A LIVELY ELECTRONIC COMPENDIUM OF RESEARCH, NEWS, RESOURCES, AND OPINION

Astronomy Education Review

Volume 2, Sep 2003 - Jan 2004
Issue 2

Accessible Universe: Making Astronomy Accessible to All in the Regular Elementary Classroom

by **C. A. Grady**
NASA Goddard Space Flight Center
N. Farley
Howard County Public Schools
E. Zamboni
Howard County Public Schools
F. Avery
Howard County Public Schools
B. Clark
Howard County Public Schools
N. Geiger
Howard County Public Schools
B. Woodgate
NASA Goddard Space Flight Center
Posted: 10/10/03

The Astronomy Education Review, Issue 2, Volume 2:1-19, 2004

Abstract

Astronomy is one of the most approachable of the sciences and enjoys tremendous popular interest, beginning at the elementary level and continuing on through college and in the popular media. Space-related topics are some of the most popular science topics in the elementary grades and can serve as a springboard to other sciences, mathematics, technology, and reading for the typical student. Not all students are typical: 10% of American students are identified as having disabilities affecting their education sufficiently that they receive special education services, with perhaps an additional 10% less severely affected. At the elementary level, these students usually receive their science education in comprehensive (mixed-ability) classrooms. Budgetary limitations for most school systems have meant that, for the bulk of these children, individualized accommodations and adaptations for science instruction are not readily available. We have piloted a suite of curriculum materials, modified activities, and instructional strategies, incorporating both Web-based astronomy resources and assistive technology to more effectively teach astronomy to children with disabilities in the elementary regular education

classroom.

1. INTRODUCTION

Astronomy is one of the most approachable of the sciences, with a steady stream of new discoveries and wide public interest. At the elementary level, space-related topics are some of the most popular science topics and can serve as a springboard to other sciences, mathematics, technology, and even reading for the typical student. However, not all students are typical: 10% of American students are identified as having disabilities sufficiently impacting their education that they receive special education services; various estimates suggest that an additional 10% may either have milder impairments or superior intelligence that enables them to partially compensate for more severe impairments. Ten percent of the students receiving special education services have sensory, physical, or neurological disabilities. The remaining 90% have specific learning disabilities, speech and language impairments, emotional disturbances, mild mental retardation, developmental delays, or attention deficit/hyperactivity disorder (President's Commission on Excellence in Special Education 2002).

As a result of the National Science Education Standards (NRC 1998) and the current emphasis on statewide testing emphasizing both knowledge of academic content areas (Maryland high school assessments) and problem solving skills, there is increased time spent on science—and specifically astronomy and space science related areas—in the school curriculum. In Howard County, Maryland, the advent of statewide testing has produced a revision of the science curriculum. Astronomy-related units are taught beginning in first grade and continue through the elementary program before becoming a primary science focus in middle school, where astronomy is taught as one of three science themes for sixth grade. The current astronomy and space science curriculum has been modified in the past two years in response to the National Science Education Standards (NRC 1998)—incorporating group-learning experiences as well as increased time for activities involving manipulatives (things that can be handled, such as toys or models)—in keeping with current understanding of best educational practices for typically developing students. The science units are taught with the aid of a detailed curriculum, extensive rubrics (instructions for the classroom teachers), and standardized material kits that are available to all schools in the district. The modernization of the curriculum resulted in a suite of science activities oriented toward the typical student learners who comprise the majority of the population.

In tandem with the trend to teach with the National Science Education Standards, schools are required to comply with the Individuals with Disabilities Education Act '97 (PL 105-17, which is a reauthorization of the earlier PL 94-142; see Henderson 2001 for a summary of laws affecting education of children with disabilities). This law favors placing children in the least educationally restrictive environment. For the approximately 10% (~6.3 million) of children with disabilities under Individualized Education Plans, the majority now spend some or all of their school day in a comprehensive (mixed-ability) classroom. They are not alone: up to an additional 10% of the student population have milder impairments potentially impacting school performance, but not sufficiently severe to enable these children to qualify for special education. At the elementary level in Howard County, science activities are routinely taught as integrated learning activities where children with a range of learning issues are in the regular education classroom, since science activities, particularly those involving manipulatives, lend themselves to cooperative learning.

However, unless the activities have a good match to the sensory, sensory processing, cognitive, and motor skills of the children, and can offer access to learning tools that level the playing field for children with disabilities, group learning activities can encourage passive participation rather than active learning, and send the message that certain subjects and activities are not appropriate interests or career choices. This is of special concern because the special needs population has a school dropout rate twice that of the general population, a 50% lower rate of participation in higher education (President's Commission on Excellence in Special Education 2002), lifelong disproportionate underrepresentation in the workforce and, in many cases, significant underemployment (see http://www.census.gov/hhes/www/disability.html). With a shift toward jobs requiring more of a technology background, it is crucial that instructional materials and techniques used with this population not imply that science and technology are not for individuals with disabilities. This situation is aggravated in the case of astronomy and space science by the strongly visual and visual perceptual nature of the materials provided to educators by the scientific community.

This need not be the situation. We live in a time when evolving technology, coupled with increasing Internet classroom connectivity, can make online research materials, assistive technology (see Warger 1998 and other papers available at http://www.ldonline.org/ld_indepth/technology), and other tools available to all. Similarly, small adaptations to current activities frequently can address the needs of many children in a comprehensive learning environment by focusing on the key concepts and minimizing distractions. Special educators, occupational therapists, and vision specialists have a long history of identifying small, targeted accommodations to improve the learning environment for children with disabilities. This historically has been done on a case-by-case basis. Budgetary limitations for most school systems have meant that for the bulk of children with disabilities (typically those with comparatively mild learning impairments), individualized accommodations have not been readily available, except perhaps for reading and mathematics instruction. Time pressures and lack of training on the part of the regular classroom teachers have meant that simple adaptations for science instruction are typically not implemented.

