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Special Session 2 Innovation in teaching and learning astronomy

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Abstract. On August 17 and 18, 2006, Commission 46 on Astronomy Education and Development held a Special Session at the IAU XXVI General Assembly in Prague. The session, on *Innovation in Teaching/Learning Astronomy*, was organized around four themes: (*i*) general strategies for effective teaching, (*ii*) connecting astronomy with the public, (*iii*) effective use of instruction and information technology, and (*iv*) practical issues connected with the implementation of the 2003 IAU Resolution that recommended including astronomy in school curricula, assisting schoolteachers in their training and backup, and informing them about available resources. Approximately 40 papers were presented orally; in addition, 60 poster papers were displayed.

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1. General strategies for effective teaching

The 20 papers constituting the first day's proceedings were devoted to the first theme. After welcoming remarks, commission president Jay M. Pasachoff and Rosa M. Ros, who later became the IAU Commission 46 vice-president, briefly summarized the main objectives of the Special Session, mentioning a variety of new methods of information dissemination (e.g., World Wide Web, Astronomy Picture of the Day, podcasts), the role astronomy can play in attracting young people to careers in science and technology, and the usefulness of technology both to observers and to teachers.

Former Commission 46 president *John Percy* of Canada next spoke about 'Learning Astronomy by Doing Astronomy'. Percy contrasted learning astronomy facts from lectures and textbooks and 'doing astronomy' in a more intellectually engaging fashion, emulating the actual scientific process, than called for in standard activities culminating in a predetermined result. While recognizing the value of 'hands-on' activities, such as making scale models of the solar system, Percy argued that 'minds-on' activities are more valuable, such as involving students in meaningful ways in their teachers professional research (even if the result is not publishable). He pointed out that in laboratories, which should mirror actual research, students can manipulate actual data, using the same computer languages and software used by real researchers. In these ways they can grasp that astronomy facts do not emerge fullblown from textbooks but are figured out by astronomers based on ongoing research. Percy spoke also of the value of having students themselves assume the role of astronomy communicators by tutoring peers or younger students or making classroom or public presentations. Percy referred to conference participant Richard Gelderman's assertion that students should they be exposed to recreational science, such as science fairs, 'for curiosity, interest, and . . . for fun, fellowship, and … mental well-being,' just as they are encouraged from their earliest years to participate in recreational sports for physical and mental health. He noted, too, that even urban students can learn to understand and make the observations that underlie the religious observances of major world faiths. He concluded with the thought that 'the ultimate goal of astronomy education' is to reach every student. While only a fraction will become professional astronomers, every student may become an amateur astronomer, with a lifetime passion for astronomy.

Like Percy, *Roger Ferlet* of France underscored the importance of engaging pupils in 'observing, arguing, sharing, discussing and interpreting real astronomical data, in order to enhance autonomy and reasoning; in brief, learning science by doing science'. Ferlet discussed the European Union's Hands-on Universe project as a tool to reverse the 'clear disaffection for scientific studies at universities' by convincing middle and high school students that scientific understanding 'can be a source of pleasure'. The project, a partnership of eight European countries under the auspices of the French University Pierre and Marie Curie in Paris, invites these younger students 'to manipulate and measure images' in class, using 'real observations acquired through an internet-based network of robotic optical and radio telescopes or with didactical tools such as Webcam,' assisted by scientific experts and by a select group of teachers who are trained in special workshops. The newly trained teachers go on to become 'resource agents' for their own countries, with a mandate to train other educators. This European undertaking is important not only to the international scientific community but to society as a whole, since not only does a 'sustainable economy' depend on innovations by 'a critical number of scientists and engineers,' but also societies that undervalue science 'regress to more primitive and much less attractive' conditions. An additional social benefit of the project is that it encourages communication among students from different countries. The positive reaction to Hands-on Universe has aroused hopes that similar European initiatives will result in 'Hands-on life' for biology, 'Hands-on Earth' for geology/ecology, etc'.

Former Commission 46 president *Edvard V. Kononovich* of Russia described a manual about the Sun, the Earth, and their interactions assembled by the Sternberg Astronomical Institute of Russia for older high school students and for 'students of natural faculties of universities and teachers colleges' with an interest in solar problems. The manual is also a useful teaching aid for courses covering solar physics and solarterrestrial relations. The manual, which makes use of both groundbased observations and results from *SOHO*, *Yohkoh*, *Ulysses*, *TRACE*, *CORONAS*, and other space telescopes, is divided into three sections. The first considers the Sun as a star, solar activity, and helioseismology. The second describes the Earth in space, its structure, its atmosphere, its magnetic field, its weather and climate, and active phenomena on the terrestrial surface. The third section considers such solar-terrestrial relationships as ionospheric disturbances, solar cosmic rays, and auroras.

Bill MacIntyre of New Zealand presented 'A Model of Teaching Astronomy to Pre-Service Teachers that Allows for Creativity in Communicating Students' Understanding of Seasons'. (In MacIntyre's paper, 'students' are teacher trainees, not the young people they will go on to teach.) MacIntyre began by distinguishing among mental models ('cognitive notions held by individuals'), expressed models (mental models that have been communicated to others), consensus models (expressed models valued by a social group and widely used by it), scientific models (consensus models that are used by scientists for further scientific developments), and teaching models (used to provide opportunities for teachers-in-training to develop their understanding of basic astronomy along with pedagogical skills). A goal of the 'investigating with models' approach is to have students understand 'the limitations and strengths' not only of their own models but also of scientists' models. Since expression of a scientifically inaccurate mental model has the potential to embarrass the student, teachers must make sure to have the revelations take place 'in a small group' and 'in a nonthreatening way'. The exercise requires students to collect evidence that will either support or lead them to change their mental models, a requirement that guarantees they will practice 'aspects of the nature of science (observations, inferences, creativity and empirically based knowledge) that relate to the systematic nature of investigating'. MacIntyre described in detail the process by which two teachersintraining creatively developed new expressed models after identifying specific aspects of their original expressed model that other members of their group had difficulty comprehending. Why is such an exercise for teacher trainees useful? 'If we expect classroom teachers to cater for the creative-productive gifted students during astronomy teaching in primary and secondary schools, then pre-service teacher training must model the appropriate classroom environment that allows it to occur'.

