Teaching Astronomy: Why and How?

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Abstract This paper, delivered to an audience of astronomers and schoolteachers, explains why astronomy *should* be part of the school curriculum, but often is not. It suggests some actions which astronomers and teachers can take to improve the situation.

1. Introduction

The audience for this presentation at the 1997 Spring Meeting of the AAVSO—an equal mix of teachers, amateur astronomers, and professional astronomers—was a wonderful symbol of the types of partnerships that can enhance science education. Teachers have an intimate knowledge of the teaching and learning process; astronomers can provide advice on curriculum content and resources, and share their experience and enthusiasm for their science. This meeting focussed on the important contributions which amateur astronomers have made to our understanding of variable stars. Let me remind you that amateur astronomers (and professional astronomers, of course) can also make important contributions to *education* (Percy 1997). For a comprehensive overview of astronomy education, particularly in North America, see Percy (1996). The introductory paper in that book contains a more complete account of international astronomy education issues.

2. Why Teach Astronomy in the Schools?

As Fraknoi (1996) has eloquently pointed out, astronomy education takes place in many settings outside the classroom: books and magazines, radio and TV, astronomy clubs, amateur and youth groups and camps, and on the Internet. These can be powerful influences, but they are voluntary for both students and the public. There is much to be said for including astronomy in the formal school curriculum, as long as the right material is taught, and taught well. Then we can be assured that most or all of the population will eventually be exposed to the core concepts and skills of astronomy. Through a combination of school and public education, astronomy becomes part of the national culture.

For centuries, astronomy was a core subject in a good, classical education. Why is astronomy *still* an important subject for the school curriculum?

- Astronomy has influenced our history and culture through its practical applications and its philosophical and religious implications. Our calendars have an astronomical basis. Many cultures (including ours) have written their mythology in the sky. The dual meaning of the word "heaven" demonstrates

the ancient link between astronomy and religion. (Many people, of course, still believe that the "heavens" influence their daily lives, even though there is no theoretical or empirical evidence to support the pseudo-science of *astrology*.)

• Astronomy still has practical applications to timekeeping; calendars; daily, seasonal, and long-term changes in climate; and navigation. It deals with the external environmental influences on the earth: the radiation and particles from the Sun, the gravitational influences of the Sun and Moon, the impacts of asteroids and comets.

• Astronomy has advanced mathematics, science, and technology, and is a dynamic science in its own right. Many of today's most exciting science news stories concern astronomy; the 1997 exploration of Mars by *Pathfinder* is an obvious example.

• Astronomy deals with our cosmic roots, and our place in time and space. We understand the origin and evolution of our sun and our planet by studying the origin and evolution of stars and planets elsewhere. Most of the elements in our bodies were synthesized in stars. Our star is one of hundreds of billions in our galaxy, which is only one of billions of galaxies in the universe. Is our planet the only one in the universe that sustains life? As Henri Poincaré said, "Astronomy is useful...because it shows how small our bodies, how large our minds."

• Astronomy reveals a universe which is vast, varied, and beautiful. The beauty of the night sky, the spectacle of a comet or eclipse, a color image of a nebula or galaxy—all of these have aesthetic appeal.

• Astronomy harnesses curiosity, imagination, and a sense of shared exploration and discovery. (These affective characteristics of astronomy have both positive and negative consequences: they probably explain the current fascination with alien visits and abductions!)

• In the classroom, astronomy provides a useful alternative to the experimental mode in the scientific method—namely, the observational mode. It also provides many examples of the use of simulation and modeling in science. These processes are increasingly important as part of the "scientific method." Astronomers understand the universe by comparing its observed appearance with the predictions of theories or models; they cannot understand stellar life cycles, for instance, by breeding stars!

• Astronomy can be used to illustrate many concepts of physics: gravitation and relativity, light and spectra, for instance. In a geography course, it provides obvious examples of comparative planetology.

• Astronomy is the ultimate interdisciplinary subject, and "integrative approach" and "cross-curricular connections" are increasingly important concepts in modern curriculum development.

