole	http://www.thomsonedu.com
Starry Night High School®	Imaginova Canada, Ltd.	http://store.starrynightstore.com
The Universe at Your Fingertips (BO122), Summer 2005 classes only	Astronomical Society of the Pacific	http://www.astrosociety.org
Solar Motion Demo Kit (OA170)	Astronomical Society of the Pacific	http://www.astrosociety.org
Cycles Book by Jay Ryan (KT 111)	Astronomical Society of the Pacific	http://www.astrosociety.org
Miller Planisphere Model 40	Celestial Products	http://www.celestialproducts.com
Project Star Celestial Sphere Kit (PS-02)	Learning Technologies, Inc.	http://www.starlab.com
Project Star Cardboard Spectrometer Kit (PS-14)	Learning Technologies, Inc.	http://www.starlab.com
Scale Model Solar System Kit (PS-05)	Learning Technologies, Inc.	http://www.starlab.com
Holographic Diffraction Grating Film (PS-08b)	Learning Technologies, Inc.	http://www.starlab.com
Edmund Mag 5 Star Atlas (3009118)	Edmund Scientifics	http://scientificsonline.com

Content Knowledge Assessment

To assess the content knowledge of the teachers both before and after *Space Science for Teachers* (*SST*), the course employed the *Astronomy Diagnostic Test version 2.0* (*ADTv2.0*) [8]. The *ADTv2.0* was developed by the Collaboration for Astronomy Education Research with funding from the National Science Foundation (NSF), and consists of twenty-one multiple-choice questions in content areas that are stressed in the National Science Education Standards (NSES) for space science and astronomy [9]. The questions on the *ADTv2.0* are designed to assess students' conceptual understanding of space science and astronomy. They require students to apply learned astronomy facts and concepts in contexts and situations beyond those that they were introduced to in class. They are therefore more difficult than simple fact-based questions requiring only rote learning. Many questions include distracters that address common misconceptions. Since the Virginia *Standards of Learning* are closely aligned with the NSES in space science and astronomy, the test should give a good indication of a teacher's content knowledge as related to the Virginia *Standards of Learning*.

The reliability and validity of the *ADT* has been nationally tested in undergraduate, introductory astronomy classes [10]. In the national test of undergraduate students, the average pre-course score was 32.4% and the average post-course score was 47.3%. The averaged pre- and post-course scores for six of the seven sessions of *Space Science for Teachers* (*SST*) are listed in Table 6. Because one of the instructors gave a different pre-/post-test, it is not included; however, positive achievement gains were shown by the participants. Note that the *SST* teachers' pre-course scores were similar to, or higher than, the national average score of post-course undergraduate students. This implies that the average teacher attending the course enters with a conceptual understanding of astronomy and space science that is equivalent to or better than a single semester, undergraduate astronomy course.

Table 6
***Astronomy Diagnostic Test* Pre- and Post-Course Results**

Course	Mean Pre-Course Score	Mean Post-Course Score	Difference (%)	Normalized Mean Gain (Post-Pre)/(100-Pre)
Weighted Mean	**52.5%**	**70.6%**	**18.1%**	**38.1%**

In the national test, it was found that undergraduate students' scores increased by 14.9% after a one-semester, introductory astronomy course. This is a normalized gain of 22% (normalized gain is the realized gain divided by the maximum possible gain (or [POST-PRE]/[100-PRE]). In *Space Science for Teachers*, the weighted mean pre-course score was 52.5% and the post-course score was 70.6%, for a gain of 18.1%. The gain realized in the two-week *Space Science for Teachers* was higher than the average gain in a full-semester, introductory astronomy class. In addition, the normalized gain of 38.1% was larger than the normalized gain in the national sample of introductory astronomy courses. Furthermore, in each course, the post-course scores of the vast majority of teachers were higher than the pre-course scores (see Table 7).

Table 7
Comparison of Pre- and Post-Course *ADT* Scores

	Number of Teachers Whose *ADT* Scores Increased after the Course	Number of Teachers Whose *ADT* Scores Remained the Same after the Course	Number of Teachers Whose *ADT* Scores Decreased after the Course
Percentage	**90%**	**7%**	**3%**

One disadvantage of the *ADT* is that it consists of only twenty-one astronomy and space science content questions. A significant fraction of the teachers score very high on their pre-course test, which leaves little or no room for improvement during the course.

