Introduction

The quantity and quality of the astronomy that is taught in our schools has a critical impact on the health of astronomy. It affects the recruitment and training of future astronomers. It affects the awareness, understanding, and appreciation of astronomy by the citizens who, as taxpayers and decision-makers, support our work. They form the society and culture within which we operate. In many countries, astronomy does not appear in the school curriculum at all; in other countries, it has a place in the curriculum, but the curriculum may be flawed, or teachers may have neither the training nor the resources to present it effectively. Much is known about effective teaching and learning of astronomy. Very little of this knowledge is implemented in schools and universities. Rather, teaching may be ineffective; it may sometimes intensify misconceptions, and may create an incorrect or negative impression of our subject.

Yet we live in a golden age of astronomy. In the last half-century, astronomers have explored dozens of planets and moons in our solar system, and astronauts have set foot on one moon – ours. Astronomers have discovered over a hundred planets around other stars. They have learned much about the life cycle of stars, including their bizarre end products – white dwarfs, neutron stars, and black holes. On a wider scale, they have mapped the universe of galaxies and, in the twenty-first century, they have determined the age, shape, and composition of the universe with unprecedented accuracy. We have begun to understand our cosmic roots: the origin of our universe, our galaxy, our star, and our planet, and of the atoms and molecules of life. We can speculate, with increasing confidence, about whether the same processes have given rise to life elsewhere in our universe.

Astronomers are not only obligated to share the nature and excitement of their discoveries with the public, but also most astronomers are keen to do so. Indeed, they are distressed if they find that the public is uninterested, uninformed, or misinformed. Fortunately, public interest tends to be high.

This conference brought together experienced and knowledgeable astronomers, astronomy educators and education researchers from around the world to (i) review what is known about effective teaching and learning of astronomy at the school level, and how it can be implemented; (ii) examine specific examples of successful (or unsuccessful) approaches to teaching; and (iii) provide guidance for improvement in the future. The emphasis was on identifying and implementing practices that are practical and widely applicable, taking account of contemporary education research, and the widespread interest in topics of astronomy, including current developments. The needs of the developing world were explicitly addressed. Large parts of the industrialized world could be considered undeveloped as far as astronomy education is concerned!

This conference focused on formal education in elementary and secondary school, since that is where the overwhelming majority of people may be exposed to astronomy. Pre-service and in-service teacher education were considered, as was introductory astronomy at the university level insofar as it affects general scientific literacy – especially among prospective teachers. The roles of planetariums, science centers, print and electronic media, professional and amateur astronomers in supporting school education were addressed, either explicitly or implicitly, as was the challenge of forming productive partnerships among astronomy educators, education researchers, teacher educators, and all the other individuals and organizations that have a role to play. The many forms of instructional technology (from robotic telescopes to the Internet) were highlighted, especially where they can be shown to promote effective teaching and learning.

One of the goals of this conference was to encourage more and better astronomy in schools around the world. A second goal, which will help to achieve the first goal, was to encourage and facilitate the development of teacher training in astronomy, and of resources and other materials for teachers. A third goal was to identify effective, efficient, culturally appropriate strategies for achieving these goals in each country. These goals are expressed in a Resolution that was presented to the 2003 IAU General Assembly by Commission 46. We are grateful to Magda Stavinschi (Romania) for starting the process which led to this Resolution. The spirit of her proposal is well expressed in the abstract of her conference paper "Why astronomy should be taught in schools – A resolution":

> Perhaps more than other post-Communist countries, Romania underwent a dramatic change after 1983. One of the sharpest problems remains the change of mentality and, implicitly, education of youngsters. Astronomy has a particularly important role in this context, especially now. Unfortunately, it does not belong to curricula anymore. Its reintroduction, as well as a new system of scientific education in agreement with the knowledge and technology of the 21st century, is compulsory in both Romania and other European countries. This international campaign and new ways for implementing astronomy in education can be carried out after the adoption of an IAU resolution (see *Newsletter* 55, October 2001). The same problems, specific not only to Romania but to Europe, too, were tackled in special sessions on "Astronomy education in Europe" at JENAM (Joint European and National Astronomical Meeting) in 2003 and 2004.

