Astronomers can learn and pursue their profession or hobby in isolation. They can also share it with others through education and outreach. The terms Education and Outreach are sometimes used interchangeably, or are used to refer to formal and informal education, or to school and public education, respectively. The two are related: science education in the schools is strongly affected by the many channels for public education — notably the mass media; public understanding and appreciation of science begins in school. Hereafter, I will use the terms Education and Public Outreach (initialism E/PO), which is widely used in the US where there is lots of money from government and private sources to support it.

E/PO is essential to attract and train the next generation of professional and amateur astronomers. We do not expect every student to become a professional astronomer, but we want to ensure that those who do are well prepared. Amateur astronomy also needs to attract young people, especially women, minorities, and other under-served groups. E/PO is also essential to promote public awareness, understanding, and appreciation of astronomy — most Canadian astronomy is supported by taxpayers. Astronomy is also an excellent vehicle for increasing science literacy in general, and science literacy is increasingly important for the health of our economy, our environment, our bodies and minds, and even our culture. E/PO (if done effectively) can present a positive image of astronomy, astronomers, and their institutions. As the following list shows, astronomy is useful for many reasons, and should be an integral part of our education system, and our culture!

- 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 list of “the hundred most influential people of the millennium”, a handful of astronomers were always included.
- Astronomy has obvious practical applications: 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 has advanced the physical sciences 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, for example, medicine and remote sensing. 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 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 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 students 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.

Finally, you should consider doing education and outreach because it is deeply rewarding and satisfying. You are sharing your passion with people who, by and large, are thirsting for it, and appreciate it.

Because astronomy has so many facets and dimensions, there are many different reasons why students and the public might want to learn about it. There are also many different venues, other than school and university classrooms: planetariums and science centres; astronomy clubs; newspapers, magazines, and books; TV and radio; the Internet; on hikes and at camps (Fraknoi 2001). All of these provide opportunities for astronomers to work with other educators and communicators in an enjoyable and effective way.

**Forms of Education and Outreach**

The many forms of E/PO can be illustrated by the remarkable work done by the RASC, its Centres and members, and by other astronomy clubs; they bring their knowledge, their enthusiasm, and their telescopes to Canadians, young and old, across the country. This work includes the following: hundreds of public lectures each year, with attendances of up to several hundred people; over two hundred "star parties" given by the RASC alone, with attendances up to two thousand people; network and cable TV and radio programs and interviews; newspaper and magazine articles and interviews; open houses at observatories and planetariums; exhibits and displays; Astronomy Day and other special events; school visits and star parties; Web sites; publications such as the Observer's Handbook and The Beginner's Observing Guide. Many RASC E/PO activities are done in partnership with other organizations — astronomical and otherwise. I estimate that the RASC reaches 400,000 Canadians each year.

Professional astronomers, graduate and undergraduate students also engage in E/PO activities of many kinds. Most university astronomy departments have public lectures and open houses (especially on Astronomy Day), and provide advice and assistance to teachers, students, and the public. Some of these activities are done through programs such as the award-winning Let’s Talk Science. It’s especially important to expose undergraduate students to E/PO as an exciting activity and possible career.

**The Canadian Astronomy E/PO Initiative**

In 2001, the Canadian Astronomical Society (CASCA), in partnership with the RASC and other organizations, embarked on a major E/PO initiative. This was motivated by several developments: (1) the report of a Long-Range Planning Panel for astronomy in Canada; (2) the appearance of astronomy in the school science curricula in many provinces; (3) heightened interest in and concern about science literacy and education; (4) two decades of E/PO experience in the US, funded by NASA, the National Science Foundation, and other organizations; (5) the availability of (modest) federal and provincial funding support for science E/PO in Canada.