In 'How to Teach, Learn About, and Enjoy Astronomy', *Rosa M. Ros* of Spain described 'what I learnt after 10 years of the [European Association for Astronomy Education] Summer School,' drawing on the questionnaire responses of approximately 600 opinions of teachers of secondary school students from over 20 countries. To make students – in this case, the teachers – 'feel like actors in the teaching-learning process', she, like other SpS2 session participants, advocates 'learning by doing'. During the summer sessions the teachers are exposed to a variety of approaches to the teaching of astronomy, including modelmaking, drawing, playground activity. Just as a classroom teacher must be prepared to answer spontaneous questions from pupils about an astronomy topic that interests them, the summer school directors had to modify their lectures to accommodate 'the topics, matters, and methods' about which the teacher participants wanted to know more, bearing in mind always that astronomy concepts must be presented in some context, not in isolation. Instead of presenting a body of facts for students to memorize, 'It is important to connect the concepts with the personalities related to the topics, with the scientific situation in the past or maybe the social implications of the subjects'. One goal of the summer school is to encourage more inspired and more passionate teaching of math and physics: 'If the teachers enjoy teaching, the students will also enjoy their classes'. Ros lamented the fact that science museums tend to mount exhibits about science that stress the 'spectacular and funny', leaving to schools 'the boring science area'. Nonetheless, she noted that 'Not everything can be fun at school', arguing that teachers must also 'introduce the culture of making an effort to students'. Even underfunded schools with limited resources can include creative astronomy activities in the curriculum: 'All schools have a sky over their buildings. It must be used to observe and take measurements. If the school does not have tools and devices for making observations, we can encourage the students to produce their own instruments'. Whatever is lost in precision by doing so is more than compensated for in student commitment.

Based on his experience as director of astronomical laboratories at the University of Colorado in the United States, *Douglas Duncan* advocated the use of 'clickers' wireless student response systems as 'the easiest interactive engagement tool' in teaching large lecture classes. Studies show that students enjoy using clickers, which transform students from 'passive listeners' to 'active participants' in the learning process. The use of clickers also enables teachers to determine their level of comprehension without waiting for testtime. Studies show that the average student in a large physics lecture course, regardless of the effectiveness of the lecturer, truly comprehends at most 30 % of newly introduced concepts. To master a new concept, students 'must think about the idea and its implications, fit it into what they already know, and use it'. They must dislodge the misconceptions with which they enter the lecture hall. While professional scientists bounce ideas back and forth among themselves and within their own minds, students often believe 'that taking notes, memorizing, and repeating material on an exam is all there is to learning'. Duncan also advocated using clickers to facilitate peer instruction, since studies show that 'when comparable numbers of students start with right and wrong conceptions, peer instruction usually results in students agreeing on the correct answer, not the wrong one'. He cautioned, however, that 'like any technology, clickers can be misused, and it is important to practice and to explain their use to students before starting'.

Gilles Theureau reported on his experience with co-author *Karl L. Klein* teaching a two-semester course for students with varied backgrounds and interests at the University of Orleans (France) on the 'history and epistemology of the concepts of stars and galaxies' from antiquity to the early twentieth century. The cross-disciplinary approach is unusual in France, 'where pupils start to be specialized' from the age of 15. The course opens with a study of world systems from the pre-Socratics to the philosophers of the Middle Ages, moves on to concepts of mechanics and planetary motion from Aristotle to Newton (and a little beyond), proceeding then to a discussion of spectroscopy and the nature of stars, and concluding with descriptions of the Milky Way and the nature of nebulae. The course emphasizes 'mechanisms of knowledge,' including observation, experiment, and theory, as well as mythology, theology, philosophy, metaphysics, physics, mathematics, and instrumentation, in order to demonstrate that human ideas of the universe evolved 'as a part of human history and culture,' that 'science belongs to the patrimony of humanity and that it has no frontiers,' and that astronomy draws on both the humanities and the sciences. The course makes use of original documents that are considered in their historical context, including Aristotle on meteorology (350 B.C.E.), Nicolas Oresme's challenge to Ptolemy's view of celestial motion (c. 1380), William Herschel's 'On the Construction of the Heavens' (1785), and Agnes M. Clerke's Problems in Astrophysics (1903). The class also paid a visit to the Nancay Radio Observatory Astronomy Museum and Visitor Center; for the majority of students, who have 'never looked at the sky,' this visit provided 'an impression of the questions of interest to past generations of philosophers and astronomers'. Although in such a course it would have been easier to evaluate students through exams exclusively, the professors opted for the more difficult choice of assigning individual written projects in the first semester and a comprehensive exam in the second semester. The professors broadened their own cultural outlook by teaching the course, but found the presentation of material to and evaluation of such a heterogeneous group of students very challenging.