Our multidisciplinary team has been piloting a suite of curriculum materials, modified activities incorporating Internet resources and assistive technology, and instructional strategies in the Howard County Public School (MD) system from grades three through five. These grades were chosen because the curriculum shifts from manipulative-based learning to more text-based material in grade four. It is at this point that many students with learning disabilities begin to struggle academically.

2. SUCCESSFUL IMPLEMENTATION REQUIRES...

A program of this kind requires experience in the regular classroom, a wealth of special education expertise—especially familiarity with assistive technology—and familiarity with modern astronomy and the Internet resources that have become available during the past few years. Typically, no single individual has this breadth of expertise. As a result, implementing this kind of program can be an opportunity to collaborate in the creation of a holistic learning environment. While this might appear daunting, the classroom and special education expertise is commonly available in school districts throughout the United States, and merely requires that classroom teachers strike up a dialogue and be prepared to work collaboratively with the special educators—particularly occupational therapists, vision specialists, and assistive technology team members—who work in their schools. Scientists participating in such a program need to have an awareness of data resources and which astronomical topics are appropriate for students in any given age range.

Implementing change in the classroom requires that the modifications fit with the existing curriculum. School districts are under tremendous budget and accountability pressure and typically do not have the luxury of starting from scratch in redesigning their science curricula. This is particularly the case for districts using districtwide tests and in an era of increasing use of high-stakes annual and exit testing (see O'Neill 2002 for the implications for students with learning disabilities at http://www.NoChildLeftBehind.gov/start/facts/testing.html). An incremental approach where the adaptations are seen as supporting the existing curriculum is much more likely to be implemented.

We also sought to encourage inquiry-based learning by making use of existing resources incorporating real data (what educators term an "authentic learning environment") in accordance with best educational practices (Rutherford & Project 2061 1990; NRC 1998). We also sought to match the resources to the developmental level of the students, and to integrate the use of technology into the modifications. This is particularly important because the high student interest in anything space-related can provide an incentive for the students to master more specialized software.

Teachers in a comprehensive classroom also require that any changes be of benefit to all of their students, not just to the special needs students who are likely to be in the minority. This requires use of resources that allow students to approach the material at different levels and accommodate the needs of the slower learners, while providing the depth that the gifted and talented students need. Modifications should also respect the students as human beings, and not make students with disabilities more conspicuous to their peers. Upper elementary students have a strong psychological need to fit in, and will actively avoid activities or equipment that make them more conspicuous, even if this means doing less well academically or expending greater effort to keep up with the class. For example, it is amazing how rapidly pencil grips (to improve fine motor control and make writing more comfortable) can be "lost" if they are used by only one child in a classroom.

We have focused, therefore, on identifying resources and activity modifications requiring minimal advance preparation and setup time, and that make use of a school district's existing investment in hardware. We further required that if any specialized equipment or software is used, it should be compatible with a school's existing investment in hardware, be usable cross-curriculum, and be usable for much of a student's academic career. Equipment was also chosen to provide the multisensory learning that many special needs students require and from which most students benefit.

3. MODIFYING THE ACTIVITIES

Students in grades three through five are generally concrete learners who may have difficulty with the kinds of abstraction that adults take for granted. This is developmental and must be factored into any demonstrations, presentation of material, and physical modeling to ensure that students make the correct inferences (see Ginsburg & Opper 1988). As an example, use of a flashlight as a representation of the Sun works for adults, but younger children may infer that this means that the Sun shines in only one direction, because that is what they see. While the ideal source representing the Sun for this age range would be omnidirectional and would float in space, a reasonable compromise at modest cost appears to be a small camping lamp (see Figures 1 and 2). Such lamps provide 360° illumination and can be shared by groups of students to further reduce cost. Similarly, use of featureless balls (e.g., white styrofoam balls) in discussions of day and night (because they have nice, crisp terminators) to represent the Earth also may be too abstract for many students in this age range. Using balls with the continents marked on them reduces the level of abstraction and provides greater similarity to space imagery, and allows for use of globes and maps already found in classrooms.

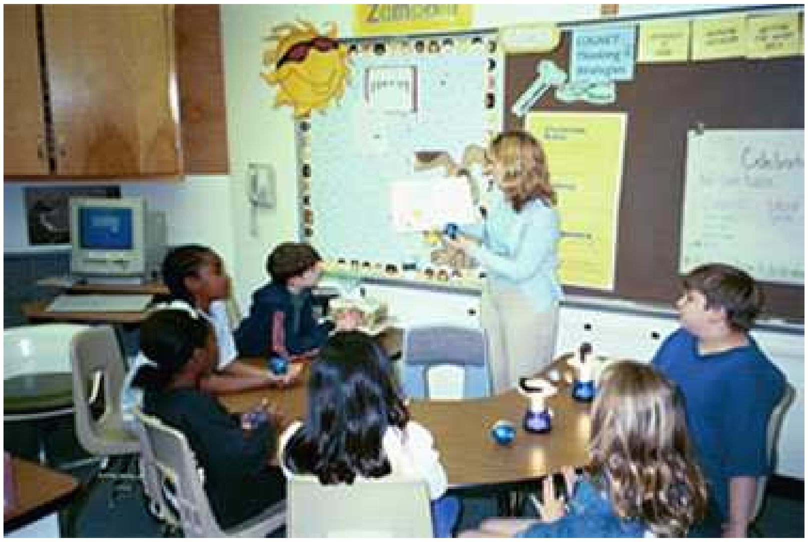

Figure 1. Small balls (4" or 10 cm diameter) with continents marked on them can be used in conjunction with small, bright camping lamps for physical modeling of day and night and seasons. The lamps must be sufficiently bright to cast distinct shadows in a darkened classroom.