The initiative is administered by CASCA and its Education Committee, with input from an Advisory Board, including representatives of the RASC and other partners. With limited funding, the initiative must be selective, and designed to provide maximum leverage; it will be targeted through educators (broadly defined) to young people in schools and youth groups, but organized in such a way that anyone interested in astronomy can benefit. The centrepiece will be a Canadian astronomy education Web site, with information and resources that are directly relevant to the needs of the target audiences; some of those needs are described elsewhere in this article. The Web site will support the E/PO activities of professional and amateur astronomers, graduate and undergraduate students, educators.
at all levels, in all settings. Workshops will be organized to help educators — teachers, youth group leaders, and astronomers — make use of the resources, i.e., to implement a "train the trainers" approach. This will be done through a "network and nodes" structure, spanning the country, and by partnering with other like-minded organizations. The emphasis will be on identifying and disseminating exemplary existing material; new material will be developed only if necessary.

Needs Surveys

As part of the Canadian astronomy E/PO initiative, we have carried out small surveys among three participant populations: RASC Centres, Grade Nine teachers, and Science Consultants. RASC Centres interested in starting or expanding their E/PO activities, and presumably other astronomy clubs, requested the following, in descending order of priority: (1) a Canadian astronomy education Web site; (2) curriculum-related materials, activities, and resources; (3) information on effective teaching and learning of astronomy; (4) information on sky events and phenomena; (5) images, slides, posters; (6) workshops on education and outreach; and (7) "templates" for school visits.

Astronomy is now a compulsory part of the grade nine science curriculum in Ontario and many other provinces. Teachers have little or no background in astronomy, and need as much support as they can get. They request, in descending order of priority, the following curriculum-linked items: (1) student activities; (2) audio-visual materials; (3) on-line resources; (4) guides to the implementation of the curriculum; (5) astronomy guest speakers; (6) regional workshops; (7) opportunities for field trips; and (8) software.

Science Consultants for school boards had very similar requests: (1) regional workshops; (2) on-line resources; (3) background information about curriculum topics — videos, for instance; the curriculum now includes several difficult topics such as the origin and evolution of planetary systems, the life cycles of stars, and the origin and evolution of the Universe; (4) astronomy guest speakers; and (5) information about sky events, and school star parties, if possible.

These suggestions will be very helpful to the Canadian astronomy community in developing its national E/PO initiative. A Canadian astronomy education Web site is a high priority. It must be selective, listing and linking to materials that are relevant and exemplary. Teachers especially do not need "yet another Web site"; they need a site that is curriculum-relevant and user-friendly; it must be "steak, not sizzle".

What People Know about Astronomy

Those who embark upon astronomy E/PO are amazed at the apparent breadth of people’s interest, especially among young children. Many people know quite a bit about astronomy, but much of it is deeply incorrect. Indeed, Professor Neil Comins (2001) has written a whole book about astronomy misconceptions, and has a list of over 1700 of them on his Web site. Comins (1998) has also divided these misconceptions into at least 16 classes. Some are truly conceptual in nature (“seasonal changes in temperature are due to the changing distance of the Earth from the Sun”) but others are due to such causes as language (“weightlessness” indicating that there is no gravity in space), incomplete observations (“the Moon is only visible at night”), religious belief (“creationism”) and popular culture (“UFOs are alien spacecraft”). One way to become aware of misconceptions is to read the literature. Another is to talk in depth with students and the public. And, astronomy instructors know that another way is to read the bizarre answers that students often give on exams.

Why Do People Acquire Misconceptions?

Faulty knowledge of astronomy can be ascribed to deficiencies in science education. Those who are knowledgeable about astronomy sometimes find it difficult to understand why others are less knowledgeable. In fact, the learning of science is not a trivial process; it occupies the efforts of hundreds of education researchers worldwide. And remember that teaching and learning are two different things; only a small fraction of teaching actually results in learning.

How People Learn

It is commonly believed that learning can occur through listening to lectures, and reading textbooks. The brain is thus filled, as an empty glass is filled with water. Learning is a much more complex process than that. There are a number of theories of learning, each of which highlights one or more aspect of this complex process.

