K-12 Education Outreach Program Initiated by a University Research Team for the Mars Global Surveyor Thermal Emission Spectrometer Project

Kenneth Scott Edgett and Philip Russel Christensen
Department of Geology
Arizona State University
Box 871404
Tempe, Arizona 85287-1404

ABSTRACT

The Arizona Mars K-12 Education Program provides opportunities for direct interaction between K-12 teachers, students, and the scientists and engineers who are involved with the Mars Global Surveyor and Mars Pathfinder missions. The program was initiated by a graduate student and university professor, and provides a model for other research teams considering K-12 education outreach efforts. The program has evolved with changes in U.S. Mars exploration plans, from Mars Observer's loss through the present effort. The main activities of the program include K-12 student visits to the Mars facility at the university, K-12 teacher workshops, newsletters, classroom visits, resource guides, and Mars education information on the Internet. University research teams should take advantage of existing resources and teacher networks when planning to start a K-12 education outreach program.

Keywords: Astronomy; earth science – teacher education; education – geoscience; education – precollege; extraterrestrial geology.

INTRODUCTION

Learning a foreign language helps one understand the structure and context of one's native language. Likewise, examining another planet provides new perspectives on the nature of one's home world. The exploration of our Solar System has led to a greater understanding of how Earth functions and how it has evolved through time (for example, see Allègre and Schneider, 1994). In addition, events such as the lunar Earthrise first seen by human eyes in December 1968, the landing of robots on Mars in 1976, and the portrait of our Solar System obtained by Voyager 1 in February 1990 have provided us with the chance to consider the broader philosophical context in which humans live (for example, see Sagan, 1994). Looking at another planet, such as Mars, offers an opportunity to not only compare it with Earth but also presents an interesting means to foster scientific literacy and teach global perspectives (Mayer, 1990; Edgett and others, 1994).

The current educational vision of the National Aeronautics and Space Administration (NASA) is "to promote excellence in America's education system through enhancing and expanding scientific and technological competence" (NASA, 1992). To this end, all new NASA planetary spacecraft missions have built-in funding for education enhancement and outreach. These missions include the Discovery-Class Programs: Near Earth Asteroid Rendezvous, Mars Pathfinder, and Lunar Prospector, plus the series of spacecraft planned for the Mars Surveyor Project. The first Mars Surveyor spacecraft will be Mars Global Surveyor (MGS), set for launch in November 1996, with an arrival at the Red Planet in September 1997. Systematic mapping of Mars during the primary mission of MGS will run from January 1998 through January 2000.

We started the Arizona Mars K-12 Education Program in 1992 when author K.S.E. was a graduate student (Edgett, 1993a). The purpose of the program is to bring the real-time experience of Mars exploration to teachers, students, and parents in our community by giving them opportunities for involvement in the Mars Observer and Mars Global Surveyor Thermal Emission Spectrometer (TES) projects. This article describes the education program, how it was established, and how it evolved as NASA's Mars exploration plans changed after Mars Observer was lost in 1993. Our purpose here is to show, by example, a model for university research teams interested in doing K-12 education outreach in their community, state, or region. The article also identifies some of the educational resources and background materials relevant to upcoming U.S. Mars missions.

THE EDUCATION PROGRAM IN BRIEF

Our education outreach effort provides opportunities for K-12 teachers and students to enhance their existing curriculum or educational experience through exposure to a real-life, interdisciplinary science project. Our main focus is on teachers, students, and parents in Arizona, but our program has expanded to include interested K-12 educators outside the state. In general, the Arizona Mars K-12 Education Program seeks to (1) promote science literacy by using the excitement generated by real Mars missions; (2) expose people to all steps of the MGS TES process, including instrument construction, testing, launch, data collection, and analysis; (3) provide opportunities for real-time access to science and scientists. We make extra efforts to connect with urban and rural schools, and pre-service and non-science teachers.