We had good success with soft, 4" (10-cm, see Figures 1 and 2) diameter balls with the continents in raised relief, so much so that some of the balls were borrowed by other grades. The soft texture makes handling the balls more pleasant for the students, particularly those who are tactile-defensive (individuals who avoid or are overwhelmed by certain kinds of tactile sensation), while the raised relief provides tactile feedback for students who need to use multiple sensory channels for learning. As a safety feature, if someone decides to throw one of the balls, classmates may be startled but are unlikely to be hurt. Balls in this size range, while satisfactory for most students, may need some modification for teaching seasons (add rotation axis with diameter similar to a primary pencil so that the ball looks like a giant pencil topper), or for students with visual acuity or orthopedic impairments. Students with visual acuity problems may need to use larger balls with raised beads along the continent margins—e.g., beach-ball sized with beads added using fabric decoration glue—while students with orthopedic impairments affecting their ability to grasp can benefit from using tactile balls for the same activities. These kinds of material replacement/modification are routine for occupational therapists and teachers of the visually impaired. While some modifications require modest use of equipment, others require only the ingenuity of the teacher. A darkened classroom better mimics the space environment (reduction in abstraction) while enabling students to focus on the points of interest (improved visual figure-ground discrimination) and minimizing distractions (useful in dealing with individuals with attention deficit/hyperactivity). Similarly, sundial activities can be done using vision, with chalk marking the location of the shadow cast by a gnomon or globe throughout the day, or on a low humidity day, using the temperature difference in and out of shadow and mats with assorted textures (furry, bumpy, sticky, and so on) to build a tactile sundial. Such an activity, while including students with visual impairments, can also be used as a springboard to discussion of the electromagnetic spectrum, particularly the infrared. Tables 1-4 list some modifications that can make space science topics less abstract, and that can make activities more accessible for all students in the comprehensive classroom. Table 5 lists the resources used in our pilot study.

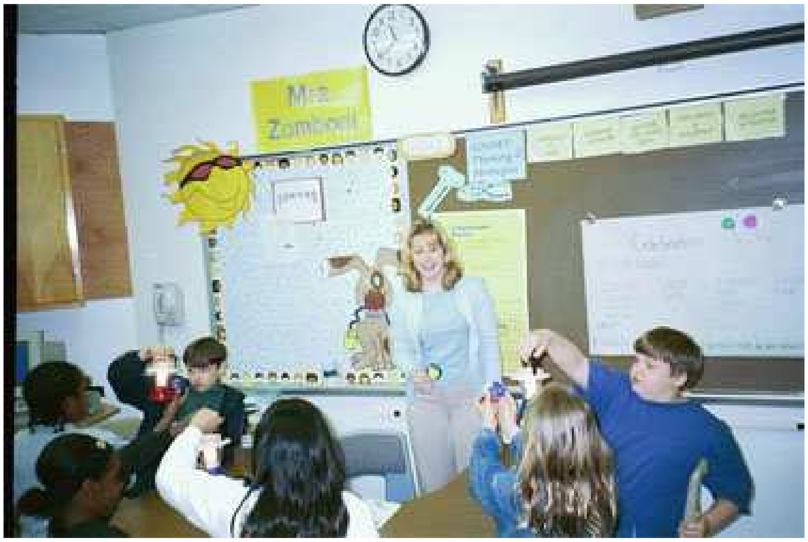

Figure 2. The balls used with this fourth grade class at Longfellow Elementary in Columbia, Maryland, had the continents in raised relief to provide additional tactile feedback.

Elementary teachers are familiar with the need to reinforce understanding of material with opportunities for students to draw pictures or make models of whatever is being studied. Commercially available model kits and orrerys can be used with this age range to provide 3-D opportunities for reinforcing understanding of space imagery (see Figure 3).

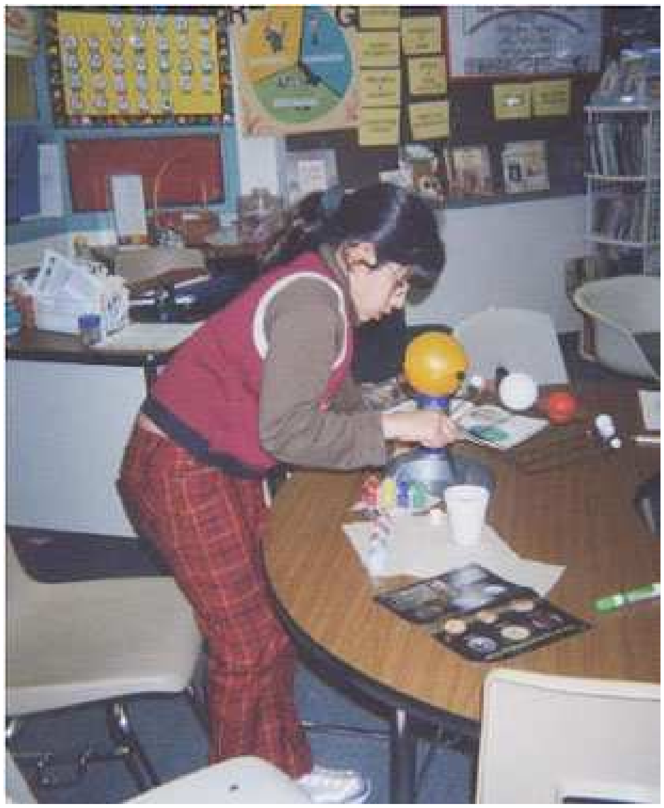

Figure 3. Painting a model in a simple orrery can provide additional reinforcement for understanding images viewed on a Web site or in books. Here a student is painting a model Jupiter.