• Astronomy attracts young people to science and technology. Research shows that students learn more effectively if they are interested in the material being taught. It is said that the two most popular topics for children are dinosaurs, and astronomy and space. (It would be interesting to know whether this popularity is age- or gender-dependent.)

• Astronomy can increase public awareness, understanding, and appreciation of science and technology, for all the reasons mentioned above. This is important in all countries—developing and developed.

• Unlike most sciences, astronomy can be enjoyed as a hobby. Amateur astronomers can continue to do science beyond school, and make important contributions to astronomical education and research. They also provide important grass-roots support for astronomy.

3. Teaching astronomy in schools: problems and solutions

Having read the above, one might wonder: why is astronomy *not* taught as a compulsory subject in every country? There are very few countries in which astronomy is taught, as a compulsory course, to every student. In many countries, there is not even a compulsory astronomy "unit" (course section). In some countries, astronomy appears nowhere in the curriculum. The "average" situation is that there is a unit of astronomy at grade level 5–9 (age 10–14), which deals with basic topics such as day and night, seasons, moon phases, planetary orbits, and some descriptive material about the planets and stars. A strong case could be made for including a unit on astronomy at grade level 6, 9, and 12, with different emphases at each level. In my own country (Canada), this is one recommendation of the Pan-Canadian Science Project—a national project to reform the science curriculum in keeping with modern understanding of effective student learning.

In studies of astronomy learning and teaching, several problems and issues have been identified in many countries around the world:

• Teachers, especially at the elementary level, have little or no background in astronomy or astronomy teaching. Astronomers and astronomy educators must therefore arrange for pre-service or in-service workshops for teachers. French astronomers and teachers have been leaders in developing workshops and other resources. They led the International Astronomical Union to develop teachers' workshops at IAU General Assemblies. At this meeting, we are continuing in that tradition.

• Students have misconceptions about astronomical topics, such as the cause of seasons, and moon phases (Nussbaum 1986; Baxter 1996; Sadler 1996). Many

of these misconceptions are based on even more fundamental misconceptions about gravity, and light. These misconceptions must be identified, and overcome, as part of the teaching process.

• Astronomical concepts must be matched to the students' levels of intellectual development (Bishop 1996). For instance, the explanation for three-dimensional concepts such as moon phases can rarely be appreciated by students younger than about 10.

• *Inquiry-based* (or activity-based, or hands-on) teaching and learning is more effective than the classical lecture-textbook approach. This applies to all levels—from elementary school to university! Unfortunately, the classical approach persists at all levels in most parts of the world.

• Practical work is a problem; "the stars come out at night; the students don't." It is possible (though difficult) to arrange for evening star-gazing sessions; local amateur astronomers may be able to help. A planetarium is sometimes available as a simulation of the night sky, but it isn't the real thing. Daytime observing of the sun and moon is possible. Students can construct their own star charts or planispheres from templates (Schatz and Cooper 1994); they can learn how to use these in class, and then put them to use in the evening.

• Teachers believe that telescopes, computers, and the Internet are essential to teach astronomy. They are certainly useful if available, but the unaided eye or binoculars are perfectly acceptable. Simple refracting telescope kits are available, from which students can learn how a telescope works by investigating and assembling one (Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco CA 94112).

• Astronomy is often considered irrelevant by education authorities because it has no apparent economic value. Section 2 lists many reasons why astronomy should still be an essential part of any education.

• In many countries (Switzerland included), there are very few women in astronomy, and probably also in physical science and science teaching. This indicates that there are reasons why women are not attracted to or retained in science in these countries—probably beginning at the school level. This situation is not as serious in all countries: France, Italy, and Spain have a higher proportion of women astronomers.

• In many parts of the world, students' interest in science is less than it was a generation ago. There are many reasons for this. In countries such as China and Russia, business and economics offer much higher salaries. In some countries, science is perceived as being unduly difficult. Perhaps astronomy can rekindle students' interest in science.

