Colonizing the Red Planet: An Interdisciplinary Activity, by D. Tomblin and M. Bentley. Science Activities, 35(2): 28-34, 1998.

Colonizing the Red Planet:
An Interdisciplinary STS Inquiry Activity

Discovering Mars

The Red Planet has been much in the news lately. The spectacular success of the Mars rover, Pathfinder, in 1997, excited people the world over. On the 4th of July millions of people saw panoramic images of Pathfinder's landing site on TV.[1] After Pathfinder, on Sept. 12, the Global Surveyor arrived at the Red Planet and took up a shallow polar orbit, from which it will make topographic maps of the Martian surface. Planetologists will scrutinize that data for evidence of plate tectonics.

Mars was also a big news item in 1996. One of the year's top science news stories was the discovery of hydrocarbon residues suggestive of fossil cells in a Martian meteorite.[2] Some scientists have since disputed this interpretation of the ancient structures, arguing that the residues could be explained more parsimoniously by abiotic means. Nevertheless, the bottom line is that jury is still out on the question of whether life ever arose on Mars, and its still a fascinating question.

For this and other reasons, Mars is likely to be in the public eye for years to come. Another orbiter-lander pair should be on its way toward the Red Planet in 1999. That orbiter will drop probes shaped like spears which will pierce the planet's surface to search for water. The lander is to descend in the south polar region.

A *manned* mission to Mars seems to be many years away, as it would cost billions of dollars. Whether such a mission should be undertaken as national (or human) priorty, is itself a science-technology-society (STS) issue for a class discussion. Spaceflight engineers have

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[1]Ares Vallis is a large floodplain in Mars' northern tropics.

[2]The meteorite, ALH84001, was recovered from an Antarctic ice field.

worked on alternative, and less costly space craft propulsion designs, which include nuclear-electric and carbon monoxide-oxygen systems. Another way to cut costs would be to send the space craft out with just enough fuel to get there; with current technologies, fuel for the return trip could be manufactured from Martian resources. Because Earth's velocity can be used as a spring board, even using traditional propulsion systems, the Mars-bound craft would travel two or three times faster than the Apollo craft that took astronauts to the Moon. All in all, a one-way trip to Mars would take anywhere from six months to a year.

Though a manned mission to Mars is unlikely before the 21st century, many believe that, ultimately, it will happen. And if astronauts do indeed explore Mars, logical next steps would be an on-going research station (similar to Antarctica's), and, eventually, a colony.

Humans might come to inhabit Mars in a variety of ways, however, and that is the content-rich, interdisciplinary problem which is the context for a project for middle and high school students, one which requires teamwork, investigation, and considerable deliberation. The *Colonizing the Red Planet* project, below, is a simulation activity based upon the hypothesis that a realistic future public policy issue which is a reasonable consequence of our country's current space exploration program. The project simulation has multiple science-technology-society (STS) connections and involves students as participants in cooperative learning teams conducting parallel investigations in different areas that require understanding, then pooling information to negotiate decisions. The culminating event in the project is a debate between proponents of two different colonization policies.

The *Colonizing the Red Planet* project can be incorporated in units of study in courses in life science, earth science, environmental studies, or biology. The content of the lesson can be adjusted for different grade levels. The *Colonizing the Red Planet* project presents an opportunity for science to be integrated across the curriculum, with social studies, language arts, and technology.

Conducting the *Colonizing the Red Planet* Simulation

In this activity, students will develop models of potential new societies on the Red Planet. Two opposing sides will be created: one side will develop a plan for *terraforming* Mars (manipulating Martian materials to create Earth-like conditions), while the other side will plan a colony whose highest priority is *minimal impact* (leaving the planet as close to pre-colonization conditions as possible).

Each side will consist of five or six task groups of students charged with developing different areas of expertise (see Figure 1). The task groups would focus on:

(1) ecosystem design and development (which could be further divided into atmosphere development and genetic engineering of organisms),

(2) government and economics,

(3) environmental issues (resource management and development),

(4) human habitation planning,

(5) geology and weather studies of Mars.

