Space Science Literacy

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Abstract

The exploration of space will be a major part of life in the 21st century. A new space race, with the Chinese and Europeans as additional new players, has already begun. This will include moon colonies, manned and unmanned trips to the planets, and more powerful satellite telescopes. Space exploration is well covered in the media, and its technological spin-offs are in thousands of gadgets used daily by millions of people. The public is fascinated with the mystery and promise of space, yet its understanding of the basic science involved in our going to, living, and working in space is very limited and often wrong. It is therefore crucial that 21st century science literacy includes a space component. This paper deals with how space science literacy is achieved through Space Exploration, a specially designed course for non-science majors. The presentation will cover some of the misconceptions people have about space, topics and pedagogy of the course, and valuable educational resources. The course covers laws and concepts of physics that help explain such things as artificial gravity and artificial weightlessness, the hazards of space environment, rockets and satellites, the electromagnetic spectrum, and Newton's Laws of motion. A historical perspective examines the motivating forces and politics behind the space race, and enables students to distinguish the realistic future possibilities from those in science fiction. Students also identify a new space science terminology, such as "gravity assist steering" (slingshot), "space weather," "escape speed," "launch window," and acronyms such as EVA, ESA, SETI, and LOX. The course is enriched with NASA audiovisuals and relevant web sites. One form of evaluation is an art project assignment, requiring students to integrate the science of space with an art form of their choice. Examples of these artistic expressions of space science will be shown.

INNOVATIVE SCIENCE LITERACY

Columbia College is an arts and media college of almost ten thousand students situated in downtown Chicago. All students are required to complete a General Studies curriculum of 48 credit hours in liberal arts, of which six credit hours are in science. Of the 15 General Studies objectives, one deals specifically with science and it reads: *"Students should develop basic scientific literacy, understand the scientific method of inquiry, and appreciate the impact of science on society."* One of the courses designed to fulfill that objective is Space Exploration. Its rationale (reason for existence) as listed on the syllabus reads as follows:

The landing of a man on the moon has been hailed by many as the most spectacular achievement of the human race. It was the highlight of a very competitive race that started with the launching of Sputnik in October of 1957. Yet, this is only the first step in a long journey full of mystery and danger, fascinating discoveries, and amazing new worlds. We live in an age whose technology, science and medicine, and even social habits are being shaped by the byproducts of space exploration. Despite the cost-not only in money but also in human lives-and political and financial criticisms, the exploration of space is here to stay. What is it that pulls us to the stars? Is there an ultimate goal in our exploration? A fundamental knowledge of the history, the science, and the technology of the space program, as well as its impact on our lives, is an important component in the education of every informed citizen.

The objectives of the course as listed on the syllabus are:

1. To understand the scientific concepts, principles, and terminology associated with the exploration of space.
2. To recognize and understand the physics principles of operation of space technology, such as rockets, satellites, and spacesuits.
3. To appreciate the many ways by which space exploration impacts our lives.
4. To understand the scientific method used by scientists to interpret information gathered by astronauts or space probes.
5. To get a sense of the human drama in the excitement, fear, glory, and disaster that were (and are) generated by the various missions to space as seen through the historical, social, and political perspectives.

The textbook for this course is Spaceflight[1], a Smithsonian Guide by Valerie Neal et al. (1995). The class meets once a week for 3 hours during a 15-week semester, serving 25 students who major in the arts or media. The course has no prerequisites, and although some students may have a physics or astronomy background, the course is designed with the assumption that students have very little science background. Each class starts with a brief discussion about the latest about space as reported in the media. Students are asked to bring to class newspaper clippings or share Internet or television news stories that deal with the latest in space. This exercise helps them recognize that space is now a regular part of the news industry and a permanent slice of our daily life. This brief and lively discussion is followed by the lecture on the specific topic. Often audio-visual aids and classroom demonstrations are used to highlight some of the most difficult concepts. Besides reading assignments, students are often asked to visit relevant space-related web sites, such as NASA's homepage and that of the Hubble Telescope (listed later).

The topics in order of presentation are as follows:

Week 1. Historical introduction. The roles of Newton, Jules Verne, Tsiolkosvky, Goddard, Oberth, and von Braun. From gunpowder to WW II V-2 rockets. Sputnik and the beginning of the space age. The space race with the Russians. The Mercury and Gemini missions. The dangers and obstacles of space, the new frontier.

Week 2. The Apollo program, and the significance of landing a man on the moon. The technological challenges and dangers of the Apollo missions. The geological treasures of the moon and prospects of colonies.

Week 3. The physics of space exploration. Gravity and the role of centrifugal force and free fall in situations of artificial gravity and weightlessness. Newton's Laws of motion and types of rocket and spacecraft motion. Atmospheric pressure and the physics related to the spacesuit. Visible and invisible light, and its role in astronomy and space safety. (See Appendix II)

Week 4. The physics, chemistry, and technology of rockets. Reasons behind their design. Propulsion and maneuvering types of rockets. Types of fuel and their advantages. Space club nations and their reasons for going to space. Navigation and telemetry. Planning the future; moon and Mars colonies, starships and space cities.