See also:
http://www.konkoly.hu/jenam03/ for information on JENAM 2003 and
http://www.iaa.csic.es/jenam2004/ for JENAM 2004.
http://www.astro.ulg.ac.be/RPub/Colloques/JENAM/

The following Resolution was proposed to the 2003 IAU General Assembly by Commission 46, and passed unanimously by the National Representatives to the General Assembly. As mentioned, the Resolution was first suggested by Magda Stavinschi (Romania), and was further developed by the Organizing Committee of Commission 46, with important contributions by Johannes Andersen (Denmark):

Considering

(1) that scientific and mathematical literacy and a workforce trained in science and technology are essential to maintain a healthy population, a sustainable environment, and a prosperous economy in any country,

(2) that astronomy, when properly taught, nurtures rational, quantitative thinking and an understanding of the history and nature of science, as distinct from rote learning and pseudoscience,

(3) that astronomy has a proven record of attracting young people to an education in science and technology and, on that basis, to careers in space-related and other sciences as well as industry,
(4) that the cultural, historical, philosophical and aesthetic values of astronomy help to establish a better understanding between natural science and the arts and humanities,
(5) that, nevertheless, in many countries, astronomy is not present in the school curriculum and astronomy teachers are often not adequately trained or supported, but
(6) that many scientific and educational societies and government agencies have produced a variety of well-tested, freely-available educational resource material in astronomy at all levels of education.

[IAU] Recommends

(1) that national educational systems include astronomy as an integral part of the school curriculum at both the elementary (primary) and secondary level, either on its own or as part of another science course,
(2) that national educational systems and national teachers' unions assist elementary and secondary school teachers to obtain better access to existing and future training resources in astronomy in order to enhance effective teaching and learning in the natural sciences,
(3) that the National Representatives in the IAU and in its Commission 46 call the attention of their national educational systems to the resources provided by and in astronomy, and
(4) that members of the Union and all other astronomers contribute to the training of the new, scientifically literate generation by assisting local educators at all levels in conveying the excitement of astronomy and of science in general.

Implementation of this Resolution will be a major challenge. It will require effective linkages between astronomers and educators; the National Liaisons to Commission 46 can play an important role here. They can work through the "astronomical community" in each country: professional and amateur astronomers, and educators at all levels and in all settings. See www.astronomyeducation.org for a list of National Liaisons.

Successful learning of astronomy will occur if the curriculum is developed and delivered in accordance with the results of educational research, and with an appropriate degree of enthusiasm and excitement. Research is therefore as essential to successful learning of astronomy as it is to astronomers' quest for understanding of the universe.

Part I

Astronomy in the curriculum around the world

Cambridge University Press
978-0-521-84262-4 - Teaching and Learning Astronomy: Effective Strategies for Educators Worldwide
Jay M. Pasachoff and John R. Percy
Excerpt
More information

Introduction

The place and nature of astronomy in the school curriculum vary greatly from one country to another, and even from place to place within a country. There are two main "systems" of education, which are usually called the "European" system and the "North American" system. These, and the place of astronomy in each, were eloquently described by Don Wentzel in his prologue to the proceedings of the 1988 IAU conference on astronomy education, held in Williams College, Williamstown, Massachusetts, USA.[1]

In the European system, there is usually a national curriculum. An often cited example is that in France, at 10 a.m. on the second Thursday in April, every student in a certain grade is learning the same thing from the same page in the textbook. Students are streamed, at an early age, into university, technical school, or the workplace. Astronomy tends to be taught to science students, by teachers who are well trained in science and science teaching.

In the North American system, the curriculum may be determined locally; astronomy is taught in a variety of places in the curriculum; and the teachers may therefore not be well trained in astronomy content or pedagogy. A recent requirement in the US's No Child Left Behind Act (a controversial law that played a role in the presidential campaign), that every teacher be certified in every subject that he or she is teaching, does not meet, for example, the reality of small schools in rural states in which a single teacher may teach some biology, some chemistry, and some physics. This requirement is, therefore, being relaxed. Only 7 per cent of the national total of school spending comes from the US federal government, but that "tail" is enough to "wag the dog."