In 'Educational Opportunities in Pro-Am Collaboration', *Richard Fienberg*, editor of *Sky and Telescope* magazine, echoed other symposium participants in asserting that 'the Best way to learn science is to do science,' and called, as Michael Bennett would do in a later paper, for collaborations among amateurs, professionals, and educators. 'Amateurs will benefit from mentoring by expert professionals, pros will benefit from observations and data processing by increasingly knowledgeable amateurs, and educators will benefit from a larger pool of skilled talent to help them carry out astronomy-education initiatives'. Noting the important contributions amateur astronomers have historically made to the field, the loss of access of professional astronomers to mid-sized meter-class telescopes, and the need to follow up on 'countless interesting objects' being discovered by automated all-sky surveys, Fienberg recommended serious amateurs-many of whom have access to digital imagers on computer-controlled mounts-be given the opportunity to do some of this monitoring. He identified the American Astronomical Society Working Group for Professional-Amateur Collaboration as a 'forum for collaboration between amateur and professional astronomers'. Fienberg noted that amateurs continue to make important contributions to astronomy in areas including occultations; variable stars; meteor showers; CCD photometry and astrometry; and the search for and discovery of novae, supernovae, GRB counterparts, comets, and asteroids. In addition to this important work, amateurs can also help with astronomy outreach within their local communities and over the Internet with other researchers and educators around the world.

Jose Maza reported on his two-decades of experience 'Teaching History of Astronomy to Second-Year Engineering Students at the University of Chile'. The course partly fills the twocourse 'Humanistic Studies' requirement that each engineering graduate must complete. As a result of the course, men and an increasing number of women who will go on to work at and often become senior executives at major Chilean companies are exposed to the basics of astronomy and to its development over history. The first part of the course, 'a tour to the scientific revolution,' begins with the ancient civilizations, leads up to Newtons construction of modern science, and ends with the contributions of Euler, Clairaut, Lagrange, D'Alembert, and Laplace to celestial mechanics. The second part begins with William Herschel and the discovery of the Milky Way and proceeds over several weeks to a discussion of the big bang, the cosmic background radiation, and dark energy, before culminating with a lecture on the history of astronomy in Chile. Maza would be happy to exchange ideas with other astronomy educators.

Jay M. Pasachoff spoke about 'Education Efforts of the International Astronomical Union'. He described how the work of the commission, which resulted from a merger of the commissions on education and on astronomy in developing countries, is carried out in ten program groups. These groups include the world-wide development of astronomy, which sends some of its members to visit countries prospective for advances in carrying out astronomy and perhaps even becoming members of the International Astronomical Union; teaching for astronomy development, which provides visiting experts or lecturers to help advance a country's astronomical education; exchange of astronomers, which arranges international visits of several months or longer for people from developing countries to visit major research institutions; the IAU International School for Young Astronomers that is held every non-General-Assembly year for some dozens of new astronomers or graduate students; a semiannual newsletter; a group charged with coordinating with international institutions such as UNESCO, and that will now work with the *International Year of Astronomy* scheduled for *2009*; a group involved in international exchanges of journals that could aid developing countries; and a group related to taking advantage of public interest at the times of solar eclipses to spread astronomical knowledge, including but not limited to the eclipse itself. All these groups, the newsletters, and other related activities are accessible through the Commission 46 Website at <http://www.astronomyeducation.org>.

Magda G. Stavinschi of Romania, who became Commission 46 president at the end of the Prague IAU XXVI General Assembly, argued that astronomy is an integral part of human culture, in the evolution of which is often played a significant role. The discoveries of archaeoastronomers have proven that prehistorical civilizations pondered cosmological questions and wondered about the place of humankind in the universe. From the beginnings of history people across cultures have recorded significant events through markers that include not only human events, such as wars and the births and deaths of leaders, but also cosmic events, notably comets and eclipses. Stavinschi called attention to the often overlooked relationship between politics and astronomy, noting the post-World War I confirmation of Einsteins general theory of relativity by the Englishman Sir Arthur Eddington. During the war, Germany, Einsteins native land and the country that employed him, was a bitter enemy of England. This scientific collaboration not only served as 'a perfect proof of scientific internationalism' but also helped reincorporate German scientists into the scientific community after the war. After briefly mentioning the links between astronomy and geography, mathematics, physics, chemistry, meteorology, technology, medicine, and pharmacology, Stavinschi pointed out some famous examples of the incorporation of astronomy in art, music, heraldry, folklore, and literature. She spoke of the importance of astronomy education: those with an appreciation of the universe understand the need to protect Earth from manmade devastation 'much before its natural end'. While the mass media have succeeded in educating the public through coverage of space missions, and television programs featuring scientists like Carl Sagan have popularized astronomy, the media also are responsible for disseminating misinformation about astronomy. After briefly reviewing the history of astrology, she pointed to the astronomers' 'moral duty' to 'prove the quackery of astrology'. She concluded by arguing that 'there is no conflict between science and religion,' since they are 'two different ways of considering the world,' and dismissed the usefulness of arguing the relationship between astronomy and philosophy, since 'all that defines philosophy intimately contains the Universe and especially man in the Universe'. Astronomy can continue to play a role in the development of culture in pointing humanity in the direction of 'what it has to do from now on'.

Margarita Metaxa of Greece, where she teaches at the Arsakeio High School in Athens, spoke about 'Light Pollution: A Tool for Astronomy Education', which can help motivate not only students but also 'the public, government officials and staff, and lighting professionals'. Like Duncan, Metaxa noted that students 'hold misconceptions about the physical world that actually inhibit the learning of scientific concepts' and that 'students can remember less' than their teachers often assume. She called attention to a two-year program on light pollution sponsored by the Greek Ministry of Education and Religion, with backing from the EU; to the Internet Forum on Light Pollution, sponsored by the netd@ys Europe project, a European Commission initiative in the area of education, culture and youth for the promotion of new media; and to a UNESCO-backed conference on 'Youth and Light Pollution' held in Athens in autumn 2003. Outside of Europe, Chile has played a significant role in educating students about 'the effects of light pollution on the visibility of stars in the night sky'. She concluded by emphasizing that bringing both astronomy and light pollution to the world's attention in order 'to protect the prime astronomical places and the 'dark skies' as a world heritage' represents a significant challenge. It is one, however, that astronomers can meet by working 'together with interested organizations'.