4. USING INTERNET RESOURCES FOR TEACHING ASTRONOMY

All too often, astronomy in the elementary school age range is presented as a collection of facts divorced from any discussion of how they were discovered, and is taught with use of press release imagery, which may not be developmentally appropriate for the students. A major limitation for many school districts is that the best time to observe astronomical objects is after dark rather than during the school day. Internet astronomy resources and the increasingly complex network of weathercams can work around these limitations in ways that have never before been possible. Within the past few years, schools have become increasingly connected to the Internet, providing a wealth of new resources for teaching astronomy. At the same time, the Internet resources can provide access to reference materials in digital form (e.g., encyclopedias, specialized dictionaries, and other text resources), making them accessible to students with visual impairments, reading difficulties, or orthopedic impairments. While the majority of astronomy resources are aimed at adults, we have identified a number of Internet resources that:

1. Are age-appropriate with a good fit to the elementary curriculum
2. Make use of minimal text or have page layouts compatible with commonly available assistive technology
3. Emphasize actual astronomical data

See http://hires.gsfc.nasa.gov/accessible for sample Web pages sorted by grade.

4.1 Webcams for Teaching Seasons and the Shape of the Earth

Third graders in Howard County, for example, spend much of their space unit (one week total) working on the concepts of day and night and how they relate to the globe. Rather than teaching this as a teacher-led demonstration using just a globe, followed by students drawing or writing to demonstrate their understanding, we propose that the class sample an east-west grid of weathercams to determine that it is not the same local time everywhere, and that some places are pre-sunrise while others are post-sunset. Such an activity was tried during the 2002-2003 academic year with one of the fourth grade classes at Longfellow Elementary in Columbia, Maryland. The class made use of a planetarium program "A Field Trip to the Sky," provided by the school district, to get the "cartoon" version of day or night at a particular location, and then used the weathercam to see reality. To further reinforce this activity, students located the site of the weathercam using a globe with one of the small camping lamps providing the "solar" illumination. The same activity was repeated using a north-south grid of weathercams to explore seasons. This kind of activity may be particularly useful for students with limited travel experience, or who may not realize that it is not the same clock time at all locations on the Earth.

4.2 CONCAMs in the Elementary Classroom

Similarly, fourth graders work on the concept of objects in the solar system revolving around the Sun. For students in urban/suburban areas who have limited familiarity with the night sky, the concept that planets move is rather abstract. All-sky Webcams such as the Continuous Camera (http://www.concam.net) (Nemiroff et al. 2000) at The Night Sky Live network can come to the rescue by providing live night sky exposure to students in North America during the class period (see Figure 4). The sky images from these all-sky cameras are developmentally appropriate because they provide a view of the sky similar to what is visible with the naked eye (albeit from really, really good sites). A comparison of images taken one year apart demonstrates that the constellations are fixed relative to each other, and that planets move.

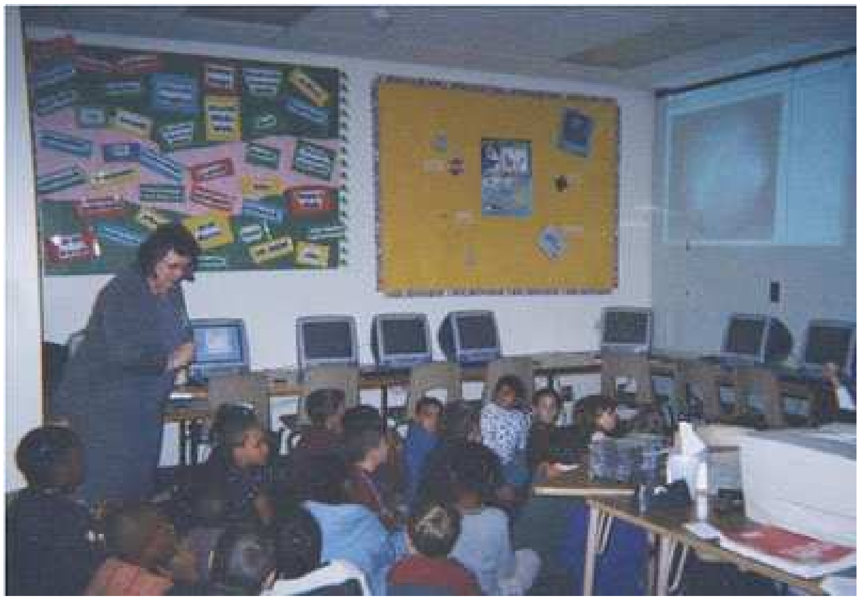

Figure 4. Instead of the more traditional classroom visit, the class visit introduced the night sky, using computer resources such as the CONCAMs, in preparation for the nighttime observing session.

4.3 Appropriate Reference Sites

The Internet offers a number of extensive astronomy-related reference sites, many of which are designed for adults. We find that the Astronomy Picture of the Day has a good mix of developmentally appropriate topical pictures and captions (Bonnell & Nemiroff 2000; see http://antwrp.gsfc.nasa.gov/apod). The captioning from this site is not only compatible with assistive technology tools, but is more digested and manageable than the original press releases and includes hyperlinks to unfamiliar terms. The short captions and access to definitions make this kind of text presentation less intimidating to students with reading difficulties. Other sites, such as the Nine Planets (http://www.nineplanets.org), can be used in our study age range with some teacher assistance.

5. THE ASSISTIVE TECHNOLOGY

A key component of our study was the integration of assistive technology—or tools to improve access and understanding of material—into the program. In particular, we have made use of three commercially available programs that run on both PCs and Macs. All three programs are familiar to special educators with interests in assistive technology.

1. eReader is an alternate Web browser that can read Web sites aloud, permitting access to text-based materials for those with dyslexia or visual impairments (see http://www.cast.org). It also reformats Web sites to minimize distractions by placing images outside of the text area (see Figure 5).
2. Write:Outloud is a talking word processor that can either read previously formatted text or be used to read student writing (see http://www.donjohnston.com). Users have control over how much material is read at one time—what educators term "chunking"—and can choose the synthesized voice.
3. We also made use of Inspiration (http://www.inspiration.com), a graphical organizer and outline

processor. Clip art, graphics files, and more conventional notes can be linked in this program to enhance note-taking and to organize material for writing or oral presentation.