The main activities of the Arizona Mars K-12 Program to date include: (1) K-12 student visits to the MGS TES facility on the Arizona State University

campus, (2) K-12 educator workshops, (3) a newsletter, "TES News," (4) development of annual curriculum guides containing Mars education material, (5) presentation of mini-workshops at state, regional, and national science-teacher meetings, and (6) placement of Mars education resources on the Internet World Wide Web (Edgett and others, 1994, 1995). The focus of these activities is upon the local connection to Mars exploration and the comparison of Arizona's geology and geomorphology with those of Mars (Edgett, 1993b). The curriculum guides, newsletters, and other material can be seen on the Internet at URL **http://esther.la.asu.edu/asu_tes/**.

During each school year, 100 to 800 K-12 students visit our facility each month. A typical visit consists of 30 minutes of discussion, hands-on activity, and instruction about the Mars Global Surveyor and Mars Pathfinder missions with a member of the TES staff. The teacher workshops constitute an on-going series. They meet on a Saturday once every six months. An example workshop, held February 5, 1994, included discussion of the process that unfolded after Mars Observer was lost, an introduction to the Internet and World Wide Web, educational products of the Space Shuttle SIR-C radar mapping mission, teacher demonstrations of classroom activities relating to Mars, and a special address by a Mars geomorphologist who did field work on a joint Russia-United States expedition to Antarctica in 1991/92 (Edgett, 1995; Edgett and others, 1995).

IT STARTED WITH MARS OBSERVER

Running TES from Home

The Mars Observer mission was funded by the U.S. Congress in 1984, and its instrument payload was announced in 1985. The spacecraft was scheduled to launch in September 1992 and systematically map and observe seasonal changes on Mars from its arrival in August 1993 through at least November 1995 (Albee and Palluconi, 1990). One of the seven instruments onboard was the Thermal Emission Spectrometer (TES), an experiment to map surface mineralogy, probe atmospheric-dust composition, and observe surface temperatures and ice-cap evolution, in the spectral range 6 to 50 μm (Christensen and others, 1992).

Owing to new capabilities in communication technology, Mars Observer was the first U.S. planetary project to allow each scientific instrument to be controlled at the home institution of the principal investigator or team leader (in this case, author P.R.C. is the TES principal investigator). TES commands were generated on computer from a facility on the campus of our home institution, Arizona State University (ASU). Likewise, raw TES data could be received at ASU and processed into data products for use by the scientific community. All command uplinks and data downlinks went via the Internet through the NASA/California Institute of Technology Jet Propulsion Laboratory (JPL) in Pasadena, California, and to/from the spacecraft using NASA's Deep Space Network.

Because we were operating TES from the campus of ASU, rather than spending several years living away from family and friends to operate TES from JPL, we realized that the project had great potential for local education and public outreach. The university (ASU) built a special facility in its 1939-vintage Moeur Building. This operation center, dubbed the "Mars Observer (now Mars Global Surveyor) Space Flight Facility," opened in 1991 and was designed with visits from the public in mind. The facility has large, wide windows and glass doors that allow the visitor to look in and see what is happening in real time. The foyer of the facility contains displays that convey the TES project and the geology of Mars, and a television is available to view NASA TV programming and images/data as they arrive from Mars.

The Outreach Begins

The TES facility at ASU is nice for visits by the public, but we mainly wanted to use it to develop a K-12 education program. We received some seed money through NASA's Planetary Geology and Geophysics Program, which provided funds for a graduate student, an undergraduate assistant, and K-12 outreach. We began the K-12 program in July 1992 by forming an advisory group composed of K-12 teachers from the Phoenix, Arizona, metropolitan area. The ten advisors in this group were located mainly with the help of a professor in ASU's College of Education. The group worked on a volunteer basis and met about once a month during the first year. The 1992-1993 advisory board helped us to establish a network of teachers through which to disseminate information about our program. They also helped us by defining the professional language of K-12 teachers (for example, the meaning of "in-service" and "pre-service"). Through our board of educators, we learned that there is a variety of networks already in existence in the state of Arizona through which we could inform teachers about our education workshops and activities. The biggest such network is the Arizona Science Teachers Association, a chapter of the National Science Teachers Association. We also learned the names of the science and environmental-education coordinators in the state capitol, and discovered some of the newsletters that serve teachers in our state.