In 'Student Gains in Understanding the Process of Scientific Research', *Travis A. Rector et al.* described 'Research-Based Science Education' as 'a method of instruction that models the processes of scientific inquiry and exploration used by scientists to discover new knowledge'. As an example of 'self-guided, cooperative groups' of undergraduates tackling 'a real research project', they summarized a student search for novae in the Local Group of galaxies by blinking images from the Kitt Peak WIYN (Wisconsin-Indiana-Yale-National Radio Optical Astronomy Observatory) 0.9 m telescope and then generating light curves and measuring decay rates through use of aperture photometry. Each student then selected a question to explore, 'such as comparing the location of novae in the galaxy and their rates of decay', presenting their conclusions both in a written research paper and in an oral class presentation. A comparison of student 'concept maps on the topic of scientific research', one completed before they undertook their research and one after, showed an overall deepening of their understanding of ten concepts inherent to scientific research. 'On average, students increased the number of the ten understood concepts ... from 2.8 before the class to 5.4 afterwards'.

In 'Effects of Collaborative Learning on Students' Achievements in Introductory Astronomy', *Myung-Hyun Rhee et al.* summarized their efforts over several years with non-science-major students at Yonsei University in Seoul, Korea. Students were divided into four groups, with one group participating in nine Collaborative Learning sessions, a second group in five, a third group in only two, and a control group participating in no such sessions at all. Students who participated in the greatest number of Collaborative Learning sessions experienced much less 'Communication Apprehension' than their peers, with the effect enduring even after six months had elapsed. The students with nine Collaborative Learning Sessions under their belts also rated higher in assessments of Academic Achievement and Class Satisfaction than students in the other three groups.

On behalf of a group of collaborators, *Stewart P.S. Eyres* of the UK described 'Worldwide On-line Distance Learning' from astronomy courses prepared by the University of Central Lancashire. The student subscribers to these online courses range in age from 16, though most are over 21. They might include a retired industrial professional with a doctorate in chemical engineering, an English teacher with a deep interest in astronomy, an employee of an examinations board responsible for school astronomy curricula, a high school student preparing for university entrance exams, a primary school classroom assistant working toward a degree, among others. While all students share an interest in astronomy, they differ in what they hope to achieve through participating in the online distance learning program. Although distance learning in the UK is often associated primarily with the Open University, the University of Central Lancashire (UCLan) has been offering adult education courses in astronomy for about a decade. It is now possible to earn an honors bachelor of science degree in astronomy through UCLan. Eyres explained why the traditional 'teacher focused' astronomy education, in which an 'expert in the subject decides what the student needs to know at the end of the course, and works backwards from there to determine where they must start,' is inappropriate to distance learning. The framework of modules in the UCLan program enables students to determine if they are capable of higher-level work before they sign up for a lengthy course of study. Students are able to study modules provided by other institutions and use them for UCLan credit. They may also receive credit for skills they may already have in such fields, for example, as IT or math. Students correspond with their tutors both through email and through 'discussion and chat tools on UCLan's virtual learning environment'. With the introduction of competitive tuition fees at UK brick-and-mortar universities, the honors bachelor of science degree available through UCLan has the potential 'to attract students from the traditional 18-to-21 year-old UK degree market'. Even students who can pay the tuition fees at traditional universities may choose to take distance courses as a way of drawing attention to their qualifications and making themselves stand out from other applicants for admission. UCLan is also thinking of entering the teacher training market.

Donald Lubowich of Hofstra University, on New York's Long Island, USA, demonstrated how he has successfully used 'Edible Astronomy Demonstrations' to motivate students of all ages and to enhance their understanding of such varied concepts as differentiation, plate tectonics, convection, mud flows on Mars, formation of the Galactic Disk, formation of spiral arms, curvature of space, expansion of the Universe, and radioactivity and radioactive dating. His materials have included chocolate, marshmallows, candy pieces, nuts, popcorn, cookies, and brownies. Echoing other participants' comments that passionate and joyful teachers are effective teachers, he urged symposium participants to be 'creative, create your own edible demonstrations, and have fun teaching astronomy'.

In 'Amateur Astronomers as Public Outreach Partners', *Michael A. Bennett*, executive director of the Astronomical Society of the Pacific (ASP), which is based in San Francisco, USA, identified 'a huge, largely untapped source of energy and enthusiasm to help astronomers reach the general public' as volunteer science educators and urged astronomers and astronomy educators around the world 'to consider more formal cooperation with amateurs'. The ASP has estimated that, if one defines 'amateur astronomer' as one who has joined a club of like-minded people, there are over 50,000 'affiliated amateur astronomers' in the US alone. It has also estimated that US amateur astronomers 'reach some 500,000 members of the general public every year' through public star parties, classroom visits, community fairs, and museum/science center events. In March 2004 the ASP, with funding from the Navigator Public Engagement Program at NASA/JPL, launched its NASA Night Sky Network (NSN) to provide amateurs 'with tested Outreach ToolKits on specific topics that can be used in a wide variety of ways with many different types of audiences,' as well as training in how to use these resources. Amateur clubs must meet certain criteria in order to become members of NSN, and approximately 200 clubs had joined by summer 2006, representing approximately 20,000 amateur astronomers who have participated in over 4500 public outreach events. NASA funding is expected to continue for this effective program. Bennett urged astronomers around the world to identify ways to engage 'outreach amateur astronomers' in their own countries.