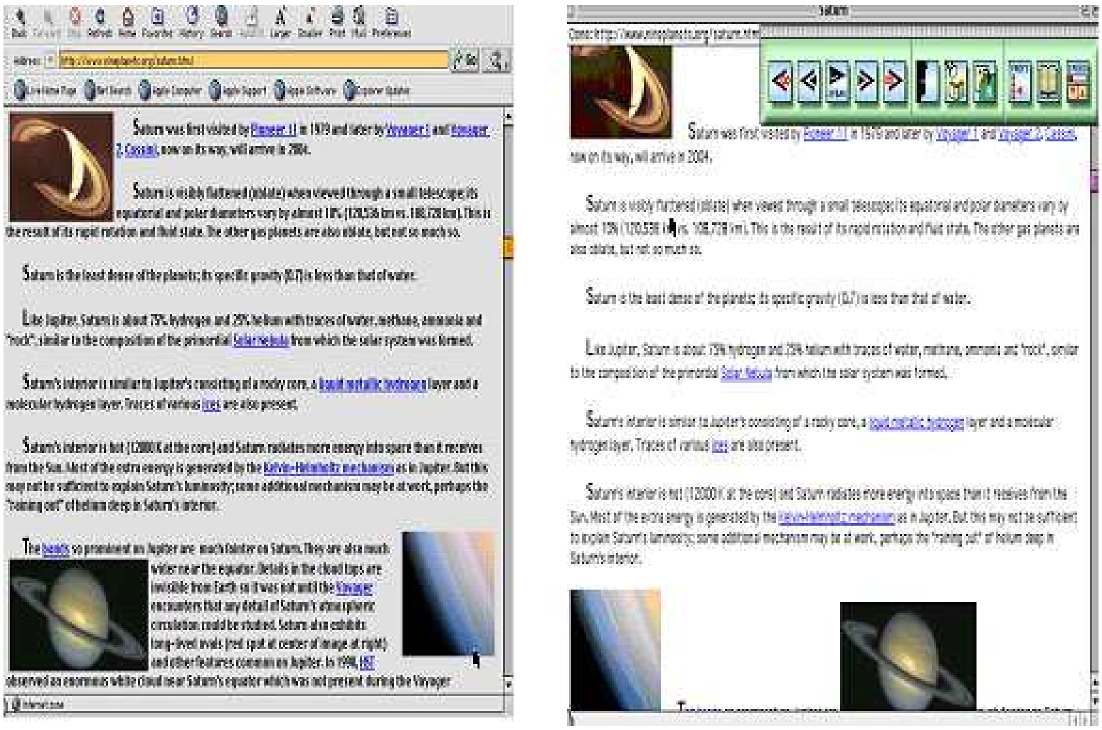

Figure 5. Specialized computer software, including text-to-voice browsers such as e-Reader, can make Web sites and other material more accessible to students with disabilities. E-Reader reformats Web pages to move images away from text and add additional white space, which can make reading easier for some individuals. The program can also read the text aloud, providing auditory feedback for individuals with dyslexia or with limited reading proficiency in English. The original and reformatted versions of the Saturn page from the nineplanets.org Web site are shown here.

6. PULLING IT ALL TOGETHER

As an example of how all of these elements come together, fourth grade students at Longfellow Elementary researched planets, participated in a nighttime observing session, and then wrote science fiction stories about the planet of their choice. We followed one student who chose Jupiter as her research topic.

1. While most of the students used books for researching planets, our student used e-Reader to access information on Jupiter from the Nine Planets Web site (http://www.nineplanets.org). The student highlighted key information from the site to begin organizing for writing.
2. All students participated in a classroom visit by a scientist to introduce the night sky. In the class visit, we used the CONCAMs (http://www.concam.net) to discuss the appearance of the night sky. The entire fourth grade was invited to the night observing session. Live observing included naked eye, binocular, and telescopic viewing (with a Meade LX-90) of the Moon, Mars, Jupiter, Saturn, Uranus, and Neptune.

3. The special needs students then assembled the Smithsonian Astro-Lab Planetarium (an orrery). The emphasis here was not the scale of the solar system, but tactile reinforcement of astronomical imagery and reading. Pictures of Jupiter were used in painting the model of that planet (see Figure 3).
4. Material from the Nine Planets Web site was then transferred to Inspiration to create a web to organize information, including pictures. The student used these notes to create a science fiction story containing three facts about Jupiter and all of the grade-level requirements for a good story.
5. The student used Inspiration and the "Creative Writer" program to write the story. Following proofing, the final version was printed out and "published" to acclaim from classmates, teachers, and the student's parents.

The story was identified as a major accomplishment at the student's Individualized Education Plan meeting later in the school year. As a fifth grader, this student feels that science is her favorite class and has successfully talked her parents into acquiring a telescope. Figure 6 shows another student presenting his report on a planet to his classmates.