During the S06A, S06B, and S07A sessions, the instructors also administered, pre- and post-course, a test containing all the released astronomy and space science questions from the Virginia *Standards of Learning* (*SOL*) tests over the last five years. *A priori*, it was expected that teachers would score well on this test because the released test items are often used by teachers to prepare their students for the *SOL*. Therefore, it was not surprising that the pre-course score was 86% which improved to 91% after the course (see Table 8). At the end of the course, each of the released test items was discussed in turn. In spite of the high scores both pre- and post-course, there was a significant amount of discussion and debate about the reasoning behind the correct or incorrect answers. The authors feel that it is worth updating and administering this test in the future, though only at the end of the course as a way to promote discussion of the *SOL* rather than as an assessment of teachers' content knowledge.

Table 8
Virginia *SOL* Released Test Items

Course	**Mean Pre-Course Score**	**Mean Post-Course Score**	**Difference (%)**	**Normalized Mean Gain (Post-Pre)/(100-Pre)**
S06A, S06B, S07A	**86%**	**91%**	**5%**	**36%**

Course Evaluations

On the last day of the course, the University of Virginia School of Continuing and Professional Studies required that the instructors distribute a standard, "Course Evaluation Form." The form consists of eight multiple-choice questions and two open-ended questions. The multiple-choice answers use a 5-point Likert scale: 5 (strongly agree), 4 (agree), 3 (no opinion or neutral), 2 (disagree), 1 (strongly disagree), and 0 (not applicable). There were twenty-four evaluations completed for the S05A course and twenty-nine completed for the S05B course. Overall, the results were excellent (see Table 9).

Table 9
Summary of Course Evaluation Data Using UVA Course Evaluation Forms

	@UVA
1. The objectives of this course were clearly stated.	4.84
2. The instructor was effective in teaching the course objectives.	4.91
3. Course materials were appropriate to the subject matter.	4.93
4. Course requirements were relevant to course goals.	4.88
5. Feedback was timely and given at appropriate intervals.	4.78
6. The instructor demonstrated openness and receptivity to student needs and opinions.	4.91
7. Facilities and equipment (e.g., audiovisual equipment) were adequate.	4.67
8. Overall, this course met my expectations.	4.89

The second half of the evaluation form consists of the open-ended questions, "What I like best about this course was," and "To strengthen this course I would suggest." The instructors carefully reviewed all the evaluation forms and will use the suggestions to improve the course in the future. A representative sample of the responses for each question is listed below. In response to "What I like best about this course was," participants had the following comments:

- "Instructors were excellent team teachers. Tremendous resources: *Starry Night*®, telescopes, activities, projects."
- "The moon phase activity, observing at night."
- "It was geared to teach not only content, but also teaching strategies."
- "Updated material, activities for the classroom, materials for the classroom."
- "The introduction of new and exciting ways to engage students with visual cues and activities."
- "Tons of hands-on materials—CD-ROM with *PowerPoint* materials, etc."
- "The practicality. The instructor is extremely knowledgeable and showed us several demonstrations that we can use in our teaching."
- "I felt like I could present most of what I learned to my students and that they would enjoy learning the material."
- "Demos, labs/projects—especially nature of science."
- "The classroom activities are engaging and useful."

In response to "To strengthen this course, I would suggest," course participants offered the following suggestions:

- "There was a very good mix of pedagogic discussion and content. I thoroughly enjoyed both. There may have been a couple of times when the length of the lectures was taxing."
- "Possibly some pre-reading information."
- "Use of tables would be easier to take notes."

- "If you had better connections with the 'powers above' then we would have had numerous nights for viewing the night sky. Please see if you can work on making this improvement."

- "More activities and small projects that the student constructs to help visualize difficult topics."

- "I would like to have been able to download the *PowerPoint* presentations before the class started (I like to follow along and make notes on them.) Avoid days that require students to sit at McCormick [Observatory] the entire day."

