Astronomy Education: An International Perspective

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Introduction

Education is important to astronomers because it affects the recruitment and training of future astronomers, and because it affects the awareness, understanding and appreciation of astronomy by taxpayers and politicians. Indeed, astronomers have an obligation to share the excitement and the significance of their work with the general public. Unfortunately, education is often neglected by the scientific and professional community, and by many research universities. The Astronomical Society of the Pacific plays an important role by bridging education and research.

There are other reasons why astronomy should be part of our education system and our culture. Astronomy is deeply rooted in the history of almost every society, as a result of its practical applications and its philosophical implications. It still has everyday applications to timekeeping, seasons, navigation and climate, as well as to longer-term issues such as climate change and biological extinctions. Astronomy not only contributes to the development of physics and the other sciences, but it is an important and exciting science in its own right. It deals with the origin of the stars, planets, and life itself. It shows our place in time and space, and our kinship with other peoples and species on earth. It reveals a universe which is vast, varied and beautiful, and promotes curiosity, imagination, and a sense of shared exploration and discovery. It provides an enjoyable hobby for millions of people, whether they be serious amateur astronomers, armchair astronomers, or casual skygazers. In a school context, it demonstrates an alternative approach to the "scientific method" - the observational/theoretical mode. It can attract young people to study science and engineering, and can increase public interest and understanding of science and technology - both of which are important in all countries, both developed and developing.

Why, then, is astronomy not taught in more schools? Why are there so many misconceptions about astronomical topics? Astronomy educators all over the world have discovered "universal" barriers to the effective teaching and learning of astronomy (and some of them have discovered solutions!):

1. Students have misconceptions about astronomical topics (such as the causes of the seasons), which are not overcome by the teaching methods which are commonly used. [In some countries, of course, seasonal effects are less pronounced than in others!]

2. Teachers have misconceptions about the teaching of astronomy (and perhaps about astronomical content as well) which discourage them from teaching it well, or teaching it at all.

3. Teachers (especially in elementary schools) have very little knowledge about astronomy or astronomy teaching, while astronomy has progressed by leaps and bounds since these teachers were in school themselves.
4. The most effective teaching tools are simple, inexpensive, hands-on activities, and these are not widely used, or not widely available. These must get around the problem that "the stars come out at night, but the students don't".

5. Teachers are not always aware of the materials available. There is not a single national or international journal which deals specifically with astronomy education, or an effective network for informing teachers of materials available. In Europe, astronomy educators have recently formed an association. Although there are language barriers to overcome, ideas and experiences can transcend language.

6. The best or most fortunate students may receive good education, but the others - girls, minorities, the disabled, inner-city or rural students - may be left out.

   We need to take a wider look at astronomy education, and its problems. We cannot afford to re-invent the wheel, ignoring the experiences of others. There are innovative projects and programs in many countries, in many cases well-tested. By taking an international perspective, we achieve a deeper historical and cultural understanding, which is especially important in our multicultural societies. We take some pleasure in knowing that, as astronomy educators, we have "kindred spirits" around the world and, in the case of the developing countries, we take some satisfaction in knowing that we can help scientists and educators less fortunate than ourselves.

**Systems of Education**

There are two basic systems of education - the traditional or European system, and the US system. In the traditional system, there is usually a national curriculum, and standardized examinations which select the best students for high schools and universities. In this system, astronomy tends to be taught in high school and university as a rigorous science. Teachers, on the average, are well-trained. In this system, astronomy is rarely taught to non-science students.

In the US system, there is no national curriculum (though there are several projects to develop national standards for the mathematics and science curricula). There are no standardized content examinations. About half of all high school graduates go on to some form of post-secondary education. Astronomy is most often taught as a unit in an earth science course in junior high school. Some schools offer an astronomy course, often taught by a teacher who is an amateur astronomer. In university, astronomy is most often taken by non-science students who are required to take a "science option" as part of their graduation requirements; about 250,000 students a year take such courses. Good textbooks and teaching material are readily available. Some science students take astronomy courses, and some, of course, major in astronomy.