Bruner’s Constructivist Theory emphasizes that learning is an active process in which learners construct new ideas or concepts, based on their current and past knowledge; this current knowledge may not agree with accepted scientific understanding! Constructivism therefore implies that, for learning to occur, the students’ minds must be engaged; “hands-on” activities are not sufficient. Piaget’s Developmental Theory pointed out, many decades ago, that learners’ ability to construct new knowledge depended on their stage of cognitive development; for instance, students much younger than 12 years old are unlikely to be able to develop an understanding of the cause of Moon phases. Vygotsky’s Social Development Theory emphasizes the role of social interaction in the development of cognition; in fact, group learning is increasingly used in universities — especially in professional faculties. Gardner’s Multiple Intelligences Theory suggests that there are seven different forms of intelligence that each individual possesses in varying degrees: linguistic, musical, logical-mathematical, spatial, body-kinesthetic, intrapersonal (insight), and interpersonal (social); naturistic (an appreciation of nature) has been suggested as an eighth intelligence. All of these can be used, to a greater or lesser extent,
in the teaching of science. For more information about these and other learning theories, see the Web site listed under “Resources” below. Effective teaching and learning should incorporate as many of these theories as are appropriate. And teachers should always be on the lookout for misconceptions, and for incomplete or ineffective learning.

Students learn more effectively when they are interested in the subject matter, and learn less effectively when they are bored. Astronomy can be an intrinsically interesting subject — having a visiting astronomer in the classroom adds interest and variety. It also reminds the students that science is a human endeavour.

In summary: educators know a great deal about effective teaching and learning of astronomy (the problem is in implementing this knowledge):

- Students form new concepts by building on old ones; their minds are not blank slates.
- Students (and many teachers) have deeply-rooted misconceptions about astronomical topics; many of these are based on even deeper misconceptions about topics such as light and gravity.
- Most students have difficulty visualizing three-dimensional concepts, or concepts involving different “frames of references” — Moon phases, for instance.
- Concepts must be introduced in logical order, and at the right stage of cognitive development.
- Teachers at all levels over-estimate what their students learn.
- Inquiry-based teaching, including hands-on activities, discussion of patterns, possible explanations, and predictions, are the most effective way of teaching; lecturing is the least effective way.
- Teaching more astronomy should give way to teaching it better.
- Expertise in astronomy does not guarantee expertise in teaching it; university professors (who normally receive no training in teaching) are the ultimate amateurs.
- All teaching should be subject to research, evaluation, and improvement.

Teachers can also benefit from astronomers in the classroom. Few teachers have any background in astronomy, or astronomy teaching. In fact, they tend to have the same misconceptions as do students and the public. They need and deserve our support. Remember, though, that they are education professionals who understand effective teaching and learning, so we can learn much from them.

**Astronomers in the Classroom**

If you are visiting a classroom or youth group (or even if you are giving a public lecture), there are a few basic issues that you should keep in mind. One is to ask, “why am I visiting this classroom?” or, “why am I giving this public lecture?” Is it to inform, inspire, or entertain? Or all three? Another interesting question is what your audience expects you to be like; what is their stereotypical image of an astronomer? For a classroom visit, you could ask the teacher to ask the students to draw a picture of you the day before your visit. You may be surprised and amused by the result! When you actually appear in the classroom, introduce yourself, and tell the audience a little about your background and your passion for astronomy. In a public lecture, the introducer may give some of this information, but it does not hurt to establish a personal human link with your audience right from the start.

This leads to a second kind of audience involvement: the question period. In a grade 6 class, I can spend an hour, just answering questions. And the questions rarely have anything to do with day and night, seasons, and Moon phases! Often, I ask the teacher to take a few minutes on the day before my visit and get each student to write down one question that they would pose an astronomer. This develops their writing skills and also allows each student to participate in the discussion — not just the most assertive ones. I can quickly sort these questions before the question period. I can also take the questions home with me and put the answers on the FAQ page of my Web site (see Resources). Another good source of answers to FAQs is Dickinson (1993).

Adults also ask questions; in my experience, the older the adult, the more (and the more interesting) their questions (Percy & Krstovic 2001!)