Underlying the paper of former Commission 46 president *Syuzo Isobe* of Japan about 'Does the Sun Rotate Around the Earth or Does the Earth Rotate Around the Earth? An Important Aspect of Science Education' is the conviction that effective astronomy teaching must begin with the consideration of four variables: the pupil's class year, ability, level of interest, and future career. While of course it is more accurate to teach that the Sun does not rotate around the Earth, it is not quite correct to teach that the Earth rotates around the Sun, since 'solar system bodies rotate around a gravity center different from the center of the Sun'. While for most students the assertion that the Earth is a sphere is adequate, students who have a higher interest level and students who may go on in scientific professions should know that the Earth 'is an ellipsoid or a geoid'.

Fernando J. Ballesteros and his colleague *Bartolome Luque*, both of Spain, made a case for 'Using Sounds and Sonification' -and not merely impressive astronomy photographs- 'for Astronomy Outreach'. The authors have a successful weekend radio program, 'The Sounds of Science', broadcast on the national radio station of Spain. Sometimes, in fact, as with pulsars, 'the images are not very spectacular but the sounds are strangely attractive'. Astronomical sounds are also available to blind people in a way that images are not. [SpS 2 co-editors' note: At least three books of astronomy images are available to the blind: Noreen Lawson Grice's *Touch the Stars, Touch the Universe: A NASA Braille Book of Astronomy* and *Touch the Sun: A NASA Braille Book*. Pasachoff reviewed them in the U.S. college honor society Phi Beta Kappa's *The Key Reporter*, spring 2006, pp. 15 - 16, downloadable at `<http://www.pbk.org>`.] Ballesteros identified a number of Internet resources for astronomy sounds, the computer software 'Sounds of Space' available for both PCs and Macs, and the possibility for professional astronomers to 'sonificate' their own data, by passing them 'to an audible format'. Addressing the issue that there is no sound in the vacuum of space, Ballesteros notes that this fact represents a teachable moment in itself, since 'in many cases the sounds will be radio signals passed to sound', as is the case with both pulsars and aurorae. Similarly, black holes, lightning storms on Saturn, and ionization tracks from shooting stars also emit radio signals. Ballesteros noted that in some cases there are real sounds, such as 'when a shooting star crosses the sound barrier,' and in others the sound may be inaudible but can be indirectly reconstructed, as in the case of 'sound waves crossing the solar surface', which the vacuum of space prevents from reaching Earth, but which *SOHO* instruments can record indirectly and reconstitute after the fact.

Basing their argument on successful activities offered for school students at the Sydney (Australia) Observatory, *Nicholas R. Lomb* and *Toner M. Stevenson* contend in 'Teaching

Astronomy and the Crisis in Science Education' that the trend in some countries to shun careers in math and science can be overcome by using astronomy 'as a tool to stimulate students scientific interest'. The matter is of some importance, since if the trend is not offset, 'there may not be enough people with Science, Engineering & Technology (SET) skills to satisfy the demand from research and industry'. Not only will it be necessary to replace retirees from the 'baby boomer' generation but also burgeoning industries including nanotechnology, biotechnology, and information technology will require workers with SET skills. In Australia, however, studies show a decline in the number of high school students studying advanced mathematics and both the life and physical sciences. Data from other countries are similarly dispiriting. Unless their parents have a positive attitude toward science, students often shun the physical sciences because they think of them as boring and irrelevant. Many students perceive science to be so difficult that only highly gifted students can succeed at them. Even those with high aptitude sometimes enroll in science courses only to improve their chances at excelling in university entrance exams. Lomb and Stevenson assert that planetaria and public observatories can improve student attitudes to science by engaging students' interest in a personal way.

In 'Astronomy for All as Part of a General Education', *John E.F. Baruch et al.* discussed the pluses and minuses of using www.telescope.org/, a Web-based education program in basic astronomy available free of charge to anyone with Internet access. The authors explained the advantages of truly autonomous robotic telescopes, such as the Bradford Robotic telescope, which can 'deliver the initial levels of astronomy education to all school students in the UK', over remotely driven telescopes that reach only 'a tiny percentage ... of students'. They also discussed 'practical solutions' for assisting teachers lacking not only a deep knowledge of basic astronomy but also confidence in working with information technology.

The 20 oral papers presented on Friday, August 18, related to the remaining three themes of the special session: connecting astronomy with the public, effective use of instruction and information technology, and practical issues connected with the implementation of the 2003 IAU Resolution.

2. Connecting astronomy with the public

The second day of the Special Session began with a status report delivered by *Dennis Crabtree* on behalf of the IAU Division XII Working Group on *Communicating Astronomy with the Public* (WG-CAP), which was established in late 2003. After giving the URL `<http:// www.communicatingastronomy.org>` for the WG-CAP's 'effective website ... describing its activities', he singled out one of those activities ('to promulgate adoption of the Washington Charter by various professional and amateur astronomy socities, funding agencies, and observatories'), mentioned that WG-CAP held 'a very successful 2005 meeting on Communicating Astronomy with the Public' at ESO and had begun planning for another such meeting in 2007, and noted that at the current General Assembly the Working Group had been converted to Commission 55 under Division XII.