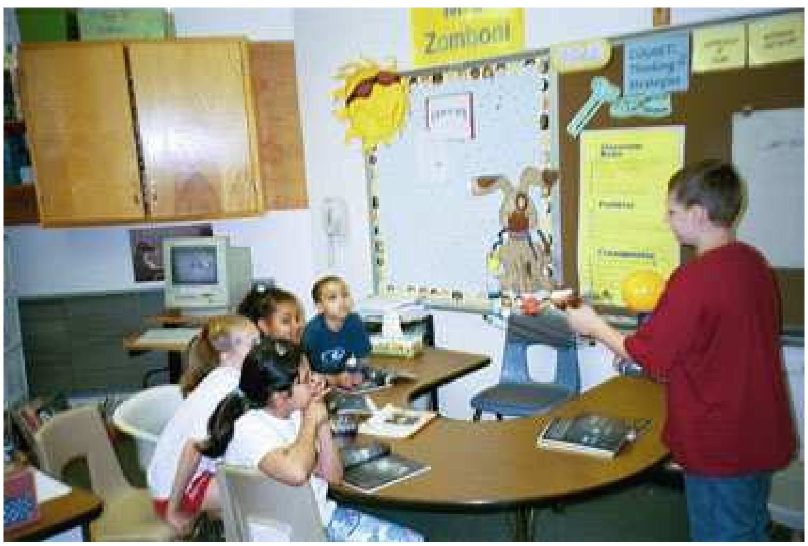

Figure 6. As all experienced lecturers know, effective use of props can enhance a science presentation. Here a student uses the orrery to illustrate his talk about one of the planets in our solar system.

7. RESULTS AND LESSONS LEARNED

Overall, our interdisciplinary approach succeeded in introducing assistive technology resources, Internet astronomy resources, and an expanded suite of manipulatives into the elementary classroom, and has identified a number of simple and comparatively inexpensive ways that the elementary astronomy curriculum can be modified to meet the needs of a diverse community of learners. Implementing this sort of program does require a team of regular educators, special educators, and at least one individual with an astronomy background. A key factor in success is that the teachers responsible for the science instruction are comfortable with working collaboratively. Scientists participating in such a program need to be comfortable with deferring to the classroom expertise of the teachers, but should be assertive about the maximum group size for talks or observing sessions because this can directly impact the learning experience for the students. As we had anticipated, the largest gains begin to be realized in the fourth grade. At that level, the curriculum shifts to being more text focused, and science units are of longer duration. In principle, there is no reason why this approach could not be implemented at the middle and high school levels.

As also expected, this pilot study was a learning experience for all of the participants.

1. Elementary teachers do not have the same training or approach to material that scientists take for granted. Astronomers are used to the concept that certain events take place at certain times only, and that this has implications for scheduling activities. Educators are used to the concept that certain months have "themes" and activities, and are less aware of when natural phenomena drive schedules, such as the implication of daylight savings time for early evening darkness and observing sessions for students.
2. Instructions for teachers need to address how to use the equipment. The Project STAR telescope kits were used by the fifth grade in our study and included instructions for assembly, but did not indicate that you look through the telescope to verify that the telescope is correctly assembled. The fifth grade teachers had their classes assemble the telescopes and then put them in large plastic bags for use at the observing session. By that point, half of the lenses had come out and components did not work. Naturally, we discovered this in the dark, on playing fields! We note that the age recommendation for the Project STAR telescopes was revised in the Astronomical Society of the Pacific catalog (http://www.astrosociety.org) to middle school and above during our pilot study. If these telescopes are to be used with elementary-age students, we suggest that the scientist make sure that the teachers have both assembly and use instructions. We also discovered that teachers really object to the term "star party" as having connotations of a social event, and prefer that evenings with small telescopes be termed "observing sessions."
3. Timing of astronomy units can enhance learning. Direct, personal experience tends to enhance learning for both adults and children. For two of the grades in our study, we were able to have the astronomy unit scheduled at a point in the year when there is early evening darkness so that the solar system objects discussed could be directly viewed. As a result, we were able to have observing sessions for the fourth and fifth grades in the study. This approach could be implemented even in the absence of an observing session (e.g., encourage Moon, planet, or constellation viewing as a homework assignment). For example, viewing Orion and noting the color difference between Betelgeuse and Rigel can make a unit on stars—such as that covered by the fifth grade in Howard County—less abstract. This is a simple scheduling modification that can and should be made without much difficulty by any school district in the United States.
4. Smaller is much better in classroom visits. The fifth grade students whom we were working with were at an extremely large school, the largest in Maryland at that time. Activities consequently could be scheduled only in huge groups. The Internet resource introduction was given in groups of up to three classes (100 students). Each presentation was split into a short talk, with illustration from the Web sites, followed by a question-and-answer period. We found that in the large group setting, questions came from a small number of students from the gifted and talented class. Special needs students did not participate, and we encountered behavior problems from the students with attention issues. The experience was totally different with the fourth grade group during the 2001-2002 school year, and with the fourth and fifth grades at Longfellow Elementary during the 2002-2003 school year because each class was handled separately. Here, the same number of questions, and in fact the same questions, came from each class, independent of academic level. Questions were more uniformly distributed over the entire class, and there was minimal squirming and acting out. Our impression was, therefore, that the same techniques for enhancing participation in science activities

by other underrepresented groups could be harnessed for the majority of special needs students, and that this should be a focus of future studies.