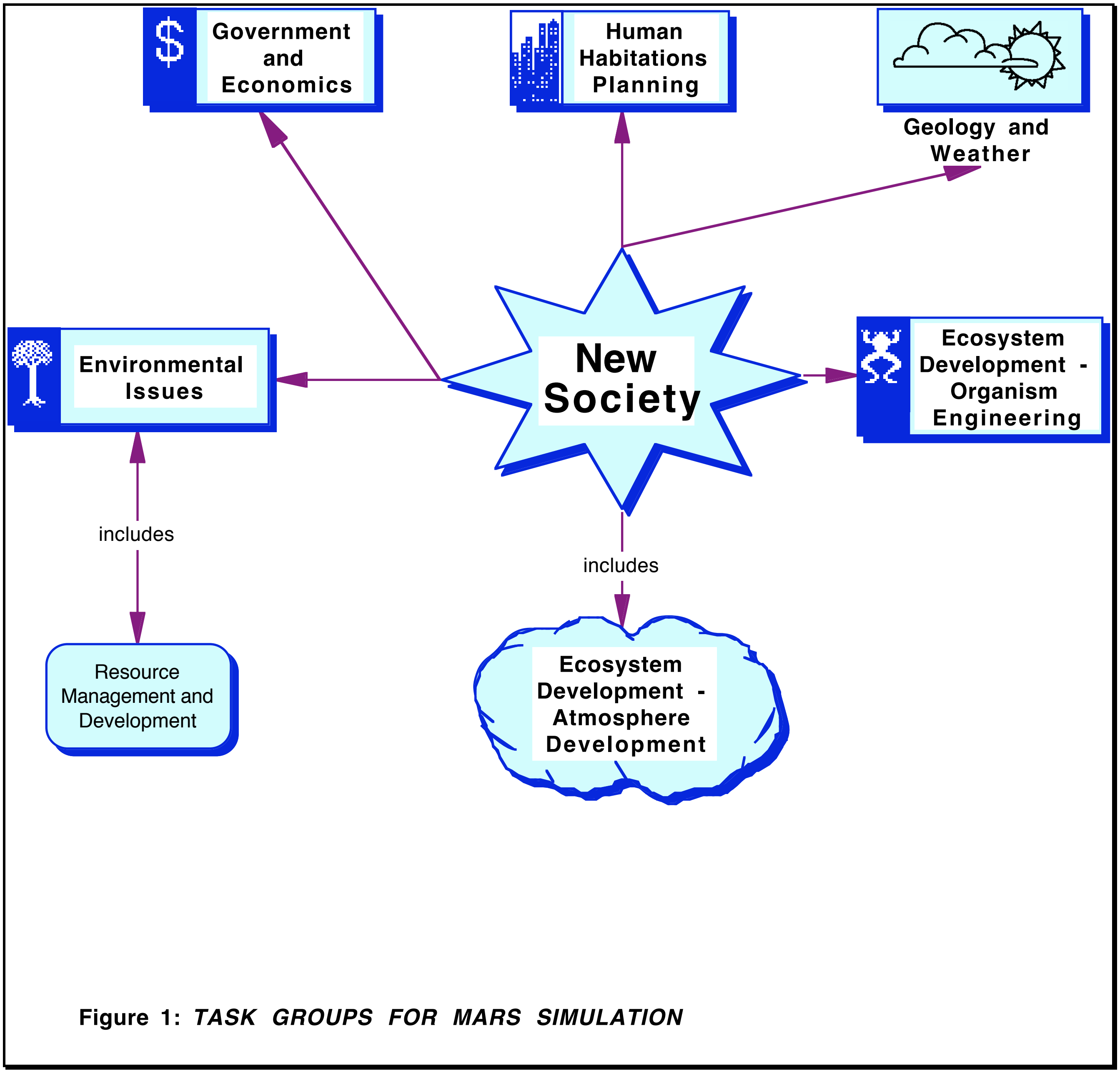

FIGURE 1: *Task Groups for Mars Simulation*

Students in each task force would inquire together into their team's particular topic area and to bring their findings, and expertise, back to their side. Student task groups can research specific topics in both conventional ways and by searching web sites on the Internet (see suggested URLs below, and also in Appendix 3).