After a status report from the Division XII Working Group, *Julieta Fierro* of Mexico won the prize for the liveliest presentation of the session, conveying 'Outreach Using Media' with the 'passion and ... joy' that she hopes all astronomers will bring to their outreach activities. While her presentation involved her leaping onto tables, throwing books out into the audience, and getting normally staid astronomers up on their feet to swing dance according to her instructions, her message was far from frivolous. She recommended that astronomers hire professional fundraisers to help find funding for astronomy outreach activities, which she believes are an ideal way to excite the general

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public about science in general. The point of Fierro's 'dance lesson' was to model some characteristics of the type of informal learning she believes astronomy educators can provide: the teaching is done incrementally to eager participants, who are given a lot of time to practice, are encouraged to learn from their mistakes, and to accept help from their peers in their quest for mastery. The point of her 'book toss' was to encourage other astronomers to follow her example in writing illustrated popular astronomy books to capture the public's attention. Book-writing is not Fierro's only outreach activity; for almost a decade she has hosted, together with a chemist co-host, a 45-minute weekly radio program, aired during the evening rush hour. Even if every astronomer does not host a regular show, everyone can be available for interviews. She also recommended television for public outreach. Noting that many media personalities lack a strong science background, she encouraged astronomers to give guest lectures at journalism schools. Fierro reported on a graduate program for public outreach, offering both a master's and a doctorate, offered by Mexico's national university, with students majoring in at least one branch of the media and one scientific field. Since Fierro's presentation was mainly directed at astronomers in developing nations, she concluded by urging public policy makers to fund scientific outreach activities, since only a scientifically literate society can flourish. Noting that 'If women are not prejudiced against science, their children will perform better at school,' she also called for special programs for women.

In 'Hands-on Science Communication', *Lars Lindberg Christensen* named several astronomy-related 'fundamental issues with a great popular appeal', including 'How was the world created? How did life arise? Are we alone? How does it all end?' He noted the growing importance of communicating science to the public, not only to attract future scientists to the field but also to create support for public funding of science. He noted that university statutes in some countries are being redrafted 'to include communication with the public as the third mandatory function besides research and education'. Christensen then identified several 'interesting 'lessons learned' from the daily work at the Education and Public Outreach (EPO) of the ESA/Hubble ST-ECF'. These included the most effective flow of communication from scientist to public, the criteria for a successful press release, the benefits to an EPO office of a 'commercial approach', the appropriate skills base in a modern EPO office, and the more efficient use of modern technology for communicating science.

Silvia Torres-Peimbert presented a 'Critical Evaluation of the New Hall of Astronomy for the Science Museum' of the University of Mexico, which opened to the public in December 2004. The Science Museum as a whole, which opened in December 1992, covers a wide range of topics, ranging from mathematics to agriculture, and also includes a library, a 3-D theater, auditoriums, and outdoor displays. The original Hall of Astronomy's displays were primarily focused on the Solar System and paid little attention to the Universe beyond. The current renovation 'comprises 60% of the space assigned to astronomy'; in a later stage the Solar System displays will be renovated. Divided into three sections (the Sun, stars, and interstellar matter; galaxies, clusters, and the Universe as a whole; astronomical tools), the primary displays of the new Hall of Astronomy convey the idea that the Universe and all its components 'are undergoing continuous evolution'. Additional displays include 'a representation of the vastness of space [through a powers of 10 display of pictures], a time line from the Big Bang to the present epoch [laid out in a long strip on the floor], and some video clips from local astronomers [answering frequently asked questions and explaining their own research],' as well as a section on the history of astronomy [in a cartoon display, including the pre-Columbian astronomers]. The exhibit's goals were to 'attract young students to science, ... present modern day astronomical results and show that astronomy is an active science, ... show that we can interpret cosmic phenomena by means of the laws of physics, ... show modern-day concepts of the structure of the Universe and its constituents, ... show that modern technology has played a major role in increasing our knowledge of the universe'. Torres and her coauthor carried out their evaluation of the new Hall of Astronomy by observing the behavior of a sample of 50 visitors and by interpreting a sample of 100 visitors' responses to a questionnaire they distributed. From their observation of visitor behavior, the authors concluded that 'The favorite displays were those that are larger and interactive'. They attribute the lack of interest in the time line 'to the fact that it is not well advertised'. From analyzing the questionnaire, the authors concluded that 'many topics are too complicated' for visitors under 15, but that older visitors 'found interesting new information'. While 'not everybody is attracted to the most challenging displays,' interested visitors enjoyed the opportunity to delve deeply into these subjects. The authors also concluded that the new hall 'can be of assistance to science teachers'.

A special lecture on astronomy education research by *Timothy F. Slater* of the Conceptual Astronomy and Physics Education Research (CAPER) Team at the University of Arizona, USA, was the final presentation on Theme 2. The main thrust of 'Revitalizing Astronomy Teaching Through Research on Student Understanding' is that the lecture-tutorial model for teaching introductory astronomy is more effective for a majority of students (excluding, interestingly enough, 'those most likely to become faculty themselves') than the traditional lecture-only model. Not only do students learn more, but the opportunity to engage in Socratic dialogue during tutorial also leads students 'to reason critically about difficult concepts in astronomy and astrobiology'. The lecture-tutorial model 'does not require any outside equipment or drastic course revision' on the part of the instructor, and is more 'learner-centered' than the lecture-only model, transforming passive listeners to active participants in the learning process. Slater made the interesting point that although the course is called 'introductory astronomy', for many of the more than 200,000 students who take the course annually 'it is their terminal course in astronomy, and in fact marks the end of their formal education in science'. For that reason, introductory astronomy 'represents an opportunity to engender the excitement of scientific inquiry in students who have chosen to avoid science courses throughout their academic career'. Since many future schoolteachers take this course, it is also an opportunity to model 'effective instructional strategies' for them. Like other participants in the session, Slater noted that professors tend to believe that their students learn more than they actually do, since students not only lack the basic vocabulary of astronomy to begin with but also come in with misconceptions that impede their grasp of basic concepts. In noting the 'small cognitive steps' students can make in the lecture-tutorial model and the method of 'having students work collaboratively in pairs in order to capitalize on the benefits of social interactions', Slater echoed points made earlier by Fierro. During the collaborative-learning tutorials, which take place in the regular lecture hall, the professor steps out of the lecturer role and into the role of facilitator, 'circulating among the student groups, interacting with students, posing guiding questions when needed, and keeping students on task'. In end-of-semester course evaluations, students 'frequently commented positively on the lecture-tutorials, even without being prompted', generally noting how much better they understand material after hashing out their difficulties with classmates.