In the North American system, a wide variety of entities – individual schools, cities, counties, or states or provinces, for example – decide on curriculum. The few states with major statewide adoptions of books or of an approved list of books, such as Texas and California, greatly influence national teaching by their choices through publishers' attempts to please them. No astronomy course is part of a widespread curriculum, though astronomy is taught as part of earth science to students of approximate age 14 on a widespread scale and on a much more minor scale at other periods. On high-school levels, an occasional astronomy course may be found, or some astronomy content may be taught – largely through the initiative of individual teachers – in physics or earth science courses. Though no recent statistics are available, a statistics expert at the American Institute of Physics informs us that, in 1986, only 3 per cent of all physics teachers also taught astronomy. (Their survey would

[1] See Pasachoff and Percy, 1990; the contents are newly available online in the Astrophysical Data System. To see any of the articles, go to: http://adswww.harvard.edu, choose "Search References," and then choose "Astronomy and Astrophysics." You can then ask for a table of contents and search by author name, title, or abstract key words.

not include teachers who taught only astronomy or astronomy plus non-physics subjects, but those numbers should be even lower.) In 1987, 11 per cent of physics teachers had taught a class on astronomy at some time, "one-third only once and more than three-quarters no more than five times during their teaching careers."

Guidelines to astronomy and other topics, such as that of the American Association for the Advancement of Sciences' *Project 2061* were written in the absence of substantial participation by astronomers and tend to shortchange our science (Pasachoff, 1996, 1998). The project has great influence on curriculum. See *Benchmarks for Science Literacy* (1994) and *Designs for Science Literacy* (2001), available from Oxford University Press (www.oup-usa.org). The former "specifies what student progress is reasonable to have been made by the end of Grades 2, 5, 8 and 12," while the latter gives general guidance on making curricula. See also the general Project 2061 website at http://www.project2061.org. Actual curricula, and the textbooks that are used to teach them, depend greatly on a range of conflicting requirements from many of the 50 US states (Pasachoff, 2002; and Pasachoff's "Textbooks for K–12 astronomy," Chapter 8 in this volume).

In practice, there is a great diversity in the place of astronomy in the school curriculum worldwide. One source of information is the Triennial Reports that are submitted by the National Liaisons to IAU Commission 46 on Education and Development. They can be found on the Commission's website: http://www.astronomyeducation.org, which is equivalent to http://physics.open.ac.uk/IAU46. Another source is the proceedings of the previous IAU colloquia on astronomy education, held in 1988 in Williamstown, Massachusetts (Pasachoff and Percy, 1990), and in London, UK, in 1996 (Gouguenheim, McNally, and Percy, 1998), or of the 1994 IAU session on the subject (Percy, 1994). The Astronomical Society of the Pacific (www.astrosociety.org), based in California, often provides curriculum-related content at its annual meetings, though the emphasis is on the North American system. Many ideas appeared in an ASP symposium on *Astronomy Education: Current Developments, Future Coordination*, held in College Park, Maryland, in 1995 (Percy, 1996). An ASP symposium on teaching astronomy, entitled *Cosmos in the Classroom 2004*, took place at Tufts University in Medford, Massachusetts, in July 2004. Though it dealt only with levels from advanced high school upwards, it stressed hands-on involvement, a technique that lends itself to lower grades as well, which are the focus of this book.

In Chapter 1, John Percy lists the many reasons why astronomy is useful and should be included in the school curriculum, somewhere. The place of astronomy in the curriculum may, therefore, depend on why the curriculum developers think that astronomy is important (or not). If they feel that the practical effects of the cosmos on the Earth are most important, then astronomy may appear as part of a geography course. If they feel that its role as a basic science, or a part of physics, is most important, then it may appear as part of a physics course. In Chapter 2, Rosa M. Ros describes the important role that astronomy can play within a mathematics course, as a tool, as an application, and as an inspiration for students.

If astronomy is felt to be an important discipline in its own right, then it may appear as a stand-alone course, or a stand-alone section of a general course such as "science." Astronomy is rich in interdisciplinary and therefore cross-curricular connections, and these are highly valued in modern curriculum design. These connections are much appreciated, especially by elementary-schoolteachers, who tend to be generalists in their background, and teach all subjects in the curriculum. A major question is how to get a wide range of elementary-schoolteachers – or, at least, students at faculties of education – familiar enough with astronomy to feel at ease in teaching it. This issue is addressed later in this volume.