Many class visits are a once-only affair; the astronomer drops in and out, never to be seen again. There are advantages to multiple visits: the class gets to know the astronomer; the astronomer and the teacher have an opportunity to learn from each other. Project ASTRO is a project of the Astronomical Society of the Pacific, funded in part by the US National Science Foundation. It has several functions: supporting ongoing partnerships between teachers and amateur and professional astronomers; emphasizing the sharing of enthusiasm; reaching out to underserved groups; and involving families and community groups through Family ASTRO. Project ASTRO produced a wealth of material for astronomer-teacher partnerships, including several dozen hands-on activities that have been well tested; see the Resource section below. Among the favourites are:

www.astrosoctociety.org/education/astro/act1/astronomer.html (Picture an Astronomer)
www.aspsky.org/education/tnl/01/01.html (Invent an Alien)
The School Curriculum

If you are visiting a classroom in elementary or secondary school, you should be aware that there is a curriculum to cover, and the teacher may want you to help. Canada does not have a national curriculum but, in the area of the sciences, there is the Pan-Canadian Science Project (Percy 1998), and the curriculum in most provinces is aligned with this. Dodd (2002) has published an excellent summary of the place of astronomy in the Canadian curriculum (K-12) in this journal. Generally, grade 1 introduces the daily and seasonal cycles. Grade 6 introduces the physical characteristics of the objects in the Solar System, and the causes of the changes that we see from earth as a result of the movements of these objects; it also introduces space science and technology. Grade 9 introduces a deeper understanding of the Solar System and the Universe, and of space science and technology; investigations into the appearance and motions of visible celestial objects; and an appreciation of Canadians' contributions to space and astronomy. The Ontario grade-9 astronomy/space unit also includes three advanced topics: theories of the origin and evolution of the Solar System; the life cycles of the stars; and theories of the origin and evolution of the Universe. These topics were to be included in a grade 11/12 course, but were "dropped down" when the grade 11/12 course did not materialize in this province. These advanced topics make the unit extra-challenging for both teachers and students. A grade-12 course in Earth and Planetary Science was eventually developed in Ontario (without the more astrophysical topics), but it is not clear how many schools will offer this course.

At the high-school level, courses in Ontario are divided into "academic" and "applied", the former being more theoretical, and the latter more practical. Astronomy, of course, naturally divides into the theoretical and the practical. Many amateur astronomers' interests — telescopes, instruments, computers, the night sky — are ideally suited for the applied courses.

The curriculum specifies more than just content. To quote the Ontario grade-9 and -10 science curriculum (Queen's Printer for Ontario 1999): "The overall aim of the secondary science program is to ensure scientific literacy for every secondary-school graduate" (my italics). The secondary-science program, from grade-9 through grade-12, is designed to achieve this aim by promoting and meeting three overall goals for every student:

- to understand the basic concepts of science;
- to develop the skills, strategies, and habits of mind required for scientific inquiry;
- to relate science to technology, society, and the environment."

While your classroom visit may convey concepts in astronomy, it can also illustrate how astronomers work and think (skills, strategies, and habits of mind), and how astronomy relates to technology (telescopes and computers), society (the many uses of astronomy mentioned above), and the environment (the night sky, and the loss thereof due to light pollution). Your presentation may introduce students to the beauty of the cosmos, and your enthusiasm may leave students with a very positive attitude to our science. This may be more important than any content that you convey.

Youth Groups

Youth groups such as Guides and Scouts have astronomy in almost every level of their programs. The purposes, however, may be different from those of the school curriculum: in Guides, one purpose is to introduce girls to science as an interest and a career; in Scouts, much of the emphasis is on practical outdoor astronomy. Since these youth groups normally meet in the evening, they are an ideal venue for introducing astronomy.

Adult Learners

Not all learning ceases with graduation; there are millions of lifelong learners in Canada. J. Miller (2001) has made some interesting observations about who makes use of "informal" (out-of-school) learning in astronomy: males; people with children; people with education (especially science education); people with an established interest in science, especially astronomy. As I have recently pointed out (Percy & Krstovic 2001), later-life learners are an especially receptive and satisfying audience.