One of the advantages of this system is that politicians and business leaders, who tend to be non-scientists, may well have taken an astronomy course as a "science option". If they were well taught, they may be interested in, and sympathetic to astronomy.

There are also two (or more) methods of education. At one end of the spectrum is the method based on memorization and regurgitation of the material presented in the lectures and textbooks. This method can be reasonably successful if the students are highly motivated and disciplined, and if the material is well presented but, in most contexts, it does not result in effective learning. At the other
end of the spectrum are the inquiry-based methods involving hands-on activities and problem-solving. This method appears to be much more effective in the long-term, according to research studies from many parts of the world.

The Needs of the Developing Countries

Whichever of these systems and methods are used, the developing countries face problems not encountered by astronomy educators elsewhere. Their special needs include: an understanding and interest on the part of astronomy educators elsewhere; opportunities to gain experience in more developed countries, and be visited by astronomers and educators from abroad; access to appropriate books, journals, and data; access to equipment. Many of the programs and projects of the International Astronomical Union (described elsewhere in this book) are intended to satisfy these needs.

In many developing countries, there is only one "lone astronomer" (or at most a small group) to do all the educational, research and administrative work which is shared among many in the more developed countries. The accomplishments of these individuals are remarkable.

Elementary School

The astronomical topics most often taught around the world are: geometry and motions of Earth, moon and sun (day and night, seasons, eclipses, moon phases, and maybe – even in landlocked countries – tides); general information about the planets, and constellation identification are also often taught. There are occasional exceptions: in the state of Parana, in Brazil, astronomy makes up a third of the school science curriculum at all levels! Unfortunately, in almost every country, elementary school teachers are poorly trained and poorly equipped for the teaching of astronomy. Teachers need to be aware of students’ misconceptions, to develop appropriate curriculum, appropriate means of feedback and evaluation, and simple, inexpensive, hands-on demonstrations and activities.

"Inexpensive", of course, is relative. In South Africa, for instance, science education must be developed in the black regions, but the cost of even the simplest imported material is prohibitive. So local solutions must be found. In China, simple equipment can be cut-out from mass-produced templates, assembled by the students, and taken home to keep.

Secondary School

There are several contexts in which astronomy is taught - if at all - in secondary school. In several countries, there are optional courses in general astronomy which can be taken. Uruguay and Greece are the only countries which I know of which have a compulsory astronomy course in high school. Teachers in Uruguay have developed simple hands-on equipment and activities to accompany this course. Elsewhere, astronomy can be introduced to illustrate concepts in gravitational physics, or spectroscopy. Often, the only astronomy in secondary school is a review of Earth motions, at a higher level, as part of a physical geography course. There are other possibilities: in one state of Australia, cosmology is available as a "distinction course" which senior students can take. There are science or space magnet schools in many countries including the US and Canada, and even an "astronomy high school" in Sweden. In China, high school students can take part in evening and weekend astronomy activities at "children's palaces" of
culture - many of which have observatories and planetariums.

In the US, generous funding from the National Science Foundation supports curriculum renewal, and the development of activities and research projects based on real astronomical data, such as variable star measurements, and digital images.

Two related problems which become apparent at the secondary school level are: (i) attracting and retaining women in physical science courses, and (ii) attracting and retaining any students in any science courses. The latter problem is particularly apparent in countries such as China and Russia, in which business and economics are providing lucrative careers. There is also the perception that physical sciences are more difficult than other fields. The women-in-science problem has some interesting geographical variations: while the proportion of women astronomers is high in France, Italy, Spain and Latin America, it dwindles to zero in some countries in northern Europe, UK, Australia, New Zealand and South Africa.