Most likely, different colonization strategies and values will emerge from each side, the terraformers will promote manipulating the Red Planets' materials to make it Earth-like, while the minimal-impact advocates will focus on how an "optimum" population of people can live in a sustainable way without significantly upsetting the Martian environment (Figure 2 compares terraformer and minimal-impact positions).

The task forces of each side researches the Martian conditions a colony will face, and through internal deliberation and negotiation, decides what information is relevant to its position. This information becomes synthesized as the opposing sides create a "new society" proposal. Each side's proposal can then be presented before a mock "Congressional (or UN) Panel" (which could be comprised of other students or adults in the school, or invited parents or community members). As the simulation proceeds, students on each side construct models of the colony they envision, using recycled materials, and/or draw maps and structure designs on posters or on classroom computers.

Colonizing the Red Planet:
Building a New Society

Terraformer Colonizers versus	***Minimal-Impact Colonizers***
Use whole planet	Develop only limited space
Make Mars like Earth	Keep Mars as undisturbed as possible
Eventually live anywhere on planet	Live in domed habitats

FIGURE 2: *Comparing Terraformer and Minimal Impact Positions in the Colonizing the Red Planet Simulation*.

Colonizing the Red Planet: **Post-activity Debriefing and Discussion**

In order to construct a plan for a model environment on another planet that is sustainable to humans, students will have to use their knowledge or acquire new knowledge about the Earth's ecological systems. An important feature of the simulation is the students' debate about alternative approaches to the problem of colonization. The ultimate issue is the ethics of colonizing Mars. There should be many accessible analogies to current environmental and bioethical issues on Earth, such as population control, resource management, genetic engineering, and so forth (see Gadgil, Berkes). In working through the issues raised by the simulation, students may come to appreciate the differences and trade-offs between long-term planning versus short-term fixes.

One approach to debriefing the lesson might involve sharing with students humankinds' experience, thus far, in creating habitable, sustainable environments. Scace craft and space stations, for example, are artificial habitations built for a few people to survive in an environment hostile to life. However, no one has yet designed a space craft as a *sustainable* environment. Biosphere 2, however, a $150 million project constructed in the Arizona desert in the early 1990's, was intended as a self-sustaining ecosphere. The huge terrarium contained 3,000 species including a very small band of *Homo sapiens*.

An important goal of Biosphere 2 was to "Maintain resilient, persistent, complex and evolving ecosystems." Perhaps the most important lesson from this project is that creating a self-sustaining ecosphere is a dauntingly complex problem. While Biosphere 2 remains the most sophisticated life support system ever designed by humans, there are no longer any pretenses about the elaborate terrarium being able to *sustain* human life in a synthetic environment.[3] In the two years the experiment ran researchers were unable to achieve an equilibrium in the carbon dioxide (CO_2) level; researchers did not foresee that excess CO_2 would be generated by micro-organisms decomposing organic matter in Biosphere's agricultural soils. In addition to the CO_2 problem, Biosphere's "ocean" became acidic and the freshwater supply salty. The crew worked overtime to 'balance' the system, adding bicarbonate to buffer the water, cutting back plants to encourage more carbon-fixing growth, postponing composting

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[3]Biosphere 2 became a research center of Columbia University in January, 1996.

by storing clippings. They even doubled then tripled rainfall on the “desert” to promote plant growth.

In the relatively short timespan of the Biosphere test, many species died out. Nineteen of 25 vertebrate species became extinct, as did most of the insect species; the katydids, ants, and cockroaches, however, became pests, ravishing much of the crop that was produced for the crew’s food. All species capable of pollinating plants became extinct, so that the crew had to pollinate some crops by hand. Many plants needing pollination were able to survive only one generation. The average Biosphere crewperson lost 25 pounds over the duration of the test. In the end it was necessary for engineers to install CO_2 scrubbers and infuse oxygen into the dome (Baskin).

The results of the Biosphere 2 project illustrate what a real challenge it is to create a fully functional, sustainable ecosystem. Yet that is the aim of the relatively new field of *restoration ecology*. Practitioners in this field seek ways to restore natural landscapes that have been damaged by human activities to full functionality, to a condition that is self-sustaining (see National Research Council, 1992, for examples of restoration ecology techniques). Through participating in the *Colonizing the Red Planet* project, students can learn about techniques of restoration and their checkered record of success in, for example, creating wetlands from scratch, or in restoring human-altered landscapes, such as the lost prairielands in America’s Midwest.