ACTIVITIES IN 1992-1993

Student Visits, Open Houses, Newsletters

Even before we formed the education advisory group in July 1992, we had been giving tours of the ASU TES facility to groups of K-12 students and their teachers. These continued throughout 1992 and 1993, and included a special open-house event on September 25th when the Titan III rocket carrying Mars Observer was launched from the Kennedy Space Center. Over 100 visitors, including children from nearby schools, came to ASU and watched the lift-off live on NASA television.

As the launch date approached, we realized there weren't very many short publications explaining Mars Observer that were available to hand out to our visitors. Thus, we initiated a newsletter, "TES News." The first three issues came out in August 1992 and

addressed Mars Observer, TES, and characteristics of Mars. These were followed in February 1993 by the fourth newsletter that provided updates on the Mars Observer mission following launch.

The First Workshops

In December 1992, our advisory group suggested that the best way to understand how to do a teacher workshop is to hold one. We chose Saturday, February 20, 1993, for the first workshop. Teachers in Arizona would be invited. There would be no registration fee, and no college or district credit given. We spread the word by (a) making an appearance at an education session held at the American Astronomical Society meeting in Phoenix, January 1993, and (b) mailings sent to teachers and science-education coordinators identified by our advisory board. Our efforts were rewarded when over 115 K-12 teachers showed up for the workshop. The second workshop, on August 21, 1993, had a similar attendance.

At the August 1993 workshop, we distributed the fifth and sixth issues of our newsletter, "TES News," and each participant got a 212-page resource manual entitled, "NASA Mars Observer Thermal Emission Spectrometer 1993-1994 Education Supplement and Guide." This volume, which we compiled, contained: background information and diagrams pertaining to Mars Observer and previous Mars missions; lists of books, maps, and articles about Mars; classroom activities demonstrated by teachers at the August 1993 workshop; and information about obtaining NASA educational material. The highlight of the workshop was a panel discussion, between the ASU TES personnel and K-12 teachers in attendance, covering the topic of career paths and how individuals in the TES group became interested in their work relating to the study of Mars. The panel consisted of scientists, engineers, computer programmers, graduate and undergraduate students, and office support staff. Tragically, about two hours after the August 21, 1993, workshop ended, NASA discovered that Mars Observer had been lost.

IT CONTINUES WITH MARS GLOBAL SURVEYOR AND MARS PATHFINDER

If at First You Don't Succeed ...

What happens to your education program when the focus of your outreach disappears? We decided that there was no question that the education program would continue. We had just completed a very successful second teacher workshop, and tens of teachers and high-school students came to our facility in the subsequent week to share in our loss and to try to understand it. In addition, efforts to explore the planets had by no means ground to a halt, that same week the Galileo spacecraft flew by asteroid Ida, Clementine was set to orbit the Moon in 1994, and Galileo would reach Jupiter in late 1995. The message we shared with K-12 students and teachers for the remainder of 1993 was that the experience of trying to learn something new about Mars did not end with the loss of the spacecraft. Experiment failure is a part of science.

New Mission Profiles

Meanwhile, we kept our fingers crossed that there would be a new mission to Mars to replace Mars Observer. In October 1993, the U.S. Congress approved funding for a new kind of spacecraft, a small lander and micro-rover team called Mars Pathfinder. This spacecraft will test new design concepts for landing on Mars using giant airbags (like those in an automobile, only bigger). The micro-rover, measuring 65 cm long by 45 cm wide and 32 cm high, will drive around the landing site area, providing a third dimension to the photographic coverage, plus chemical analyses of selected rocks and soils. Mars Pathfinder will launch from the Kennedy Space Center in December 1996 and land in Ares Vallis, Mars, on July 4, 1997. Its primary mission lasts 30 days, the rover is expected to operate for at least the first 7 days.