3. Effective use of instruction and information technology

The first of five presentations relating to Theme 3 was made by *Douglas Pierce-Price*, representing a group of collaborators from Garching, Germany, and Santiago, Chile. In 'ESO's Astronomy Education Programme,' he described several educational activities run by the Educational Office of the European Organization for Astronomical Research in the

Southern Hemisphere (ESO), some of which are run collaboratively with the European Association for Astronomy Education (EAAE). Among the recent activities of the ESO, which is headquartered in Garching with three astronomical observatories in Chile, were the coordination of over 1500 teams of international observers at the time of the 2004 Transit of Venus and the celebration of the World Year of Physics in 2005 by providing equipment for measuring solar radiation levels to students in schools throughout Chile. For several years ESO and EAAE have jointly sponsored 'Catch a Star!,' an international competition aimed at developing 'interest in science and astronomy through investigation and teamwork'. Student teams from around the world do research on an astronomical object or theme, 'and discuss how large telescopes such as those of ESO can play a part in studying it'. Although some of the contributions are judged by an international jury (with awards including travel to ESO's VLT facility in Chile or to observatories in Europe), some prizes are also awarded by lottery in order 'to avoid a sense of elitism'. In autumn 2005, ESO and its partners in the EIROforum (a partnership of Europe's seven largest intergovernmental research organizations) sponsored the first 'Science on Stage,' a science education festival. The next such festival is scheduled for spring 2007 in Grenoble. ESO also provides astronomy-related articles for 'Science in School' (a new European science education journal for teachers, scientists, and others) and produces 'Journey Across the Solar System' (a series of informational sheets) and a series of astronomy exercises 'based on real data from the VLT or HST, the former in collaboration with EAAE and the latter in collaboration with ESA. A new undertaking is ALMA ITP, where ALMA stands for the Atacama Large Millimeter Arraya new astronomical facility under construction in Chile's Atacama desert by ESO 'as part of a global collaboration' -and ITP stands for Interdisciplinary Teaching Project. The teaching material 'will highlight the links between 21st-century astronomy and the topics in engineering, earth sciences, biology, medicine, history and culture' related to ALMA's location in the Earth's driest spot. The goal of ALMA ITP is 'to introduce scientific topics to students as part of other school subjects, and also to put scientific research into a wider context'. Like other participants in the session, Pierce-Price spoke about the importance of such educational activities 'to ensure that future citizens, whatever their careers, have the scientific literacy they need to make informed decisions about issues related to science'.

Mary Ann Kadooka from the Institute for Astronomy at the University of Hawaii spoke about the special challenges and rewards of running an astronomy educational outreach program in Hawaii, which is very culturally diverse. In 'Astronomy Remote Observing Research Projects of USA High School Students,' Kadooka explained how the NSF's Toward Other Planetary Systems (TOPS) teacher enhancement workshops, held over 18-day periods between 1999 and 2003, were the first major effort to introduce math and science teachers from Hawaii and the Pacific Islands to astronomy. The participants, some of whom returned for several years, became 'a master teacher cadre to serve as the backbone of our student project efforts today'. Some of these continue to mentor former students, encouraging them to attend star parties, public lectures in astronomy, and other science-oriented events. Among the ongoing partnerships resulting from the TOPS program are those with the Bishop Museum, the Hawaii Astronomical Society, the American Association of Variable Star Observers, the Faulkes Telescope North (now part of the Las Cumbres Observatory), and NASA's Deep Impact Mission. Demonstrating that the PRO-AM relationship advocated by Fienberg and Bennett on the first day of the special session is already in effect in some locations, Kadooka described the contributions to astronomy education in Hawaii made by amateur astronomers. Hawaii's TOPS-trained teachers have mentored many student participants in science fairs in Hawaii and in Oregon (where one of Hawaii's master teachers now teaches in a Portland private school, where she offers an electivescience research course). A NASA IDEAS (Initiative to Develop Education through Astronomy and Space Science) grant awarded in May 2006 is making possible outreach to a new interisland target group of students from grades 7-10, including Native Hawaiians and 'at-risk, rural students'. To that end, mini-workshops were offered in autumn 2006 to interested and committed teachers on the islands of Maui and Molokai. To maximize the chances of entering 'exemplary student astronomy research projects' in the 2008 Hawaii State Science Fair, and with the hopes of having some of these make the cut for the 2008 Intel International Science Fair, students committed to doing research will be recruited for a summer 2007 week-long workshop on astrobiology.

Like other special session participants, *Richard Gelderman* of Western Kentucky University, USA, believes that 'our primary job as teachers is to prepare tomorrow's citizens, rather than to prepare tomorrow's scientists' and that 'Astronomy is perhaps the field of science where the biggest contribution can be made toward the creation of a scientifically literate society'. A proponent of 'hands-on, minds-on astronomy experiences', he advocates giving students 'greater access to astronomical telescopes'. In 'Global Network of Autonomous Observatories Dedicated to Student Research', he described the Bradford Robotic Telescope and 'the beginnings of global networks of autonomous observatories'. The Bradford Robotic Telescope, inaugurated in 1993, has had a positive impact on science education by providing for 'the general public's requests for queue-scheduled service observations as well as remote, manual operation', thus 'offering access to an autonomous observatory coupled with welldesigned projects and guided activities'. The opportunities that should become available from the proposed networks of autonomous observatories will doubtless enhance 'hands-on astronomical education', but 'other successful ways of engaging and teaching young people' should not be overlooked. Gelderman described some of these other educational possibilities, such as having students build their own 'simple, low-cost' telescopes, exposing them to WebCam technology, and-echoing Ferlet's earlier paper-engaging them in the Hands-On Universe program.