LESSON PROCEDURE:

Colonizing the Red Planet

Objectives:

Students will learn: (1) how government, economics, science, nature, and social behaviors interact to define our society, (2) ethical issues in science, nature, and technology, (3) how to critique plans and ideas and think independently, (4) how to integrate information to make a plan, (5) how to work with others, (6) to inquire into areas where they have little knowledge (do research), and (7) how to make a presentation, formulate a debate position, and write a report. Students will use prior knowledge of life, earth, and physical science.

Content: concepts about the solar system and space travel, plant and animal needs, carbon, water, and nitrogen cycles, photosynthesis (as a foundation of food webs), abiotic and biotic factors of ecosystem, interactions among ecosystems, weather systems, requirements of organisms to adapt (abiotic and biotic factors), human interactions with ecosystems (sustainable agriculture and meat production, water supplies, air quality, etc.), genetic engineering, environmental cost and benefits, constructing maps, management of resources, and current science and technology events. The activity invites many connections to other fields of study (social studies, writing/English, physical science, earth science, biology, history).

Materials and Resources:

1. The video "*Mars Alive*" (1995) by the BBC (a program which documents current schools of thought by premier scientists on the colonization of Mars).

2. Some appropriate internet web-sites include (also see Appendix 3):

- For orbital space settlements: spreading life throughout the solar system. Included in this web-site is information about NASA Ames annual space settlement design contest for 6-12th grade students. Also included is information about artificial ecosystems, solar energy use, the process of colonization, and much more information pertinent to this activity. This web-site is a good link to other space settlement web-sites.

http://www.nas.nasa.gov/NAS/SpaceSettlement/

- For NASA’s Jet Propulsion Laboratory. Contains information on current space news and new technologies being developed by the JPL.

http://www.jpl.nasa.gov

- For Center for Mars Exploration (NASA Ames Space Science Division). Contains current news about Mars, a Mars atlas, images of Mars, and weather information. Also contains additional educational resources.

http://cmex-www.arc.nasa.gov/

- For the Headquarters for the Mars Direct Manned Mars mission. Contains additional information on colonizing Mars. It is authored by Dr. Peter Zurbin the author of *A Case for Mars*.

http://www.magick.net/mars/

3. Library resources, including reference books, trade books, planetary atlases.

4. Expendable materials for students to use in preparing drawings, charts, maps, and modles for their presentations and debate (e.g. colored pens and markers, paper, posterboard).

Suggested procedures and time frame:

This activity sequence occurs over 12 class periods of 50 minutes each, but is adaptable to other schedules.

Class 1: (1) Introduction of material through video - 30 minutes (video is introduced; as video progresses, their are pauses where major points are discussed).

(2) Students consider a hypothetical future scenario- 20 minutes: Assume the time is the year 2020 and the world is over-populated; the public supports the colonization of Mars. However, there are two opposing views to colonizing Mars: (a) terraformers (b) minimal impact colonizers. A decision has to be made by Congress on how to best build a new society on Mars. There are pros and cons for each position. There have been historical cases of colonization from which much has been learned (for examples see Crosby, Merchant, and Bunting). Ask students: How would *you* colonize Mars?

Class 2: (1) Students are organized into two sides: (a) terraformers (b) minimal impact colonizers - 10 minutes.

(2) Within each side, students decide how to deploy themselves into task forces to develop specific areas of expertise: (a) government/economics, (b) habitation planning, (c) atmospheric development (ecosystem design), (d) genetic engineering of organisms (ecosystem design), (e) environmental and resource management and development, (f) geology and weather. At least two students should work as a team to develop each of the six expertise areas (see Figure 1). Each of the six expertise areas and the task force goals should be carefully defined to the class (who is responsible for what) - 30 minutes.

(3) At the beginning of the project, members of each task force/expertise group write a short reflective piece (up to two pages, hand written) on what their particular area of expertise means to them - 10 minutes.