Assuming that astronomy does appear in the curriculum, there is the question of which topics should be included. Again, this will be influenced by the beliefs of the curriculum designers, and the teachers: which of the "uses" of astronomy are most important? If it is the cultural and philosophical connections, then there should be a good dose of history in the course. If it is the physical and mathematical connections, then there should be measurements to make and problems to solve. If it is the aesthetic and environmental connections, then there should be observation of the real sky and/or contemplation of astronomical images. It then becomes easy to argue that all topics should be included. That may be possible for very wise teachers and students, but it usually leads to "curriculum overload."

One approach to curriculum overload is to teach basic astronomical concepts and terminology, so that students can read about and understand the details, including current developments. "Basic" concepts should therefore include concepts such as galaxies and black holes – not just moon phases and seasons. Another approach is to choose, carefully, a small number of topics and activities that touch upon all the expectations of the curriculum – knowledge, skills, applications, and attitudes. These topics would include both "classical" and "modern" ones. The skills would include generic skills, such as understanding the scientific process, that could be applied to other topics and activities. Those topics and activities that were covered would then be taught in sufficient depth so that students learned them successfully. There is no one correct answer for what aspects of astronomy the curriculum should contain. We can only hope that astronomy is there in some form and in some guise.

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1

Why astronomy is useful and should be included in the school curriculum

John R. Percy
University of Toronto, Mississauga, ON, Canada, L5L 1C6

Abstract: Why is astronomy useful? Why should it be part of the school curriculum? This paper lists about 20 reasons: cultural, historical, and philosophical reasons; practical, technological, and scientific reasons; environmental, aesthetic, and emotional reasons; and pedagogical reasons. Astronomy can attract young people to science and technology; it can promote public awareness, understanding, and appreciation of science; it can be done as an accessible, inexpensive hobby: "the stars belong to everyone." This paper then connects the reasons to the expectations of the modern school curriculum, including knowledge, skills, applications, and attitudes.

One of the goals of the conference upon which this book is based is to encourage more and better astronomy in schools around the world. A second goal, which will help to achieve the first goal, is to encourage and facilitate the development of teacher training in astronomy, and of resources and other materials for teachers. A third goal is to identify effective, efficient, culturally appropriate strategies for achieving these goals in each country. These goals are expressed in the Resolution which was presented to the 2003 IAU General Assembly by Commission 46. I am grateful to Magda Stavinschi, of Romania, for starting the process which led to this Resolution (see the Introduction to this volume). Implementation of these goals will require effective linkages between astronomers and educators; the National Liaisons to IAU Commission 46 can play an important role here. They can work through the "astronomical community" in each country, as defined by Percy (1999).

We must first know what the goals of the school curriculum in each country or region are. In my country of Canada, education is a provincial responsibility, though there has been some national co-ordination in the area of science education. The stated goals of the grade 1–8 (age 6–13) school science curriculum in Ontario are:

> to understand the basic concepts of science and technology; to develop the skills, strategies, and habits of mind required for scientific inquiry and technological design; and to relate scientific and technological knowledge to each other, and to the world outside the school.

The purposes of these goals are "to enable the students to be productive members of society . . . and to develop attitudes that will motivate them to use their knowledge and skills in a responsible manner." At the grade 9–10 (age 14–15) level, the goals are similar, except for one addition: "to relate science . . . to the environment." The overall aim is "to ensure scientific literacy for every secondary school graduate" (since some graduates may not study science beyond the grade 10 level). At the grade 11–12 (age 16–17) level, the goals and the overall aim remain the same, but the courses and their content are now tailored to the students' future paths – to university, to colleges of applied arts and technology, or to the workplace.

The science curriculum thus has four elements: science, technology, society, and environment. And it has four sets of expectations: knowledge, skills, applications, and attitudes. The last of these includes ethical issues. I would like to think that it also includes an appreciation of the cultural, aesthetic, and emotional aspects of science – all of which are relevant to astronomy.

I should stress, however, that I have been discussing “the intended curriculum.” This is not the same as “the implemented curriculum.” In the intended curriculum, astronomy is allocated one-quarter of the science curriculum in grades 6 and 9. In practice, teachers may leave astronomy to the last week or two of the year, or not cover it at all. And there is also a difference between what is taught, and what is learned. Education researchers have showed convincingly that despite (or sometimes because of) teaching, students actually hold deeply rooted misconceptions about astronomical topics. They believe, for instance, that the seasonal changes in temperature result from the changing distance of the Earth from the sun.