Mars Pathfinder is not a substitute or replacement for Mars Observer. In February 1994, NASA announced plans for a new Mars initiative called the Mars Surveyor Program. A series of orbiters and landers would be sent to Mars at every launch opportunity for the next decade, starting with Mars Global Surveyor in 1996, followed by another orbiter and lander in 1998, and additional spacecraft in 2001, 2003, and 2005. Mars Global Surveyor won Congressional approval in September 1994. Set for launch in November 1996 and arrival in September 1997, MGS carries five of the seven instruments that were aboard Mars Observer. The remaining two Mars Observer instruments will be on orbiters set to launch in 1998 and 2001.

Changes in the Education Program

Both Mars Pathfinder and Mars Global Surveyor have connections in Arizona. Our research team learned in March 1994 that the new TES was slated for the MGS mission. Since MGS was funded in October 1994, construction and testing of the new TES has been underway at the Hughes Santa Barbara Research Center in Goleta, California. TES is scheduled to be delivered in April 1996 for integration with the MGS spacecraft.

Mars Pathfinder has two Arizona connections. The imaging system, IMP ("Imager for Mars Pathfinder") is being built and run by a team under Dr. Peter Smith at the University of Arizona in Tucson (Smith, 1994; Smith and others, 1995). A sub-experiment related to IMP is the Wind Sock, designed to obtain wind velocity profiles at the landing site (Smith and others, 1995). The Wind Sock experiment is being put together by Dr. Robert Sullivan and Dr. Ronald Greeley of Arizona State University.

With the changes in NASA's Mars exploration plans have come exciting changes in the Arizona Mars K-12 Education Program. In 1994 we received funds from the Mars Pathfinder Project to assist in K-12 education outreach for that mission. Our role in Mars Pathfinder education outreach includes bringing information to teachers and students about the IMP and Wind Sock teams. This effort involves cooperation with the IMP team to assist them in educational outreach by incorporating IMP and Mars Pathfinder

into our newsletters, World Wide Web pages, teacher workshops, student visits, and visits to classrooms around the state.

ACTIVITIES IN 1994-1995

Crusin' the 'Net

Our first big change in 1994 was to go "online" by placing our educational materials on the Internet. By the time of the Shoemaker-Levy 9 Impacts on Jupiter in July 1994, almost everyone in the U.S. had probably heard about some of the new tools for browsing the "information superhighway," such as NCSA *Mosaic*. *Mosaic* and similar tools, like the newer *NetScape,* allow the user to very easily peruse materials available in a variety of formats on the Internet. Our education materials, including the 1993-94 and 1994-95 "Education Supplement and Guide," the "TES News" newsletters, and a slide set about the Mars Observer TES, first became public on the Internet in February 1994. Table 1 contains a list of relevant URLs for locating information about Mars and the new Mars missions. Our "Home Page" appeared just in time for our third K-12 educators' workshop, held on February 5, 1994.

Workshops Try New Things

The February 1994 workshop introduced about 100 Arizona and southern California teachers to the Internet and World Wide Web. By giving these educators an opportunity to "play with" NCSA *Mosaic*, we thought they might learn enough to be able to go back and explain to their schools and districts just what the Internet is all about. Of course, we do not know the exact impact of our initial lesson. We repeated the activity at our subsequent workshops in August 1994 and February 1995, and we have noticed qualitatively that there seems to be an increased awareness as to how these tools are used and how soon the schools may have them available. When Mars Global Surveyor and Mars Pathfinder reach the Red Planet in 1997, much of the data will be available to teachers and students via the Internet.