Class 3: Students spend time in the library or on classroom computers to use the internet and books to research each area of expertise - 50 minutes.

Class 4: (1) Task forces report to their groups; information synthesized.

(2) Students on each side begin planning their version of a new society for Mars.

(3) Each student writes an exit paragraph on how his/her area of expertise is contributing to their group's new society - 50 minutes.

Classes 5 and 6: Student work repeats the format of classes 3 and 4 – 50 minutes.

Classes 7 and 8: Students work in the two main groups to formulate their final plans and begin building/designing their presentations (make posterboards, work on final papers, work on outline of presentations) – 50 minutes.

Classes 9 and 10: Groups present and defend their proposals before the Congressional Panel (1 group per day). Allow each group 30 minutes for their presentation, after which the Panel will have 20 minutes to ask questions and discuss the proposals – 50 minutes.

Class 11: In classes 9 and 10 both plans are presented and that sets up the debate. Students prepare for the debate in class 11. Each group composes questions to ask the opposing group and also plan their own defense – 50 minutes.

Class 12: The debate occurs. Allow each group 10 minutes for their presentation, after which each group will have 5 minutes to rebut and sum up. Groups are encouraged to involve as many team members as possible in questioning the opposing group and defending some aspect of their own group's proposal. Following the debate, the Congressional/UN Panel renders its statement of preference and justification for one approach to colonizing Mars – 50 minutes.

Assessment

Student learning as a result of this lesson can be assessed in a variety of ways. We offer the following suggestions:

1. After Classes 2, 4, and 6 each student writes a brief reflection about what they have learned in their task force/area of expertise and how that relates to all the other areas of expertise on their side. The teacher should look for a progression from simple to more complex responses.

2. Student understanding of the scientific concepts can be assessed by the quality of work brought into the overall project by each task force team.

3. Each student is expected to participate and contribute to the overall presentation by his/her side, which can be assessed through classroom observation (i.e., involvement in drawing a poster or map, discussion with other students, participation in the oral presentation and in the debate, number and quality of questions or comments made during the presentations and debates, etc.).

4. Each student completes final essay in which he/she comments on what was learned in his/her area of expertise and how s/he thinks this links to other aspects of the project. This essay includes the student's own personal opinion on the terraform vs minimal impact issue.

5. Each student completes a bibliography, or an annotated bibliography, containing each of the resources accessed and used during the project.

These suggested expectations for students during the project are summarized in a table presented in Figure 3: *Checklist of Expectations for Students*.

Student Name:____ Class:____________
Group:____
Task Force/Area of Expertise:____

	Responsibility	**Date Due**
Paper 1	What does area of expertise mean, and how does it connect to the other areas? (2 page reflection/progress paper)	Class 3
Participation Class 1and 2	Student contribution to class discussion (questions/comments), attention/engagement, cooperation in group formation	Class 1 and 2
Library Class 3	Student use of library resources (what was found?). Was time spent wisely? Teacher observes student research.	Class 3
Synthesis Class 4	Student sharing ideas, expertise. How was expertise communicated? Did student listen to others? Did student give suggestions and comments? How was information integrated withother's ideas?	Class 4
Paper 2	Same as paper 1 but with more details on student's area of expertise. Student ideas should be more complex.	Class 5
Library Class 5	Same expectations as first library day	Class 5
Synthesis Class 6	Same expectations as first synthesis day	Class 6
Paper 3	Same as paper 2 accept student ideas should be more complete and coh	Class 7
Final Plans Class 7	Students build an oral/AV presentation. Different areas of expertise should be integrated into the presentation. Note participation: Did student make comments, suggestions, raise questions? How did student contribute to group effort?	Class 7
Final Plans Class 8	Same as class 7	Class 8
Presentation Class 9	Did student participate in the presentation? Did student ask questions, make comments? Was area of expertise clearly presented? Did student connect his/her topic area to other areas and the whole?	Class 9
Presentation Class 10	Same as Class 9	Class 10

	Responsibility	**Date Due**
Debate Preparation Class 11	Was student attentive (e.g. took notes) during presentations re. arguments? Did student help plan group's defense? What questions were asked of other side?	Class 11
The Debate Class 12	Did student participate in the debate? Did student ask questions, make comments? How well did student argue in support of side? Did student listen to others?	Class 12
Final Paper and Bibliography	Each student expected to prepare a 5-6 page paper on particular area of expertise, specifying how it links to other topic areas. Student expected to clearly state and support a position on an approach to colonization. A bibliography of all information used during the project should be submitted.	After Debate

FIGURE 3: *Checklist of Expectations for Students*.