Giving a Good Presentation

Whether you are giving a class or youth group presentation, or a public lecture, there are certain "golden rules" for giving a good presentation:

- Plan ahead: if you are visiting a classroom, talk with the teacher; if you are giving a public lecture, find out about the audience, and check out the lecture room.

- Don't worry if you are nervous: most people are (or should be); but try to be enthusiastic and lively!

- Make sure that all parts of the text and images on your visuals are actually visible (large font, appropriate colour), whether you are using slides, overheads, or PowerPoint; also, make sure that your voice is audible, especially if there are seniors in the audience; use a microphone (or speak loudly) if necessary.
Organize your presentation! Start at a very basic level; divide your presentation into manageable segments (seven minutes is a typical attention span); summarize the segments, and summarize the presentation as a whole.

Be clear and concise: avoid unnecessary jargon; define any new terms, and keep them to a minimum; this is especially important if there are ESL (English as a Second Language) students in the group.

Use analogies and other examples from everyday life; use demonstrations and hands-on activities, especially in the classroom.

Know how much time you have, and keep to it: rehearse, rehearse, rehearse!

Some of these same rules apply if you are participating in a star party and answering questions at your telescope. Remember that most of your viewers will be unfamiliar with astronomical terminology, and with the 3D geometry that produces the effects you see in moon phases, the moons of Jupiter, and the rings of Saturn. There is no better way to learn how to explain things simply and vividly than to read an article or book by Terence Dickinson!

PARTNERSHIPS, NETWORKS, AND NODES

The Canadian astronomy E/PO initiative will succeed if members of the astronomical and educational communities work together, as partners. That means professional and amateur astronomers, and educators of all kinds. Every partner has something to offer. Good partnerships are based on communication and respect.

We envision a structure in which astronomy education resources are identified (and created only if necessary), and disseminated through a national network in many ways. A Web site will be useful, but is not always sufficient. A related need would be for workshops to “train the trainers” in all parts of the country. This can be accomplished through a system of “nodes”.

Nodes may be located in major cities, and/or any centre where there is astronomical activity. The nodes are made up of members of the local astronomical and educational community. In 2002, we re-established the Greater Toronto Area node. It includes representatives of two universities, the RASC, the Ontario Science Centre and Royal Ontario Museum, the Canadian Space Resource Centre, the Toronto District School Board, and a science journalist or two. Two activities were: (1) to organize a one-day workshop for teachers on Astronomy Day 2002, and (2) to organize a series of star parties across the GTA to see the array of five naked-eye planets in April-May 2002. In Montreal, there are plans to organize a node on the Project ASTRO model (see Resources below). Other informal nodes undoubtedly exist. We welcome suggestions about such a partner/network/node structure.

RESOURCES

ACTUA (Hands-On Science and Technology for Youth):
www.planetactua.com

Canadian Careers in Astronomy:
www.hia.nrc.ca/STAFF/jpv/carr/careers.html

Ontario Curriculum:

Frequently Asked Questions:
www.utm.utoronto.ca/~astro/astrofaq.htm

Guide and Scout Astronomy:
www.utm.utoronto.ca/~astro/guidescout.htm

Hands-On Activities - General:
www.astrosociety.org/education/activities/activities.html

Hands-On Activities - Exemplary Pedagogical:
www.leaer.org/teacherslab/pup/

Learning Theories:
www.understanding.com/about_learning.cfm

Let’s Talk Science:
www.letstalkscience.uwo.ca

Long-Range Plan for Astronomy in Canada:
www.casca.ca/lrp/

Misconceptions:
www.umephi.main.edu/ncomin/ and
www.badastronomy.com/bad/misc/

Misconceptions: On-Line Questionnaire:
www.oise.utoronto.ca/~ewoodruff

NASA Picture of the Day:
antwrp.gsfc.nasa.gov/apod/

Project ASTRO, Family ASTRO:
www.astrosociety.org/education/astro/project\_astro.html

Public Speaking Tips:
www.toastmasters.org/tips.asp

Sky Information On-Line:
www.astronomy-watch.com/home.htm

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