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

- *Innovations in Astronomy Education*, ed. Jay M.. Pasachoff, Rosa M. Ros, and Naomi Pasachoff, Cambridge University Press, 2008
- *Teaching and Learning Astronomy*, ed. Jay M. Pasachoff and John R. Percy, Cambridge University Press, 2005
- ..... and proceedings of earlier conferences in this series
- *Astronomy Education Review*, http://aer.aip.org
- IAU Commission 46: http://iau46.obspm.fr

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 ...

Astronomy Education Review

- 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

Slater & Adams 2002, *Learner-Centered Astronomy Teaching*, Prentice-Hall

- 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

Percy, J.R. 2008, *Preparing for IYA 2009,* ASP Conf. Series 400, 363

- 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

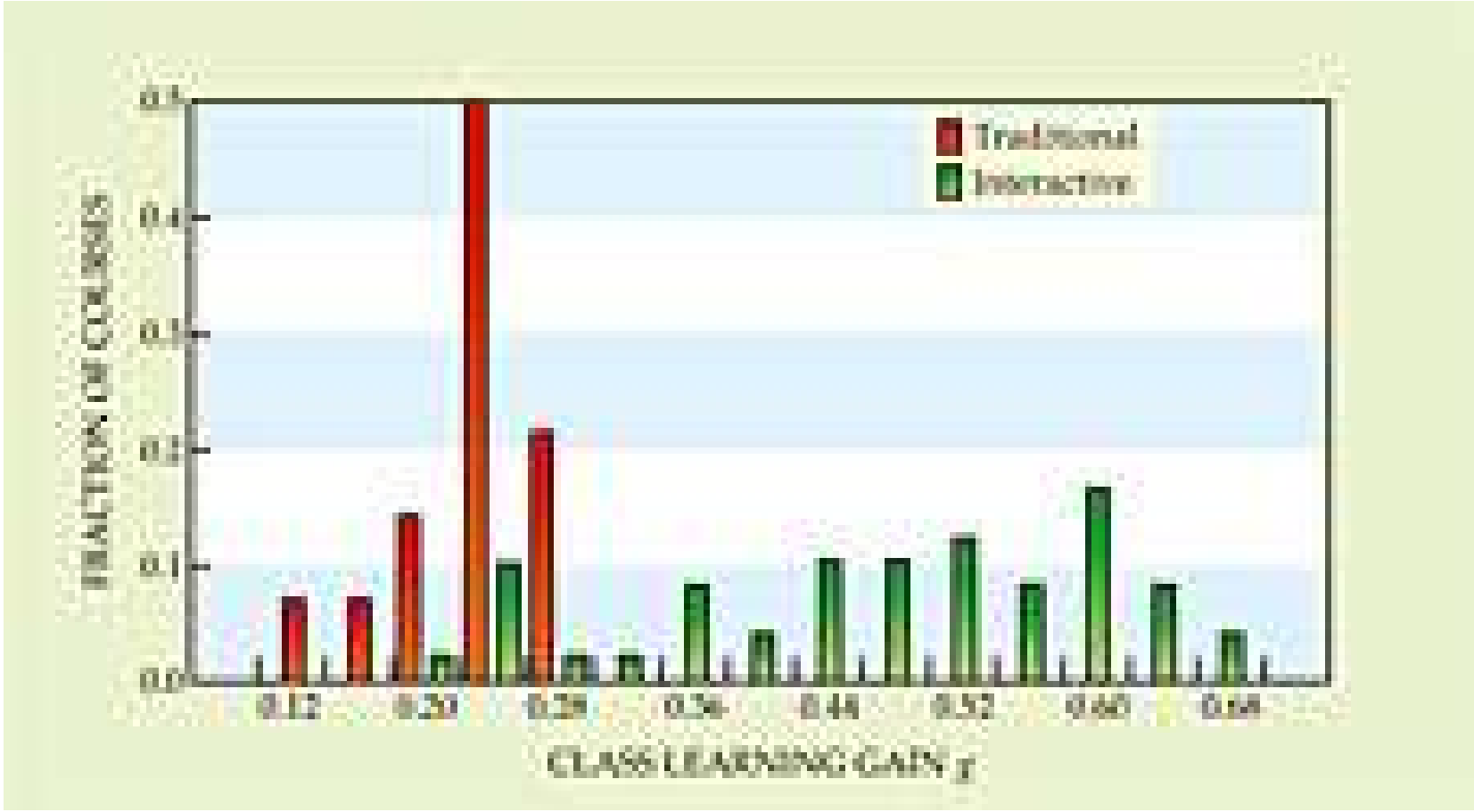
- Skilled amateur astronomers measure variable stars
- Students develop and integrate science and math skills by analyzing them
- Results are presented at AAVSO meetings and in AAVSO Journal as feedback to observers

Astronomy Education for Non-Science Students

- I recommend "Teaching and Learning Astronomy in the 21st Century", by Edward E. Prather, Alexander Rudolph, and Gina Brissenden, *Physics Today,* Oct. 2009, 41-47.; see also Slater and Adams, *Learner-Centered Astronomy Teaching.*
- 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!