The February 1995 workshop involved our first major experiment since we began holding workshops in 1993. This time, we invited K-12 teachers to bring students. We envisioned teams of one teacher plus one student. However, some teachers brought up to seven students, while others came alone. This was our largest workshop to date, with about 250 participants. The workshop was also different because it was a joint effort involving the Challenger Center for Space Science Education (see Rowley, 1993). The workshop featured Challenger Center's "Touching the Future" activities and a keynote address by astronaut Mike Mullane, who handed out signed copies of his children's book to all attendees (Mullane, 1995). We charged a registration fee for the first time, but we also preserved a no-fee option in which teachers did not have lunch with the keynote speaker. The workshop had special sessions about Mars, model rocketry, and the Internet. Quest Aerospace Education, Inc. of Phoenix, Arizona presented the model rocket lesson, and the East Valley Astronomy Club of Arizona presented a star party in the evening so that participants could view Mars and other objects through telescopes. The workshop was subsidized by funds from NASA, Honeywell, Inc., and the American Institute of Aeronautics and Astronautics. Attendees came from all over the state of Arizona and some from out of state (as far away as North Carolina and Washington).

The February 1995 workshop was a good experience for us, because it combined a whole new set of unknowns – K-12 students, registration fees, and coordination with a number of different organizations. The workshop demonstrated the power of cooperation among universities, industries, nonprofit organizations, small businesses, and government agencies, to enhance science education for teachers and students in our region. While the February 1995 workshop was a big success, we learned one important lesson: it is very difficult to organize an education event that includes students of all age groups from K through 12. Most of our events and activities were aimed at middle- and elementary-school children. It is difficult to engage at one time a group that includes students who are in kindergarten and those that are the top science students in their senior class. This might seem obvious in retrospect, but we mention it here as a guide for others thinking about inviting students to a K-12 workshop. It is better to consider holding separate workshops for different age groups.

Mars Pathfinder Home Page, Jet Propulsion Laboratory, Pasadena, California
http://mpfwww.jpl.nasa.gov/

Mars Global Surveyor Home Page, Jet Propulsion Laboratory, Pasadena, California
http://mgs-www.jpl.nasa.gov/mgs-home.html

Arizona Mars K-12 Education Program, Arizona State University, Tempe, Arizona
http://esther.la.asu.edu/asu_tes/

Imager for Mars Pathfinder Home Page, University of Arizona, Tucson, Arizona
http://www.lpl.arizona.edu/imp/imp.html

Mars Global Surveyor Camera, Malin Space Science Systems, San Diego, California
http://barsoom.msss.com/

Mars Atlas and Viking Orbiter Image Finder, NASA Ames Research Center, California
http://ic-www.arc.nasa.gov/fia/projects/bayes-group/Atlas

NASA Spacelink (Contains current NASA educational information, lesson plans, etc.)
http://spacelink.msfc.nasa.gov

Table 1. Internet URLs for sites relevant to the 1996 U.S. Mars Missions. Some addresses are subject to change over time, these were all good as of January 1996.

Some of the Things on Our Horizon

Mars Pathfinder will land in July 1997, and Mars Global Surveyor is expected to map the Red Planet

into at least January 2000. Russia hopes to launch spacecraft to Mars in 1996 and 2001, Japan has one set for 1998, and the U.S. will launch another orbiter in 1998 and a lander in 1999. Thus there remains at least five more years of potential for educational outreach centered around these Mars missions.