5. Evening observing sessions: Our experience with the fourth and fifth grades again indicated that smaller groups tend to work much better, with more opportunity for students and parents to ask questions. Participation in the sessions appeared to be limited to the higher functioning students in the fifth grade during the 2001-2002 year, but was more uniformly distributed in the fourth grade (despite competing with the week before Christmas).
6. Independent of the level of student participation, one unexpected benefit of the observing sessions was the opportunity for the teachers to informally ask questions without the need to "be the expert" in the classroom. If only limited science resources are available (e.g., too few astronomers, professional or amateur, to do observing sessions for all classes), districts might consider having an evening observing and astronomy training session scheduled as in-service training for their staff.
7. A major outcome of this study was student enthusiasm for science. The special education students at Longfellow Elementary in particular benefited tremendously from the enhancements made to the space curriculum. Some of these students had previously been exempt from content classes, while others had experienced frustration due to limited resources needed to demonstrate abstract concepts. One particular student on a non-diploma track had little exposure to previous space units. He began his inclusion experience asking the question "What is space?" Throughout his participation in classroom activities as a fourth grader, he used many hands-on materials and current technology to begin to discover space. He shared a mutual enthusiasm with his peers as they showed the Earth’s revolution and rotation using the balls and lanterns. They viewed different places around the world that were observed through Web cameras. He was able to make a real-life connection instantly. The use of the "Read Out Loud" program helped him to gather information about the planets. He demonstrated his mastery of the material by scoring an "A" on the planet quiz and continues to retain the information. He also earned a high score on his research project about Mars. For this project he used lower level books, Internet sites, and the Inspiration program to organize his material.
8. This student also received guidance from a fifth grade special education student who had participated in the study as a fourth grader during the 2001-2002 academic year, when he was writing his science fiction story. The fifth grader, who has severe language difficulties, made wonderful progress the previous year using the same resources. In the past, she had not retained the majority of the content material when instructed in the general education class, even with numerous modifications. The 2001-2002 year was her year to shine. It was the classroom teacher’s thought to have her act as the "space expert" with the fourth grade student. When she worked with the fourth grader, the teacher could see how easily she shared her knowledge about space. She was confident and quite fluent, demonstrating that she has maintained what she has learned about space. She also continues to display enthusiasm for space and a desire to learn more. The experience of these students and their classmates has demonstrated that space is accessible to all students. Buoyed by this success, the teachers at Longfellow Elementary are now using this approach as a model for other content units in fourth and fifth grade.

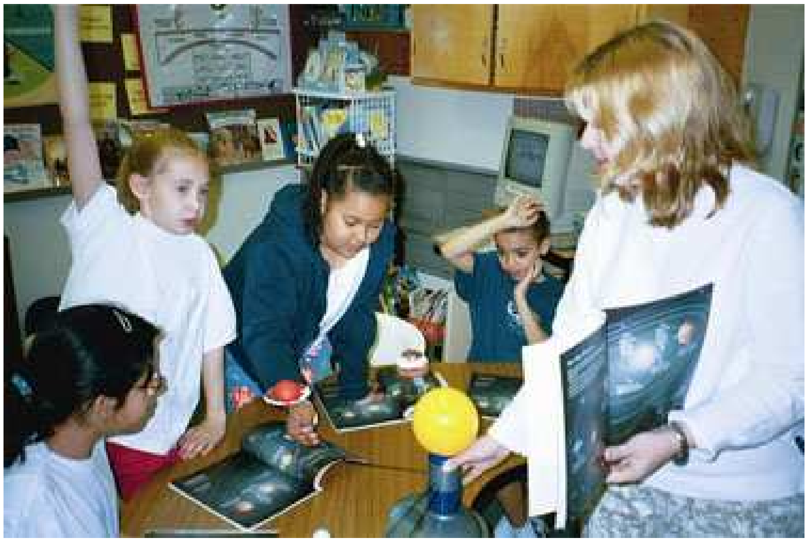

Figure 7. Prepare for enthusiastic learners!

Acknowledgments

We would like to thank the staff and students of Bollman Bridge Elementary, Jessup, Maryland; Longfellow Elementary, Columbia Maryland; and Pointer's Run Elementary, Clarksville, Maryland for making this pilot study possible. Thanks also to Cathy Imhoff, Karl Cox, Andrew Cox, and Gerry Williger for assistance with telescopes and logistics during the observing sessions. We would also like to thank Keith Feggans of Sigma Space Corp. of Landover, Maryland for assistance with the Web site for this study. Computer resources were provided by the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center (GSFC). We would like to thank the referee of this paper, Edna deVore, for many useful comments. The parent science proposal for this study is a program of coronagraphic imaging of proto-planetary disks and outflows associated with forming planetary systems. Support for proposal HST-EO-8474 was provided by NASA through a grant from the Space Telescope Science Institute to the Howard County Public Schools and to NOAO. The Space Telescope Science Institute is operated by the Association of Universities for Research in Astronomy, Inc. under NASA contract NAS 5-26555. NOAO is operated by the Association of Universities for Research In Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.

Table 1. Making space imagery more concrete

Physical models	Use balls with markings similar to globes and maps in the classroom as model Earths. White styrofoam balls, while providing crisp terminators, are too abstract a representation of the Earth for grades 3-4 in particular. For younger students and/or those with developmental delays, supplement the Earths with a toy camera to represent the spacecraft taking the images. Have students move to several vantage points rather than viewing the models from a single location.
Illumination	Camping lamps or other light sources that are not directional and that are sufficiently bright to cast distinct shadows.
Minimizing competing light sources	Dim or turn off room lights; cover windows as needed to have the "Sun" provide the bulk of the illumination. This modification has the advantage of minimizing distractions for more visually distractible students (and is a staple of classroom management techniques!).
Provide multisensory input	Balls with continents in raised relief (Earth) or craters in raised relief help students orient their viewpoints. For modeling seasons, insert primary-sized pencils into the balls to provide a rotation axis (grades 3-4). By grades 5-6, 1"- diameter balls designed as pencil-toppers work well.
Reinforcing the images with tactile output	Give students opportunities to draw, model with clay, or assemble model planets. Make a moon by dropping pebbles (1", 2", etc.) into a pan with flour covered by a thin cocoa layer. This activity can be used as a qualitative way of understanding the surface of the Moon, Mercury, and so on in this age range. (Hint: for younger students, have this be a group activity with one pebble per student.) To model icy moons in the outer solar system, do the activity with a pan filled with ice slush with a cocoa dusting.

