Teaching and Learning Astronomy

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Outline

• Introduction
• Astronomy education research
• Astronomy education in schools: elementary; secondary
• Astronomy education in colleges and universities: science students; non-science students
• Graduate astronomy education
• Astronomy communication and outreach to the public
• International Year of Astronomy 2009
Useful References

- ..... and proceedings of earlier conferences in this series
- *Astronomy Education Review*, [http://aer.aip.org](http://aer.aip.org)
Astronomy Education: Why It Matters to Astronomers

- Attracts students to science and technology, and to astronomy; there is declining interest in Physical Sciences
- Directly impacts the school and university training of these students
- Affects public awareness, understanding, appreciation, and support of astronomy (and science in general); we are accountable to the taxpayers who support us
- Astronomy should have a strong role in our educational system and in our culture, based on its scientific, technological, and cultural dimensions
- Astronomy teaching and outreach are exciting and inspiring!
Astronomy Education: Why It Matters to Society
Longer List: Percy, J.R. 2005, in Teaching and Learning Astronomy, CUP, 10

- It permeates the history, philosophy, culture, and religion of almost every society
- It has obvious (and non-obvious) practical applications
- It has advanced mathematics, computation, and technology, and is a forefront science in its own right
- It reveals our cosmic roots, and our place in space and time
- It reveals a universe that is vast, varied, beautiful, and inspiring; it harnesses curiosity and imagination
- It has many applications to education, especially with its multidisciplinary connections
- It provides an enjoyable hobby for millions of people
Astronomy Education Research
Astronomy education should be based on ...

- Formal education research
- Informal action research
- Published best practices
- Reflection
- Constant assessment and improvement
- Ref: http://aer.aip.org
A General Model for Education
Hodson, D. 2001, OISE Papers in STSE Education, 2, 7

- Set objectives and goals.
- Choose appropriate curriculum, including knowledge, skills, applications, and attitudes.
- Choose effective and appropriate methods of teaching all of these.
- Assess all of the above, throughout the teaching (formative assessment), not just at the end (summative assessment).
- Use this for the improvement of all parts of the teaching process.
Bloom's Taxonomy
Bloom, B.S. 1984, Taxonomy of Educational Objectives, Allyn & Bacon

• Levels of understanding, from lowest to highest: (i) knowledge; (ii) comprehension; (iii) application; (iv) analysis; (v) synthesis; (vi) evaluation

• [Alternative: SOLO Taxonomy; it is based heavily on understanding connections between pieces of knowledge].

• Too much teaching is done and evaluated at the lower levels.

• We should prepare our students to function at the higher levels – to be critical thinkers
Astronomy Education Research Charter

• An appeal to all parts of the astronomy education community – astronomers, astronomy educators, astronomy education researchers, museums and other public EPO organizations, professional societies, funding agencies

• Goal: to heighten the prominence and effectiveness of astronomy education

• Based on discussions at a one-day symposium in Boston

• Modelled after The Washington Charter

• References: Astronomy Education Review, 6, (2), 130 (2007); 8 (1) (2009)
Neuroscience-Based Education
What Promotes Neural Connections?

- Learning by doing
- Physical movement
- Using more than one sense to learn
- Having fun learning
- Being emotionally calm and open to learning
- Building on information already there [*constructivism*]
- Discerning patterns
- Taking some risk, but not too much
- Having a positive connection with the teacher
- Knowing why you are learning [*relevance*]
Neuroscience-Based Education
What Blocks Neural Connections?

- Hunger, stress, fear, boredom, tiredness
- Facts that don't connect to anything else
- Being told that there's only one way to learn
- Believing that you are born with a fixed level of intelligence
- Believing that girls and boys are good at some things but not others

[Source: Alanna Mitchell [author, Atkinson Fellow], Toronto Star, 31 October – 7 November 2009]
The School Curriculum
[is there a university equivalent?]

- The school curriculum may be determined nationally, provincially, locally, or some combination of these.

- We must distinguish between: (i) the curriculum that is mandated; (ii) the curriculum that is taught by the teachers; (iii) the curriculum that is learned by the students.

- In Ontario, the revised secondary school science curriculum emphasizes science skills and careers, and applications to society: “STSE”: science, technology, society, environment.
Challenges in Elementary School Astronomy Education

- Astronomy may not be in the curriculum and, if it is, it may be inappropriate and uninspiring, or may not be taught; textbooks may be of poor quality
- Teachers have little background in science and mathematics, and usually none in astronomy
- Students (and teachers) have deep-rooted misconceptions and superstitions about astronomy
- Suitable hands-on activities are less obvious; “the stars come out at night, the students don't”
- Reaching under-served communities
Teacher Education

- Few teachers have any background in astronomy, or astronomy teaching
- There is little contact between astronomers and faculties of education
- There is little time, in pre-service teacher education, for specific training in astronomy
- In-service teacher education may reach the interested teachers only
- **Solution**: use high-impact, wide-reach approaches such as working with Ministries of Education, school boards, textbook publishers, and science teachers associations; provide selective, useful resources