- "Assign specific readings in the textbook associated with the lecture the next day."

- "Better explain project. Have written directions."

- "Having the course in a room that had better computers, especially since we needed them for working on our projects."

- "Begin class with 'top ten' list of big astronomy questions we and our students have."

Based upon the results of the course evaluation forms from the George Mason University 2006 course (2007 course evaluation forms not available at the time of this writing), teacher participants also seemed to be pleased with the course. Utilizing a 5-point Likert scale, instructor preparation scored a mean of 4.93. On the same scale, course organization scored a mean of 4.81, instructor motivation scored a mean of 4.69, intellectual challenge scored a mean of 4.2, instructor fairness scored a mean of 4.94, and the overall course rating scored a mean of 4.75.

Written comments from the George Mason University course participants are summarized below.

- Great guest speakers.
- Great teacher resources provided.
- Target audience kept in mind.
- Excellent organization of learning.
- Great visualizations and hands-on learning.
- Good activities to demonstrate concepts.

- Excellent team teaching approach.
- Provided hands-on materials that could be used in classroom.

Suggested improvements from the George Mason University course participants included the following:

- Preference for starting later in the day, and not be required to return for observing sessions;
- Preference for having more night time observing sessions;
- Desire for it to be more intellectually challenging;
- Desire to have a review, specifically for the final post-test examination; and,
- Preference for better questions on the post-test.

Recommendations

Opportunities for grades 4-12 teachers for in-service professional development in the areas of astronomy and space science should be made available at regular intervals in all areas of Virginia. The models presented here for such in-service opportunities are worth emulating: some tuition support is provided; and, teachers receive appropriate materials and technologies for use in their own classrooms, along with instruction in how to use them. The ten-day summer course has advantages of intensity and strong daily instructor-to-teacher and teacher-to-teacher interaction. The hybrid model represented by the Abingdon course is suited to circumstances where the teachers are widely dispersed in rural areas. The use of on-line technologies such as *Blackboard*'s® Discussion Board and chat function served also to build participant and instructor-student rapport. A follow-up study of changes in participants' classroom instruction might also look for differences in the effectiveness of the summer versus hybrid delivery models. ■

Acknowledgments

The authors wish to acknowledge the assistance of the following persons in the successful implementation of the *Astronomy* courses for teachers: Randy Bell, Ian Binns, Dr. Julia Cothron, Rick Diecchio, Robert Ehrlich, Wendy Frazier, Tawana Gilyard, Lee Ann Hennig, Fred Kourmadas, Steven Peters, Art Poland, Mary Quillen, Greg Redfern, Donna Sterling, Joe Weingartner, and Heather Weir.

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[2] *State of Virginia Critical Shortage Teaching Endorsement Areas for 2005-2006 School Year*, Virginia Department of Education, Richmond, VA; Internet: http://www.doe.virginia.gov/VDOE/newvdoe/critical-shortage-areas2005-2006.pdf.

[3] iClicker website, Internet: http://www.iClicker.com.

[4] R.R. Hake, "Interactive-Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses," *American Journal of Physics*, **66**(1) (1998) 64–74.

[5] "Solar System Ambassadors Program," NASA Jet Propulsion Laboratory; Internet: http://www2.jpl.nasa.gov/ambassador.

[6] "Speakers Bureau," NASA; Internet: http://www.nasa.gov/about/speakers/nasa-speakers-howto.html.

[7] *Edmund Mag 5 Star Atlas*, Edmund Scientific, Tonawanda, NY, 1975.

[8] *Astronomy Diagnostic Test*, Montana State University; Internet: http://solar.physics.montana.edu/aae/adt/.

[9] B. Hufnagel, "Development of the *Astronomy Diagnostic Test*," *Astronomy Education Review*, **1** (2002) 47-51; Internet: http://aer.noao.edu/cgi-bin/article.pl?id=4.

[10] G. Deming, "Results from the *Astronomy Diagnostic Test* National Project," *Astronomy Education Review*, **1** (2002) 52-57; Internet: http://aer.noao.edu/cgi-bin/article.pl?id=5.