Week 5. The space shuttle. Anatomy, design and step by step operation from take off to landing. Its advantages over standard spacecraft. Understanding the causes of the Challenger and Columbia disasters. Limitations and criticism of the shuttle.

Week 6. Daily life in space. The impact of microgravity on muscles, bones, and blood. The role of exercise. Redesigned toilets, sleeping quarters, and eating facilities. The history, physics, and anatomy of spacesuits. Space weather potential dangers.

Week 7. Review and mid-term exam.

Week 8. Benefits and spin-offs of the space program. The different types of satellites. Remote sensing from space. The role of the visible and invisible electromagnetic spectrum. Every day items born out of space technology. Space and the military.

Week 9. Space probes and missions to planets. Data gathering "sense organs" of space probes. Exploration of our solar system. Planets, moons and asteroids. The significance of liquid water on Europa. Unusual features of other moons of the solar system.

Week 10. Stellar evolution and the birth and death of stars. Nebulae, white dwarfs, neutron stars, pulsars, and black holes. The role of gravity in the birth, life, and death of a star. Nuclear fusion. The Big Bang model of the universe and supporting evidence.

Week 11. The Milky Way Galaxy. Dimensions, motions and composition. The science behind the SETI program. (Search for Extra Terrestrial Intelligence). The Frank Drake formula for calculating number of intelligent civilizations in a galaxy.

Week 12. Field trip to the Science Museum for a close up study of historic artifacts from the space race era.

Week 13. The viewing of A. C. Clarke's epic film *2010: The Year we made contact.* A scientific/ technical analysis and discussion of the movie.

Week 14. Artistic expressions of space. Student presentations of art projects that integrate space science with an art form of their choice.

Week 15. Final Exam (Comprehensive)

The pedagogy used is shaped by the popularity of the subject of space exploration and the curiosity generated by news coverage of both successful and disastrous missions, like those of Apollo 13, or the destruction of the Challenger and Columbia shuttles. Popularity and curiosity generate discussion sessions with full participation. These regular discussion sessions require students to search the media before the next class, and gather the very latest and interesting stories about the exploration of space. Only a minimum of physics equations are used and no mathematics at all. Although the course includes a series of physics demonstrations, it was never intended to include labs. Despite that, students are drilled in the nature of the scientific method and its strength, as well as its limitations in the type of questions it can tackle. Audiovisual aids include NASA videos and slides as well as selected web sites. Some of the best web sites for space exploration are:

NASA Homepage www.nasa.gov (Special section for educators)

Jet Propulsion Lab. www.jpl.nasa.gov (Missions to and images of the solar system)

Space Telescope Science Institute www.stsci.edu (Images of stars and galaxies)

National Air and Space Museum www.nasm.si.edu (Free publications for teachers)

James Oberg web site www.jamesoberg.com (Latest books and articles. Excellent links)

Images of earth from space http://terra.nasa.gov/

Like the general public at large, students have some "standard" misconceptions about science, including space science. One of the most common is that the reason why astronauts in orbit around earth float inside their spacecraft is because at that height there is no gravity. Yet, another is that for a spacecraft to be travelling its propulsion engines must always be operating. Another is that the reason why the gravity of the moon is less than that on earth is because the moon has no atmosphere. Some other misconceptions are from popular science fiction films. One such misconception is that future spacecraft can travel many times faster than light, and that aliens have built ancient monuments on earth. This is where a clear understanding of the scientific method of inquiry helps students filter fact from fiction by seeking solid evidence and objective verifications. Such understanding then extends to the distinction between UFOlogy (the study of UFOs) and SETI. Both deal with the question of extra terrestrial intelligence, yet SETI (Search for Extra Terrestrial Intelligence) is a legitimate science, whereas UFOlogy is not. People who understand this distinction can afford to deal with both with fascination. However, when people cannot distinguish between them, and have no sense of the standards and requirements of the scientific method, any tabloid story of monsters and alien abductions can be just as realistic and believable as the landing of a man on the moon. Even this was challenged lately by a television show that suggested that the landing of astronauts on the moon was really a big Hollywood hoax, and a conspiracy designed to win the space race with Russia. The course deals with all these issues, and students are encouraged to express their views and beliefs on such matters. Healthy discussions provide a good opportunity to clarify the distinction between science and fiction.

One major work of fiction that is used in this class is the classic movie of *2010: The year we made contact* based on a novel by Arthur C. Clarke. The film, shown at the end of the semester, is based on accurate and realistic concepts of science and technology. Students have to complete a questionnaire on the physics principles and the different types of technology incorporated in the film. Examples of these are rocket propulsion and docking techniques, space radiation, remote sensing, Newton's laws of motion, atmospheric braking, and stellar evolution.