Extending the lesson

A look at the planet Mars in the night sky would be an appropriate extension activity, and potentially an exciting experience for many students. Of course, since they change position from night to night, planets don't appear on star charts. Many daily newspapers provide information, usually in the weather section, about the position of planets visible from that location. Another readily available source for this information is the *Farmer's Almanac*. Current issues of magazines such as *Astronomy* and *Sky and Telescope* also provide this information.

Another extension might be this simple experiment to demonstrate that Mars' red color is due to iron oxide. Notably, the iron oxide needed *water*, rather than oxygen, to form. For the experiment/demonstration, obtain these materials: steel wool (fine works better than coarse), aluminum pie pan or other shallow dish filled with 2 - 3 centimeters of water, three test tubes or narrow jars, a wooden splint, and matches, tongs or pot holder, corks or stoppers for the tubes (if available). Do this: Push some steel wool, which is iron, down to the bottom of the three tubes. Turn the first tube upside down and set it aside (or cork it). Turn the second tube upside down and set it into the pan of water. Using tongs or a pot holder, hold the third tube upside down and burn the splint or wooden match into the tube until the flame goes out from lack of oxygen. Quickly cork the tube or place it upside down on a surface so that more oxygen doesn't get in. The third tube now should be filled mostly with nitrogen and carbon dioxide. Be sure the tubes are placed where they will not be disturbed. Wait 24 hours and have students examine the tubes. Have them check daily to observe what happens to the steel wool in each tube. Mars, like Earth, has a lot of iron in its rocks.

The language arts connection in the *Colonizing the Red Planet* project can also be extended further. One possibility is to engage students in reading a fiction book whose plot is focused on the colonization of Mars (picking up after the terraformers have prevailed), but which has non-fiction astronomy and planetary science information woven throughout. Such a book is Michael Bentley's *Astronomy Smart, Jr.* (1996, The Princeton Review), available in bookstores in the reference section.

References cited

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Bentley, Michael. L. *Astronomy Smart, Jr.* New York: The Princeton Review, 1996.

Berkes, F., ed. *Common Property Resources: Ecology and Community-based Sustainable Development.* London: Belhaven Press, 1989.

Bunting, R. *The Pacific Raincoast: Environment and Culture in an American Eden, 1778-1900.* Lawarence: University of Kansas Press, 1997.

Crosby, A. W. *Ecological Imperialism: The Biological Expansion of Europe, 900-1900.* Cambridge: Cambridge University Press, 1986.

Gadgil, M. "Diversity: cultural and biological." In *Trends in Ecology and Evolution,* 2 (1987): 369-373.

Merchant, Carolyn. *Ecological Revolutions: Nature, Gender, and Science in New England.* Chapel Hill: The University of North Carolina Press, 1989.

National Research Council. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy.* Washington, DC: National Academy Press, 1992.

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APPENDICES

Appendix 1

Mars compared to other planets -

Planet	*Mass (Earth = 1)*	*Diameter at Equator (km)*	*Surface Gravity (Earth = 1)*	*Rotation Period (the 'day')*	*Orbital Period (the 'year')*
Mercury	0.056	4,878	0.38	58.646 days	87.97 days
Venus	0.815	12,104	0.90	244.3 d	224.68 d
Earth	1.00	12,756	1.00	23 h 56 min 4.1 sec	365.26 d
Mars	**0.107**	**6,796**	**0.38**	**24 h 37 min, 22.6 sec**	**686.95 d**
Jupiter	317.83	143,800	2.54	9 h 50 min 30 sec	4,334.3 d
Saturn	95.15	120,660	1.16	10 h 13 min 59 sec	10,760 d
Uranus	14.54	51,118	0.92	17 h 14 min	30,685 d
Neptune	17.23	49,500	1.19	16 h 3 min	60,189 d
Pluto	0.002	2,302	0.06	6 d 9 h 21 min	90,465 d