College and University

The situation in the US is outlined in detail in the other papers in this volume. At some large universities such as Maryland and Texas, the number of students enrolled in astronomy courses (mostly for non-science students) is so large that there can be a diversity of courses, with ample resources (instructors, teaching assistants, equipment ...). At the other end of the scale are the two-year colleges which typically offer one or two courses, often staffed by overworked instructors with little background in astronomy. Fortunately, the US National Science Foundation, NASA, and professional and educational societies such as AAPT, AAS, and ASP provide strong support for undergraduate astronomy education. This includes the development of curriculum and lab activities, provision of real data such as images for lab experiments or research, funding of telescopes and instruments for undergraduate research, and enhancement of instructor skills through workshops and education sessions at society meetings.

In Sweden, where the weather is often cloudy, several universities have co-operated in developing a "standard" radio telescope and receiver for use in undergraduate teaching.

There may also be astronomy courses for science students not majoring in astronomy. In some countries, academic programs are so rigid that is is almost impossible for students to schedule these courses, except as "extras". This problem could possibly be solved by "marketing": informing both students and departmental administrators of the benefits of having students take these courses - the additional perspective, knowledge and skills provided.

Distance Education

In some countries, distance education is much better developed than in North America. The Open University, in the UK, is probably the best example. Its one astronomy course has a larger enrolment than all other astronomy courses in the UK put together! The University of South Africa (UNISA) has 150,000 students across Africa and beyond. These universities can often put a lot more thought and effort into their courses than most of us can - simply because of the economy of scale. They must also use a form of self-paced learning - which is probably more effective than the lock-step approach which is usually used in the traditional lecture mode.
The Training of Astronomers

Undergraduate astronomy major programs, and MSc and PhD programs, are quite similar from one country to another, though there are some differences which reflect political and economic realities. Astronomers may be trained in astronomy departments or in physics departments; in either case, they receive strong training in physics and mathematics as well as astronomy. The fact that some physics graduates have done their research work on astronomical topics raises the interesting question "how does one define 'an astronomer'?" The training in physics and mathematics, along with laboratory and computing skills, obviously qualifies the graduate for a wider range of jobs. And "jobs" is a major concern for astronomy graduates in almost every country. Even in the most industrialized countries, government budgets are shrinking, and many academic positions are filled by tenured faculty hired in the "boom years" of the 1960's and 1970's. In some countries, there is a feeling that astronomy (and other science) training should be broadened even more - to include teaching and communications skills, computing, and business. On the other hand, in other countries, employers outside astronomy are reluctant to hire graduates without specialized training in their field.

Another issue is research training. In some countries, students receive little or no experience in research until they enter a PhD program. Even then, they may take on a research problem suggested by their supervisor, rather than being forced to develop their own. In the US, there is extensive government support for undergraduate research, in the form of grants for telescopes and instruments, and for summer salaries for students and their supervisors. At my own university (Toronto), there are new first-year seminar courses, and second-year "research opportunity" courses, as well as the traditional "senior thesis" courses.

In many countries, the barriers to undergraduate research are (i) shortage of books and journals; (ii) shortage of research data, and (iii) shortage of faculty willing and able to supervise undergraduates. Problems (i) and (ii) can be partly alleviated by electronic access to publications and data. Problem (iii) is an attitude problem which needs to be changed.

For students from the developing countries, there is a special need to broaden the perspective, since most of the students' experience will come from one or two astronomers. The IAU's International Schools for Young Astronomers, and the Vatican Observatory Summer Schools, play an important role in this regard.