4. What astronomers and teachers can do

There is a limit to what can be accomplished in astronomy education through the efforts of outside organizations and individuals. Ultimately, success comes from the efficient and effective actions of local individuals and groups. Here are some of the things which can be done—in any country. Read this list, and consider what *you* might do to enhance astronomy education in your "sphere of influence."

• *Make astronomy education a part of your local and national scientific and educational institutions and organizations.* Appoint an education coordinator, and form an education committee or network; include an education column in your journals, magazines, and other publications; organize education sessions, and include public lectures and teachers' workshops, as part of your professional and amateur scientific meetings; work closely with other relevant organizations in education programs and projects.

• *Be aware of developments in astronomy education and related topics.* Learn about current research on effective science teaching and learning; organize local discussions and conferences on astronomy education, and participate in conferences on science education in general; be aware of curriculum changes in your country, and make sure that there is more and better astronomy every time the curriculum is revised; consider adopting or modifying existing astronomy education materials (such as the excellent material developed by French astronomers and teachers), rather than "re-inventing the wheel."

• *Seek more funds for science education.* Governments respond to the wishes of voters, and foundations and corporations will support projects which have wide support. Proposals from coalitions of organizations, representing a variety of "stakeholders," are more favorably viewed than proposals from individuals. In most parts of the world, there is less government money to support culture and education. We must become more entrepreneurial and politically knowledgeable in seeking alternative sources of funds.

• *Do your personal "bit" for education (and/or support those who do).* If you are a professional or amateur astronomer, pass on your knowledge and enthusiasm; publicize the practical and cultural benefits of astronomy; give or arrange at least one public lecture each year; write at least one popular article (or assist the local media in doing so); meet with teachers, students, and the public; encourage interested students (especially girls and other under-served groups) to consider a career in science or science education; support your local schools and teachers. If you are a teacher, make contact with your local professional or amateur astronomer; establish an effective partnership with them; share your knowledge of astronomy teaching with your colleagues.

• *Help to improve astronomy in the media.* The media have a significant effect on science education. Scientists and teachers often criticize the media, rather

than working constructively with them. Cultivate and work with them, and encourage your colleagues and students to do likewise; speak out against pseudo-science and other irrationality; assist your local school or public library in choosing good astronomy books; consider writing a book, article, or newspaper column yourself.

• *Lobby for, and help develop:* a planetarium, a public observatory, a science center or museum. These facilities can be quite modest in cost, especially if volunteers or students are used as staff. Your chances of success are greatest if the proposal comes from a coalition of organizations including teachers and amateur astronomers—as well as academics.

• *Get more and better astronomy in:* planetariums, museums, and science centers; camps, parks, and conservation areas; day and night schools. Working with these organizations has the useful "side effect" that you will get to know the people there, which helps in forming coalitions.

There are many individuals and organizations around the world which are prepared to advise and assist you. I am certainly one. The International Astronomical Union's Commission on the Teaching of Astronomy has the goal of developing and improving astronomy education at all levels throughout the world. You can visit their WWW site at: http://physics.open.ac.uk/IAU46/ This site links to many other useful sites around the world.

5. Addendum, 2006

Several additional resources have been developed since 1997 to support the teaching and learning of astronomy. Percy and Wilson (2000) is the proceedings of a 1999 AAVSO/ASP/RASC conference on Amateur-Professional Partnerships in Astronomy Research and Education. Pasachoff and Percy (2005) is the proceedings of an international conference on Teaching and Learning Astronomy. Another resource is the on-line journal *Astronomy Education Review* (http://aer.noao.edu), the only journal devoted to astronomy education. Yet another resource is the AAVSO's Education and Outreach Committee. Their webpage is www.aavso.org/education The Astronomical Society of the Pacific (www.aspsky.org) continues to be an excellent source of information and materials for education and outreach. Their *Project ASTRO*, *Family ASTRO,* and other educational programs are exemplary. In Canada, the Canadian Astronomical Society maintains an excellent education website www.cascaeducation.ca.

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