Table 2. The night sky

Physical modeling of the night sky	Decorate classroom walls with either glow-in-the-dark or conspicuous "stars." Dim the lights, use a bright camping lamp as the Sun, and have the students look toward the Sun (day) and away for night. Have them spin in place to model the Earth's rotation.
Understanding all-sky (fish-eye) views of the night sky	Have students lie down outside on playing fields with feet pointing south, and notice how the sky and horizon appear. This is the same viewing geometry as for the CONCAMs and for Miller planispheres (star finders).
Find the planets in all-sky images	Use parallax to enable students to identify solar system objects. Comparison of CONCAM images taken one year apart places the Earth and background star field in the same orientation, but the planets move. This comparison can be done as a computer activity or with printed images (flipbook). Here you are making use of the human brain's ability to identify moving objects. A classroom activity illustrating parallax involves locating the position of a "star" (on posterboard mounted on an easel) relative to two "background" objects. Students note the location of the star from each of two observing stations. This can be done in a large classroom or as an outside activity. If you have a displacement of at least 2m from one observing station to the other, individuals with vision in only one eye can see the difference. Recording the relative locations of the star and reference objects can be done on paper at one observing station and on transparency film at the other. Laying the transparency over the paper version makes the displacement obvious.

Table 3. Modifying the activities for low visual acuity/normal tactile sensitivity

Tactile sundial	On a clear, low humidity day (preferably cool) with a distinct temperature difference in and out of shadow, use the Sun's infrared radiation to locate the shadow cast by a beach ball Earth. Mark the shadow location with textured placemats (furry, nubbly, tacky, rough, and so on) to build up a sundial in the course of a day.
Day & night (in the classroom)	Use beach ball Earths and a heat lamp (suitably shielded for safety reasons) as the Sun. Students use the temperature difference in a cool room to locate the Earth's shadow.
Planets and the solar system	Modify the find-the-planets activity by using a raised relief "orbit" pathway for the Earth's orbit, and a loudly ticking clock or beeping adaptive PE ball to be the planet to be located. Background objects could be modeled as fainter clocks or beeping toys. This activity uses the same skills needed for goalball, a popular game for students with visual impairments.

Table 4. Modifying the activities for students with fine motor deficits

Adapted balls for physical modeling involving the Earth	Use a tactile ball with the continents marked. Two brands, Gertie and Slo-Mo, can be held by an individual who has essentially no control of the fingers, but who can bring the arms/hands to the midline. We have not seen commercially available Gertie balls with continents on them for a few years, but continent margins can be marked using decorative fabric-glue beads. (This is a nice way to involve your school's OT and art teachers.)
Seasons	Drill a hole in a 4" squishy ball and insert a primary pencil. The grip can be further built up using whatever pencil grips the OT recommends for the student.

Table 5. Toys, software, and instructional materials used in the pilot study

Resource	**Where to Find**	**Cost**
Earth balls (4", 10 cm diameter) — squishy balls (latex covering — check to make sure students do not have any latex allergies)	Toysmith 1-800-356-0474	$1.25 ea or $30/24 balls
	National Solar Observatory Visitor's Center, Sunspot, NM	$2 each
	Lick Observatory Visitor's Center, Mt. Hamilton, CA	$2 each
	Smithsonian Natural History Museum (not the Air and Space Museum)	More expensive but better fidelity; discount available with educators' ID
Mini camping lamps	Rayovac Adventure Lites	$8.90
	Prodigy Lites at Target, K-mart	$7.90
Smithsonian Astro Lab Planetarium (the orrery)	Superstores (BJ's), Smithsonian Air & Space Museum	$14.00
Project STAR telescope kits (better for middle school)	Astronomical Society of the Pacific (www.astrosociety.org)	$13.95 each or $64.95/10 with plain tubes

Videos: —The Solar System: A FirstLook —Space Science for Children: All About the Moon —Earth Science: Our Home in Space	100% Educational Videos (1-800-483-3383)	$49.95 each (discount if order 5 or more)
e-Reader	Center for Applied Special Technology www.cast.org	$199 each
	AT:LAST 410-290-1327	$165 each (discounts for lab packs available)
Write:Outloud	Don Johnston, Inc. http://www.donjohnston.com	$99 (volume discounts available)
	http://www.inspiration.com	$99 ea ($59 school price and discounts with lab packs)
Inspiration	http://www.inspiration.com	$39.95 each, lab packs available
A Field Trip to the Sky (planetarium program)	http://www.sunburst.com/	$99.95 (provided by school district)

References

Bonnell, J. T., & Nemiroff, R. J. 2000, Astronomy Picture of the Day in the Classroom, *AAS*, 197.5404B. antwrp.gsfc.nasa.gov/apod.

Ginsburg, H. P., & Opper, S. 1988, *Piaget's Theory of Intellectual Development: an Introduction, 3rd edition*, Englewood Cliffs, N.J.: Prentice-Hall, 1.

Henderson, K. 2001, An Overview of ADA, IDEA, and Section 504: Update 2001, *ERIC EC Digest E606*, www.ldonline.org/ld_indepth/legal_legislative/update_504_2001.html.

National Research Council. 1998, *National Science Education Standards, 5th edition*, Washington, D.C.: National Academy Press.

Nemiroff, R. J., Rafert, J. B., Ftaclas, C., Pereira, W. E., & Perez-Ramirez, D. 2000, Educational Aspets of the CONCAM Sky Monitoring Project, *AAS* , 19712004N.

O'Neill, P. T. 2002, Pass the Test or No Diploma: High Stakes Graduation Testing and Children with Learning Disabilities, http://www.ldonline.org/ld_indepth/assessment/oneill.html.

President's Commission on Excellence in Special Education. 2002, A New Era: Revitalizing Special Education for Children and their Families, www.ldonline.org.

Rutherford, F. J., & Project 2061. 1990, *Science for All Americans*, American Association for the Advancement of Science. New York: Oxford University Press, 197.

Warger, C. 1998, Integrating Assistive Technology into the Standard Curriculum, *ERIC/OSEP Digest E568*, www.ldonline.org/ld_indepth/technology/ERIC_E568.html.