Training Teachers

Pre-service training of teachers usually takes place in a university setting. Lack of teacher training in astronomy is a universal problem. There is now adequate research on student learning processes, and ample material on activities and resources. The problem is in exposing pre-service and in-service teachers to this material. In many countries, there is a structural problem in the universities, namely that astronomy and education departments do not interact. In-service teacher workshops must then provided by educational and scientific societies (like the ASP), outside the educational system. The French Comite de Liaison Enseignants et Astronomes has played a leading role in teacher training for almost two decades, by organizing summer workshops, developing and testing activities and equipment, and providing a follow-up magazine "Les Cahiers Clairaut" for over 1000 teachers. Astronomers and teachers have also been very active in Spain, where there have been a series of five international conferences on the teaching of astronomy.
Informal Education

Informal education (sometimes called popularization, or public education) has a major impact on both the public and on students. Any astronomy instructor knows that their students are interested in the latest news reports on astronomical topics. Popularization is one way of reaching politicians and other decision-makers. Surveys in many countries (such as Canada, UK, US) show that, despite (or because of) the impact of the news media, the level of public scientific literacy is rather low. Some scientists disapprove of those colleagues who work to popularize science. We must change this attitude by explaining to our students that popularization is not only important, but it is also fun. We must give them training and experience in working with schoolchildren, teachers and the public, and assure them that education is an honourable profession. Popularization requires some ability, and lots of enthusiasm, initiative and patience. It demonstrates clearly that science is a human endeavour. There are always opportunities for popularization, especially in smaller centers, and in less developed settings. Amateurs frequently play an important role.

Mass Media

The highest-impact forms of popularization are TV, films, newspapers, newsmagazines and (in some countries) radio. Patrick Moore, a self-proclaimed amateur astronomer from the UK, has hosted a monthly TV program for almost 40 years; the average viewing audience is 4,000,000! Terence Dickinson, another amateur astronomer, from Canada, writes a weekly astronomy column in a newspaper with a readership of over a million. Yet these media are largely ignored by the astronomy education community. They were not present at this symposium, and I, as the chair of the Organizing Committee, am directly to blame. We must find out how to make contacts with these media, what they want from us, and how we can provide it. We can issue short and simple press releases, provide the media with names of willing contacts from the astronomical community, and make use of the media to capitalize on events such as eclipses and comets, and on major astronomical discoveries.

Specialized Media

Specialized magazines such as Astronomy, Mercury, and Sky and Telescope are always looking for photos, short articles, and news notes. Local club newsletters are another vehicle for getting started in popularization. In the developing countries, there are often simple science magazines, and astronomy is a "must-have" in these - sky charts, upcoming astronomical events, and recent discoveries. You are guaranteed a readership which is interested and reasonably knowledgeable.

Planetariums, public observatories, and science centers and museums, play a special role in popularizing astronomy. They may be the major astronomy facility in their region or country. They often come about as a result of a sustained campaign by local professional and amateur astronomers and teachers. Their visibility provides an excellent naming opportunity for a government, corporate or private donation. Occasionally these facilities are installed in a shiny new building but, as often as not, they are installed in a converted building, in a school or university, or in a simple, inexpensive building. Imaginative sources of funding must often be found.

Planetariums come in all sizes. Their purposes are to educate, enlighten and entertain. They present public and school shows, lectures and courses, publications
and other information. They may train teachers, and planetarium staff. They may provide a home for the local astronomy club. They may have exhibits, or a small observatory. Planetariums may reflect their local geography or culture. There is a planetarium in Norway which specializes in programs about the northern lights. In India, where astronomy is deeply rooted in culture, planetariums make use of the cultural connections in developing their shows. Despite their key role in astronomy education, planetariums do not always enjoy close links with the rest of the astronomy community. That deficiency must be overcome at every level.

Public observatories are dedicated facilities for research by staff, students and amateurs, for skygazing by amateurs and the public, and for education of people of all ages. They serve as a focus for astronomical activity, as do planetariums. They are a cultural facility which is common in countries where science is a part of culture - Europe, and increasingly in Japan - but not so much in North America. Public observatories can come about as a result of strong marketing. In Brazil, a group of amateur and professional astronomers mounted a successful campaign to convince several municipal governments to build public observatories in their cities.

