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Why Astronomy is Useful and Should be Included in the School Curriculum

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One of the goals of this Special Session 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 Stavinchi, of Romania, for starting the process which led to this Resolution. Implementation of these goals will require effective linkages between astronomers and educators; the National Representatives to IAU Commission 46 can play an important role here. They can work through the "astronomical community" in each country, as defined by Percy (2000).

We must first know what are the goals of the school curriculum in each country or region. 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 path — to university, to colleges of applied arts and technology, or to the workplace.

The science curriculum thus has four elements: science, technology, society, and environments. And it has four sets of expectations: knowledge, skills, applications, and attitudes. The latter 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 are due to 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 which 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 enters the era of space exploration.

- 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 which 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 pseudo-science.

- 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.