The Museum of Science and Industry in Chicago is famous for its Crown Center, a section devoted to the space program. It houses, amongst other items, the Apollo 8 capsule, the first spacecraft to carry astronauts around the moon; a real size model of the lunar lander; spacesuits; a moon rock; models of the Mercury and Gemini capsules; satellites; and rocket engines. The class field trip to the Museum is designed towards the end of the semester, so that the items that the students examine have more relevance to them. To some extent the experience is as much an exploration of science as it is a trip back through the history of the space race. Students are very excited about the experience of the field trip, so much so that many of them revisit the Crown Center with friends and relatives, proudly acting as guides by speaking with a fair degree of confidence and an air of expertise about the artifacts.

Students are evaluated through the standard means of quizzes, a midterm, and a final exam. One unusual assignment is to develop and present an artistic expression of space exploration, a project in any art form that integrates concepts of the science or technology covered in the course. Students can work on their own, or in pairs, and are guided by examples of exceptional projects done by past students in the course. Such projects can be in the form of paintings, sculptures, poems or songs, films or videos, computer graphics, and even theatrical and dance performances. This assignment makes a tremendous impact on the learning experience of the students, who always demonstrate an amazing level of creativity and originality. Students present their projects to the class during the last weeks of the semester. The best projects are included in "Artistic Expressions of Science and Mathematics," an annual exhibit of art projects by students sponsored by the Science and Mathematics Department. The philosophy behind this type of assignment is described in an article by the same title[2].

Space exploration can be the exciting and friendly new subject matter through which we teach science to our students. Centered on the adventures and mysteries of space, we can teach a whole series of classical science-from Newton's physics to those of Einstein-to science or non-science majors. But more than just a vehicle that can deliver science education, the exploration of space also provides a new, much needed vocabulary of space science literacy. Space exploration will remain, without a doubt, an intricate part of our life. In the words of Arthur C. Clarke[3];

> *"The phenomenal success of recent films (and books) about space and interstellar travel is much more than a passing fad of the entertainment industry. It is a response to one of the deepest and most fundamental of human instincts – the desire to explore, to uncover the wonders of the universe."*

REFERENCES

1. Neal, V., Lewis, C. S. & Winter, F. H. (1995). *Spaceflight.* New York; Macmillan.

2. Papacosta, P., & Hanson, A. (1998). Artistic Expressions of Science and Mathematics, *Journal of College Science Teaching Vol. XXVII* No. 4 (February), pp. 250 - 252.

3. Gatland, K. (1984). *Space Technology.* New York; Crown

Appendix I: Acronyms and special terminology

Acronyms

ICBM	Inter Continental Ballistic Missile
NASA	National Aeronautics & Space Administration
ESA	European Space Agency
EVA	Extra Vehicular Activity (space walk)
STS	Space Transportation System (shuttle)
EMU	Extravehicular Mobility Unit (spacesuit)
LOX	Liquid Oxygen
SETI	Search for Extra Terrestrial Intelligence
TIROS	Television & Infra Red

	Observational Satellite
DSN	Deep Space Network
SRB	Solid Rocket Booster
COBE	Cosmic Background Explorer

Special terminology

Launch window Multistage Thrust Heat-shield Telemetry

Reentry Slingshot Geostationary Heliocentric Geocentric Perigee

Apogee Solar wind Fuel cell Nuclear generator Docking Splashdown

Zero-g Escape speed Descent engine Command module Service module

Black hole Hybrid rocket Polar orbit Light year Microgravity

External tank Oxidizer Space probe Retrorocket Space weather

Appendix II

Physics Laws, terms and concepts used in Space Exploration

Newton's Laws of Motion

Newton's Law of Gravity $F = \mathbf{G\ M\ x\ m / r^2}$

Law of Conservation of Energy

Centripetal and Centrifugal Forces

Conservation of Angular Momentum

The Atmosphere, Pressure and Friction

Electromagnetic Spectrum, Radioactivity and Greenhouse effect.

Nuclear fusion and $E = \mathbf{m\ c^2}$

Photoelectric effect

Thermoelectric effect

Slingshot technique (Gravity assist)

Doppler effect and Spectral Red shift

Fundamental particles.

The Frank Drake formula **N = R* fp ne fL fi fc L**

Classroom Demonstrations

Newton's Laws of Motion (Strings, balloons and magic)

Artificial Gravity (Centrifugal force demo)

Artificial Weightlessness (Free fall demo)

Conservation of Angular Momentum (Spinning on a chair)

The dangers of the vacuum of space (Balloons in a bell jar inflated by vacuum)

Spectroscopy (Spectra of different elements)

Geiger Counter – Radioactivity (Transmission of gamma rays)

Brownian Motion (Using a mechanical model & projector)

Photoelectric Effect (Solar cells)

Thermoelectric Effect (Thermocouple junction)

Doppler Effect (Using sound and a slinky)

Expanding Universe (Balloon analogy)

Dr. Papacosta is Professor of Science and the Physics Coordinator at Columbia College Chicago. His pedagogy emphasizes the integration of science with other disciplines such as history, art and the humanities. He is currently the President of AAUP-Illinois (American Association of University Professors). ***The Splendid Voyage***, his book about science, was translated in numerous languages. In 1994 Dr. Papacosta was named Teacher of the Year at Columbia College.

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