It would be interesting to start by asking: “why is astronomy *not* included in the curriculum?” Here are some possible reasons; I thank my colleagues in IAU Commission 46 for their comments on these:

- astronomy is perceived to be irrelevant to practical concerns such as health, nutrition, agriculture, environment, engineering, and the economy in general; this is particularly true in developing countries;
- most schoolteachers have little or no knowledge of astronomy, or astronomy teaching; in fact, they may have the same deeply rooted misconceptions as their students;
- astronomy is perceived as requiring night-time activities (“the stars come out at night, the students don’t”), and expensive and complex equipment such as telescopes;
- astronomy is perceived as being solely “Western” by some non-Western cultures;
- there may be conflict – real or perceived – between astronomy and personal beliefs such as religion, culture, and pseudoscience; in fact, astronomy is sometimes viewed as being as speculative as these fields are;
- many of the available resources are designed for affluent schools in affluent countries, or for different latitudes, longitudes, and languages;
- astronomy may be seen as allied with high technology, with all its real and perceived dangers.

Many of these reasons are based on a lack of an astronomical “tradition” in a country or region. This is one more reason for all members of “the astronomical community” to speak and work together in promoting astronomy.

Now we can address the main topic of this presentation: the reasons why astronomy is useful, and should be part of the school curriculum – in science, or some other place. These reasons can be divided, broadly, into several groups:

- Astronomy is deeply rooted in almost every culture, as a result of its practical applications, and its philosophical implications.
- Among the scientific revolutions of history, astronomy stands out. In the recent lists of “the hundred most influential people of the millennium,” a handful of astronomers were always included.
- Astronomy has obvious practical applications to timekeeping; calendars; daily, seasonal, and long-term changes in weather; navigation; the effect of solar radiation, tides, and impacts of asteroids and comets with the Earth.

- Astronomy is a forefront science that has advanced the physical sciences in general by providing the ultimate physical laboratory – the universe – in which scientists encounter environments far more extreme than anything on Earth. It has advanced the geological sciences by providing examples of planets and moons in a variety of environments, with a variety of properties.
- Astronomical calculations have spurred the development of branches of mathematics such as trigonometry, logarithms, and calculus; now they drive the development of computers: astronomers use a large fraction of all the supercomputer time in the world.
- Astronomy has led to other technological advances, such as low-noise radio receivers, detectors ranging from photographic emulsions to electronic cameras, and image-processing techniques now used routinely in medicine, remote sensing, etc. Its knowledge is essential as humankind continues to explore outer space.
- Astronomy, by its nature, requires observations from different latitudes and longitudes, and thus fosters international co-operation. It also requires observations over many years, decades, and centuries, thus linking generations and cultures of different times.
- Astronomy reveals our cosmic roots, and our place in time and space. It deals with the origins of the universe, galaxies, stars, planets, and the atoms and molecules of life – perhaps even life itself. It addresses one of the most fundamental questions of all – are we alone in the universe?
- Astronomy promotes environmental awareness, through images taken of our fragile planet from space, and through the realization that we *may* be alone in the universe.
- Astronomy reveals a universe that is vast, varied, and beautiful – the beauty of the night sky, the spectacle of an eclipse, the excitement of a black hole. Astronomy thus illustrates the fact that science has cultural as well as economic value. It has inspired artists and poets through the ages.
- Astronomy harnesses curiosity, imagination, and a sense of shared exploration and discovery (I think Ontario science teacher Doug Cunningham was the first to put this so eloquently).
- Astronomy provides an example of an alternative approach to "the scientific method" – observation, simulation, and theory, in contrast to the usual experiment and theory approach.
- Astronomy, if properly taught, can promote rational thinking, and an understanding of the nature of science, through examples drawn from the history of science, and from present issues such as pseudoscience;
- Astronomy, in the classroom, can be used to illustrate many concepts of physics, such as gravitation, light, and spectra.
- Astronomy, by introducing students to the size and age of objects in the universe, gives them experience in thinking more abstractly about scales of time, distance, and size.
- Astronomy is the ultimate interdisciplinary subject, and "integrative approach" and "cross-curricular connections" are increasingly important concepts in modern school curriculum development.
- Astronomy attracts young people to science and technology, and hence to careers in these fields.
- Astronomy can promote and increase public awareness, understanding, and appreciation of science and technology, among people of all ages.
- Astronomy is an enjoyable, inexpensive hobby for millions of people.