- *Galileo Teacher Training Program* is a cornerstone project of IYA
Challenges in Secondary School Astronomy Education

- Astronomy may not be part of the curriculum and, if it is, it may not be taught
- Curriculum may be inappropriate, or not aligned with students' interests
- Curriculum is increasingly crowded, and teachers' duties are increasing
- Teachers have little or no background in astronomy, or astronomy teaching
- Practical activities are more difficult than in other sciences
John Percy's IYA Projects to Support the Revised Secondary School Science Curriculum in Ontario

- On-line resource to provide teachers with a strategy and framework for the grade nine (age 14) astronomy and space curriculum [almost complete]

- A similar resource for teachers of grade six (age 9) [under development]

- A two-hour Teachers Workshop as part of the annual conference of the Canadian Astronomical Society.

- A three-day Summer Institute for teachers of secondary school astronomy, August 17-19, 2009, at the University of Toronto

- Some of the 20 sessions on astronomy at the November 2009 conference of the Science Teachers Association of Ontario, my partner in these projects

- A project to connect *GalileoScope* with the Ontario astronomy and optics curriculum.

- Astronomy consultant to the Ministry of Education; reviewer of textbooks.
General Challenges in Post-Secondary Education

- Instructors and teaching assistants receive little or no training in teaching.
- In most research universities, research receives more support than teaching but
- The Boyer Report (Reinventing Undergraduate Education, 1998) has begun to have an effect.
- Systematic surveys of student “engagement” are being carried out; National Survey of Student Engagement (NSSE: nsse.iub.edu).
- Media evaluate and rate universities, but their methodology is not always unbiased.
- Many students enter university with weak academic skills (such as mathematics) and attitudes (“The Millennium Generation”)
Astronomy Education for Science Students – Problems in Some Universities

- Tendency for over-specialization; preparing majors for graduate or professional school.
- Preparing students for a variety of real-world careers e.g. teaching; *see Rethinking Science Careers*, by Sheila Tobias.
- The value of double-major programs, and other breadth
- Providing students with research experiences as early as possible; linking teaching and research in other ways.
- Providing students with generic research skills.
Linking Teaching and Research

- Enable students to carry out research projects, where possible
- Build research experiences and skills into lab courses; use real data and software; use remote telescopes (effectively)
- Design creative and meaningful assignments
- Encourage students to use the Internet critically, access research papers, write high-quality reviews and lab reports
- In lectures, expose students to current research, instructor's research interests
- Take real or virtual tours of astronomical facilities
My Research Experiences for Students

- Research Opportunity Program: second-year students receive full-course credit for a research project
- Ontario Work-Study Program: up to 200 hours of career-related employment during the year
- Senior thesis: full-course credit for fourth-year students
- University of Toronto Mentorship Program: outstanding senior high school students can work on research at the university
- Summer studentships: some funded by the Natural Sciences and Engineering Research Council
AAVSO Variable Star Research Projects
American Association of Variable Star Observers

- Skilled amateur astronomers measure variable stars
- Students develop and integrate science and math skills by analyzing them
- Results are presented at AAVSO meetings and in AAVSO Journal as feedback to observers
Astronomy Education for Non-Science Students


- Abstract: “A national study of teaching and learning in courses that introduce astronomy to nonscience majors shows that interactive learning strategies can significantly improve student understanding of core concepts in astrophysics.”

- Caveat: “But the quality of implementation is crucial; professional development must be provided, and encouraged.”

- And, of course, students should also be inspired by their instructors!
“Teaching and Learning Astronomy ...”
learning gains through traditional (red) and interactive (green) methods
Engaging Students ...  
... even in large classes

- Minds must be constantly engaged
- Think-pair-share; lecture-tutorials; ranking tasks (Prather et al.)
- Peer instruction (Green, P.J. 2003, *Peer Instruction in Astronomy*, Prentice-Hall)
- Effective use of “clickers” for a variety of purposes
Graduate Education in Astronomy

- Quality of graduate teaching, supervision, and mentoring; professors receive little or no training in any of these
- Effectiveness of, and balance between graduate courses and research projects
- Importance of students' non-academic traits and abilities: motivation, enthusiasm, autonomy, flexibility, initiative, creativity, time-management and communication skills
- Graduates report that they wish they had received more training in communication, teaching, mentoring, management, teamwork, and working in a multidisciplinary environment
Teaching Graduate Students to Teach
The University of Toronto Situation
(many universities do better)

- Graduate teaching assistants (TAs) are required, by their union contract, to be provided with at least three hours of training, in total.
- There is a comprehensive TA Training Program, provided through the Centre for Teaching Support and Innovation; about 100 students take this each year, and 600 attend workshops.
- There is a non-credit graduate course Teaching in Higher Education; about 120 students take this each year.
- There is a wide variety of lectures, workshops, and resources provided by CTSI, but few TAs access them – only the most interested
- In the Department of Astronomy and Astrophysics, there are occasional lectures, a sporadic Education Discussion Group, and many informal discussions over coffee.
Teaching and Learning Astronomy in the Developing World

- The same basic principles apply: developed countries do not have a monopoly (or overwhelming success) in effective astronomy education
- Effective partnership between the handful of individuals in “the astronomical community”
- Creative use of inexpensive available materials and resources, including the Internet
- Developed countries have an obligation to provide effective support; the IAU can play a substantial role
Astronomy Outreach and Communication

• General education considerations apply:

• Choose objectives: to convey knowledge? To convey enthusiasm? To present a good image of astronomy and astronomers? To entertain? To inspire?