The Arizona Mars K-12 Education Program will continue the type and frequency of activities it has been doing in the past three years, but new events and activities will be added. The program continues to expand and reach educators both in and outside of Arizona. One event that involves the Arizona Mars K-12 Education Program was a field trip to the Channeled Scabland of Washington, which took place in September 1995. The field trip brought together about 60 Mars scientists, Mars Pathfinder engineers, and K-12 teachers to explore the Missoula flood terrains of central and eastern Washington (Edgett and others, 1996). The Scabland region is considered a good analog to the proposed Mars Pathfinder landing site in Ares Vallis (19.5°N, 32.8°W). Another activity we are planning will involve development of classroom exercises that make use of data obtained by the past and future Mars missions. This curriculum-development project was started by the nonprofit organization, The Planetary Society, in late 1992. The Planetary Society (65 N. Catalina Avenue, Pasadena, California, 91106) produced "MarsLink" education kits, one in 1993, one in 1994, and a third is due in 1996. The Arizona Mars K-12 Education Program will assume responsibility for future kits of similar purpose and scope.

SUGGESTIONS FOR STARTING SIMILAR OUTREACH EFFORTS

Who Does All the Work, Anyway?

We often get inquiries from faculty and graduate students at other universities and colleges who are interested in establishing some form of K-12 education outreach program. One of the biggest questions we get is, "how do you find the time?" From 1992-1994, our education program was directed by a graduate student; starting in 1995 that same person (author K.S.E.) began to run the program as a postdoctoral research assistant. Additional paid staff included one to three (at any given time) undergraduate and graduate students from ASU's College of Education. The staff was mainly responsible for giving tours to K-12 visitors, maintaining the mailing list, and advising the director based on their training and experience in education. The staff and director reported to the TES principal investigator, P.R.C., who oversees all activities of the research group.

In addition to the director and staff, the Arizona Mars K-12 Education Program benefits from enthusiastic volunteers from within the MGS TES research group. Not everyone in the research group wants to do K-12 education outreach, but most of our personnel have a strong interest and are willing to help when specific tasks are identified. Such tasks include helping to run teacher workshops and maintaining the Internet World Wide Web pages. Often, members of our research team are asked to give talks in classrooms or to clubs, and they can get advice and materials (slides, hand-outs, props) by asking the education program director and staff.

Use Existing Resources

One of the best ways to minimize the time commitment needed to run the education outreach activity is to take advantage of existing resources. In our case, one aspect of this approach is to make use of programs and projects that are geared toward using the planet Mars to enhance science education. For example, the Challenger Center for Space Science Education (1029 Royal Street, Suite 300, Alexandria, Virginia, 22314) has two programs, "Marsville" and "Mars City Alpha," which we encouraged educators to consider using in their classroom. The "Mars City Alpha" is a kit that can be purchased for use in grades 5-8. In this activity, students design an international Mars colony while enhancing scientific knowledge and developing teamwork, problem-solving, and decision-making skills. Some education resources about Mars and the planets were described by Metzger (1992) and NASA (1993). A recent article by Bullock (1994) includes details about the Mars Pathfinder and Mars Global Surveyor missions. Additional education materials can be found on the Internet by using the URLs listed in Table 1 as a starting point; most NASA education products, for example, are found via NASA's Spacelink.

Another invaluable resource for a university research team doing education outreach is the university itself. Our university has been very supportive of our education efforts by waiving overhead costs on small education grants, providing exposure through the News Bureau and through contacts developed with the College of Education.

Making Contact with Teachers

Teachers have a variety of established networks for spreading the word about a workshop or education program. Once you find these networks, getting the word out is simply a matter of keeping a database and sending out mailings to key educators connected with the various networks. We have found that within the U.S., the best way to make contact with teachers is through the state chapter of the National Science Teachers Association (NSTA). In Arizona, this group is the Arizona Science Teachers Association (ASTA). We advertise workshops in the ASTA newsletter, and we present mini-workshops at ASTA's annual convention. One goal of our outreach program is to reach non-science teachers; this has been encouraged by asking educators on our mailing list to share workshop announcements and newsletters with their non-science colleagues. Other contacts for reaching teachers in the community include the university news bureau, state and school-district science coordinators, and the state geological survey. For example, we ran an article comparing Mars and Arizona in the state geological survey newsletter (Edgett, 1993b), and this newsletter was mailed to every earth science teacher in Arizona.