Science centers also come in many sizes and forms. There are major facilities such as the Exploratorium in San Francisco, the Ontario Science Centre in Toronto, and the Deutschesmuseum in Munich. There are also small science centers, such as one which I visited in the Department of Physics, at the University of Pretoria. It featured simple hands-on exhibits, with a staff of one enthusiastic teacher who presented programs to thousands of schoolchildren each year. There are science centers in old observatories (as in Sydney, Australia) and railway stations (as in Christchurch, New Zealand). There are even travelling science centres (as there are travelling planetariums). In Mexico, the science centre has taken some of its exhibits into the subway stations, where they are experienced by millions of travellers. Interactive exhibits are now the norm (though the old-fashioned static exhibits should not be overlooked), and leading science centers now work in partnership with their communities to reach a wider audience, including minorities, the disabled, and other under-served groups.

Books are a traditional means of reaching the public. In North America, Carl Sagan’s *Cosmos*, and Stephen Hawking’s *A Brief History of Time* immediately come to mind. In the UK, Patrick Moore has published over a hundred books. In virtually every other country I have visited (even the developing ones), someone has taken it upon themselves to write astronomy books - often with a special local flavor.

Public lectures are often thought of as a rather low-impact form of popularization, but they have the advantage of showing that science is done by real people, who can communicate their enthusiasm to the public. The great Indian cosmologist and educator Jayant Narlikar once gave a series of public lectures (in the local language, not in English); the last lecture attracted over 10,000 people! Public lectures can be organized at schools or universities, astronomy clubs, planetariums or science centres. Service clubs and seniors' clubs are especially receptive and satisfying. It is easy to give a public lecture if you follow a few simple rules: start from basics; keep it clear and simple (no jargon and equations); use models, analogies, pretty pictures and legible slides or viewgraphs; be enthusiastic; keep the discussion under control.

Non-credit courses can also be influential (because the "students" are often professionals from other fields) and satisfying (because the students are interested, receptive, interactive and appreciative). Courses for retired people, like the North
American ElderHostel program, will be increasingly in demand.

The Role of Amateurs

Amateur astronomers are those who do astronomy as a hobby. They range from armchair astronomers, through recreational skygazers, to those who make "serious" contributions to astronomy. Many are professionals in other fields. Their talents and accomplishments are significant. They also have a desire to learn. Amateur astronomers in Hong Kong, for instance, have a training program for their club leaders and, at one time, the leading university in Hungary had a special program of courses for leaders of amateur groups.

In almost every aspect of education, amateur astronomers are enthusiastic and effective partners. Professionals should cultivate them and work with them, rather than - as is sometimes the case - look down upon them. Amateurs form groups which interested people can join; hold public lectures; visit schools to help teachers, talk with students, and demonstrate telescopes; hold "star parties" in the parks; organize International Astronomy Day programs; mount travelling displays and programs in libraries and shopping malls; participate in teacher training workshops; lobby for planetariums, science centers and observatories; provide information to the media; write books and articles, and produce TV shows. These are things which my local amateur group (Toronto Centre of the Royal Astronomical Society of Canada) does. Perhaps other groups do even more. We should remember that an amateur astronomer - Frank Bateson - was the "father" of all astronomy, both amateur and professional, in New Zealand. Amateur astronomers also discover comets which excite public interest in astronomy and (in the case of the AAVSO's "Hands-On Astrophysics" project described elsewhere in this volume) generate data which teachers can use for educational purposes. The direct contributions of amateurs to research are well known, of course, but the educational contributions are often overlooked.

It is difficult to do justice to the whole range of international astronomy education in one short article. I refer you to "The Teaching of Astronomy", edited by J.M. Pasachoff and J.R. Percy (Cambridge University Press, 1990), the proceedings of an International Astronomical Union colloquium held at Williams College, Williamstown MA in 1988. This is still the best overview of the topic.

Discussion

Bisard.

I feel the title "Teaching Astronomy" for ASP or IAU future conferences should be altered to "Learning Astronomy." This would be more appropriate to student-centered learning research and best practice strategies coupled with cognitive structure research results.

Crawford.

One useful response is a list of addresses, such as for developing country organizations needing journals.