• Consider the audience, their nature and needs

• Choose content which is appropriate to objectives

• Use effective communication strategies and methods

• Use formative and summative assessment, for constant improvement

A Tale of Three Toronto Institutions
1. The David Dunlap Observatory

- Founded in 1935, as part of the University of Toronto
- Houses Canada's largest telescope (1.88m)
- As a result of declining research, education, and outreach use, it was recently sold to a developer
- The local astronomical society is presently operating it for EPO
- Future: uncertain
A Tale of Three Toronto Institutions

2. The McLaughlin Planetarium

- Founded 1968 at the Royal Ontario Museum
- For years, one of the world's major planetariums
- Closed by the ROM in 1995 as a result of threatened funding cutbacks, even though attendance was healthy
- Toronto no longer has a major planetarium
A Tale of Three Toronto Institutions

3. The Ontario Science Centre

- Founded in 1967 as an agency of the Ontario government
- Despite administrative challenges, it has become the most-visited cultural institution in Canada
- A major centre for astronomy education programs and exhibits for students, teachers, and the public
Communicating Astronomy to the Public

- **Why**: to attract youth to science; to increase public awareness, understanding, and appreciation of astronomy; to be accountable!

- *The Washington Charter* for communicating astronomy to the public

- IAU Commission 55; its *Journal*; its conferences

- International Year of Astronomy 2009
International Year of Astronomy 2009
http://www.astronomy2009.org
Where the Slogan Came From
International Year of Astronomy 2009

- Celebrates the 400th anniversary of Galileo's development and first use of the astronomical telescope
- Led by the International Astronomical Union, supported by UNESCO, endorsed by the UN General Assembly
- Celebrated in 147 countries
IYA: Vision and Aims

- **Vision**: to help the citizens of the world rediscover their place in the universe through the day and night-time sky, to appreciate the impact of astronomy and basic sciences on our daily lives, and to understand better how scientific knowledge can contribute to a more equitable and peaceful society.

- **Aim**: to stimulate worldwide interest, especially among young people, in astronomy and science under the central theme “The Universe, Yours to Discover”. IYA events and activities will promote a greater appreciation of the instrirational aspects of astronomy, that embody an invaluable shared resource for all countries.
IYA: Objectives

Relevant to curriculum, but rarely stated explicitly

- To illustrate the remarkable cultural influence of astronomy over time, and its connections to culture today.
- To demonstrate the inspirational nature of astronomy, especially for young people.
- To remind humanity that we are responsible for the long-term future of our planet.
- To show astronomers as a global family of peaceful, international collaborators.
- To encourage scientific and critical thinking in society.
IYA in Canada

• **Vision:** To offer an engaging astronomical experience or Galileo Moment to every person in Canada, and to cultivate partnerships that sustain public interest in astronomy.

• **Goal:** a million genuine Galileo Moments; we surpassed the goal in October.

• **Success:** effective, enjoyable partnerships between professional and amateur astronomers, and other individuals and organizations in “the astronomical community”; sustained efforts of thousands of volunteers.

• **Website:** http://www.astronomy2009.ca
Example: Circulating Stamps

- Issued by Canada Post in April 2009
- Used by hundreds of thousands of Canadians in all walks of life
- Illustrate Canadian astronomical heritage, and the beauty of the cosmos
- Among the most popular stamps issued by Canada Post
Example: “The Galileo Project”
Reference: *CAPJournal*, in press

- Multimedia program by the Tafelmusik Baroque Orchestra, one of the world's best: music, drama, images, movement
- Brought astronomy to 10,000+ non-scientists in Canada, Mexico, and US (in 2010)
- Creative, effective educational version inspired thousands of 11-year-olds
- Outstanding reviews!
Example: Partnership with Aboriginal Communities

- Uniting Elders and youth through Aboriginal night sky stories (Left: Muin (the Great Bear) and the Seven Bird Hunters)
- Respecting the environment: dark-sky preserves
- Creating science pathways for youth to pursue interests and careers in science and technology
Example: An Astronomical Heritage Tour

- Partnership with Heritage Toronto
- Walking tour of astronomically significant sites in and around the University campus, 1830s to present
- Left: Toronto Observatory (1853)
Final Thoughts

- Raise the profile and importance of effective astronomy education and outreach at all levels
- Do this by strategies that are high-impact and wide reach
- Adopt methods of teaching, outreach, and communication that have been shown to be effective by formal or action research or experience
- Establish effective partnerships within all parts of “the astronomical community”
- Constantly practice assessment and improvement
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