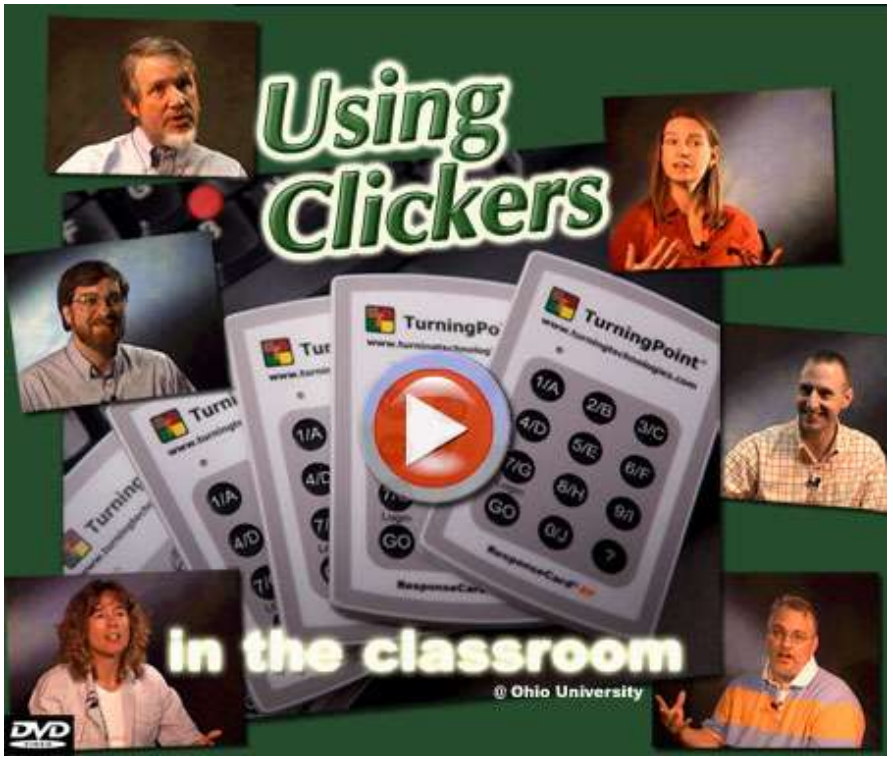
“Teaching and Learning Astronomy ...”

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

Ref: Percy, J.R. 2007, *Astronomy for the Developing World,* CUP, 229

- 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
- Reference: *Astronomy for the Developing World,* ed. Hearnshaw and Martinez, CUP 2007.

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 *conten*t which is appropriate to objectives
- Use effective communication *strategies and methods*
- Use formative and summative *assessment*, for constant *improvement*
- Sample Reference: *EPO and a Changing World*, ed. C. Garmany et al., ASP Conference Series 389, 2008.

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, unnderstanding, 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

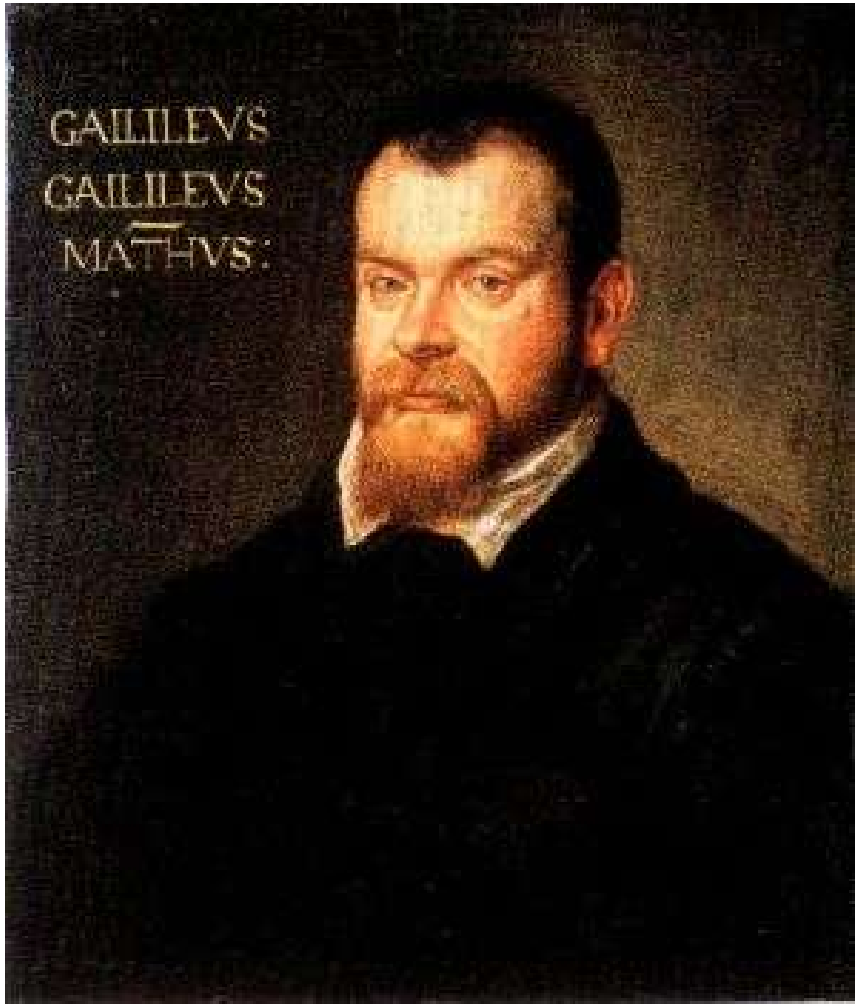
http://www.astronomy2009.org

THE UNIVERSE
YOURS TO DISCOVER

INTERNATIONAL YEAR OF
ASTRONOMY
2009

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 instirational 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

Thanks and Acknowledgements

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- This presentation: http://www.astro.utoronto.ca/~percy/madrid.pdf