Appendix 2

Agencies, organizations, and businesses that provide resources - charts, maps, slides, photographs, books, computer software - for studying Mars and other topics in astronomy -

Adler Planetarium, 1300 South Lake Shore Dr., Chicago, IL 60605

The Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122

The Hansen Planetarium, Dept. F, 1098 South 200 West, Salt Lake City, UT 84101

NASA's Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91103

The Royal Astronomical Society of Canada, 124 Martin St., Toronto, Ontario M4S 222

The McDonald Observatory, RLM 15.308, The University of Texas at Austin, Austin, TX 78712

National Aeronautics and Space Administration - NASA publications should be ordered through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

National Geographic Society, 17th and M Sts., N.W., Washington, D.C. 20036

Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138

Smithsonian National Air and Space Museum, Educational Services Division, Washington, D.C. 20560

Tersch Enterprises, Box 1059 Colorado Springs, CO 80901

Appendix 3

Additional internet resources

For information about Mars and other planets, comets, and asteroids, check out the following URLs (*active at the time of publication*, 1998):

- For the Near Earth Asteroid Reconnaissance mission - This site provides information on comets, asteroids, and meteorites.

http://hurlbut.jhuapl.edu:80/NEAR/Education2/NEARcurrlynx.html

- For NASA's Ames Research Center Comet Research - This site provides information about comets.

http://quest.arc.nasa.gov/comet/

- For the 'Earth Science Emporium' - This site provides a wide range of links related to planetary science.

http://nlu.nl.edu/bthu/nlu/eight/es/Homepage.html

- For the Mars Virtual Space Craft - This site lets you pilot a virtual space craft approaching Mars. By clicking on various buttons, the view changes, moving the space craft down or up or right or left. When certain features on the surface are within the field of view, their names appear in a list which can be clicked on for an instant zoom. If you are using a 28.8 kb modem, the images appeared quickly enough to maintain the illusion of a virtual trip.

http://fi-www.arc.nasa.gov/fia/projects/bayes group/ Atlas/ Mars/ VSC/ views/ entrance/ entrance.html

- For a SKY CHART for the northern hemisphere, from the Bishop Museum Planetarium in Hawaii -

http://www.bishop.hawaii.org/bishop/planet/sky.html

- For *Sky and Telescope Magazine's* weekly news bulletin - This site will keep you abreast of the lasted celestial happenings.

http://www.skypub.com/news/news.html

- For the Hubble Space Telescope Project - This site provides many fantastic images to explore, and has information on HST projects.

http://quest.arc.nasa.gov/livefrom/hst.html

- For NASA's K-12 Internet Initiative - This site offers lots of links to space science stuff, using the Net in school, NASA on-line resources, schools on line, etc.

http://quest.arc.nasa.gov/

- For another NASA site, the 'Observatorium' - This is NASA's public site for space data.

http://www.rspac.ivv.nasa.gov/

Appendix 4

Additional resources for unit:

Night sky observing guide -

Leventer, A., and G. Seltzer. *Earth from space* (National Audubon Society Pocket Guide). New York: Alfred A. Knopf, 1995.

Perspectives on Environmental History –

Bowler, P. J. *The Environmental Sciences*. New York: Norton & Company, 1992.

Merchant, Carolyn. *The Death of Nature: Women, Ecology, and the Scientific Revolution*. San Francisco: Harper and Row, 1980.

Periodicals featuring articles on Mars and other astronomy topics -

Sky and Telescope
49 Bay State Rd., Cambridge, MA 02238

Astronomy
1027 N. Seventh St., Milwaukee, WI 53233

Mercury
Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122

The Griffith Observer
2800 East Observatory Rd., Los Angeles, CA 90027

Periodicals covering Mars and other science topics -

Science News
1719 N St., N.W., Washington, DC 20036

Scientific American
415 Madison Ave., New York, NY 10017

National Geographic
Washington, DC 20036

Natural History
Membership Services, Box 4300, Bergenfield, NJ 07621

Smithsonian
900 Jefferson Dr., Washington, DC 20560

Discover
Time & Life Building, New York, NY 10020