David H. McKinnon and co-author *Lena Danaia*, from Charles Sturt University, Bathurst, Australia, described in 'Remote Telescopes in Education: an Australian Study', how 'the use of remote telescopes can be harnessed to impact in positive ways the attitudes of students'. Echoing the earlier paper by Lomb *et al.*, McKinnon lamented the decline in science enrollments 'during the post-compulsory years of education' in Australia and elsewhere. In the mid-1990s McKinnon built the Charles Sturt University (CSU) Remote Telescope, which enabled students to get their own images of celestial objects. Impressed by 'the motivational impact that the control aspect of the CSU Remote Telescope had on primary age students', the Federal Government of Australia commissioned a study that developed educational materials for students and their teachers and assessed some outcomes in those who used them. Students who were given access to remote control of the CSU telescope not only acquired 'a significantly greater ability to explain astronomical phenomena', but also 'increased their astronomical knowledge significantly' and significantly improved their 'attitudes towards science in general and astronomy in particular'. McKinnon concluded by expressing the hope that access for students to the Las Cumbres Observatory's global telescope network will confirm 'the hypothesis that a love of astronomy can be engendered in more students'.

The final paper related to the 'effective use of instruction and information technology' was 'Visualizing Large Astronomical Data Holdings', by *Carol Ann Christian et al.* As 'huge quantities of observed or simulated data' become available, it is important both for educators and researchers to optimize the visual display of the astronomical information. Christian described several tools available for scientific visualization, including the

Sloan Digital Sky Survey Navigate Tool, which enables users of the SkyServer website to browse, create finding charts, and display portions of the sky in the form of catalog data; World Wind, a NASA Learning Technologies project, which allows exploration of Mars and the sky 'as represented by a number of all-sky surveys'; Digital Universe Atlas, from the American Museum of Natural Historys Hayden Planetarium, which enables users to browse the sky, find brown dwarfs, and carry out a number of educational activities; Science on a Sphere, developed by NOAA, which already makes it possible to examine data and phenomena on Earth, Mars, and the Moon, and soon will be adapted for all-sky survey data; and Google Earth, which currently enables the display of astronomical images, and should eventually 'allow interfaces to data archives, press release archives, and possibly the National Virtual Observatory'. McKinnon concluded by expressing the belief that 'with the emergence of large multi-wavelength all-sky survey data and collections of data ... visualization tools can be important for public understanding of science and education both in formal classroom and informal science center settings'.

4. Practical issues connected with the implementation of the 2003 IAU Resolution

The responses of a number of different countries to the IAU Resolution were discussed in this session, beginning with *Edvard V. Kononovich*'s 'Stellar Evolution for Students of Moscow University'. Advanced students specializing in astrophysics and with a strong background in theoretical astrophysics are assigned 'a special practicum work' that requires them to solve five problems using a PC program based on Paczynski code and supported by the Web interface, enabling them to use the Internet. Problem 1, which deals with zeroage main sequence (ZAMS) stellar models, requires students 'to calculate ZAMS models for three different star masses and two variants of the chemical composition'; problem 2, dealing with main sequence stellar models, requires student 'to calculate the evolutionary tracks for three stars with different masses during the time of hydrogen burning in the star core'; problem 3, dealing with 'the evolutional peculiarity of stars with different masses and different chemical composition,' requires them 'to calculate the evolutional tracks for three stars with the same composition and different masses,' and in one case 'to change the chemical composition'; problem 4, dealing with 'structure of red giants and supergiants,' asks students 'to calculate an evolutionary star track up to the supergiant branch'; and problem 5, relating to the evolutionary model of the present sun, asks students 'to compute the standard solar model ... using as free parameters that of the convection zone and of the chemical composition'.

Moving from the particular to the universal, *Maria C. Pineda de Carias* presented 'Astronomy for Everybody: An Approach from the CASAO', the acronym for Central America Suyapa Astronomical Observatory, part of the National Autonomous University of Honduras, where currently all professional astronomers in Honduras are employed, along with regional and foreign colleagues. After noting that 'Honduras is a country of very young people' and that 'most students are at elementary school level' with fewest students in university, she explained that the astronomical observatory of Honduras was inaugurated in 1997. In the ensuing decade not only did the observatory receive 'regional accreditation' but also initiated 'a regional program in astronomy and astrophysics at both undergraduate and graduate levels' for Central Americans'. She described three different outreach programs, targeting different audiences. One program, aimed at 'elementary and secondary school students, teachers, college students, parents, and media communicators', involves two-hour visits by groups of 20 to 100 to CASAO, where an astronomer delivers a lecture 'organized and adapted to the interest of the participants', followed by practical activities aimed at familiarizing the visitors with the use of 'small telescopes to observe the sun and planets' and at demonstrating 'how the Maya of Central America used stelae' to measure solar time and design solar calendars. The goals of this program include motivating 'the study of science, mathematics, and space exploration,' arousing 'curiosity for learning about what exists' beyond 'our own environment,' and introducing new resources for teaching and learning science. A second program involves Friday-night visits by the general public to the observatory. The goals of the 'Astronomical Nights Program' are to familiarize visitors with the night sky and the visible universe and give them the opportunity to make naked-eye observations under the guidance of a professional astronomer. Recognizing that most of the beneficiaries of these two programs come from the capital city, Tegucigalpa, the observatory is making an effort to reach children elsewhere in the country. A third program, 'Introduction to Astronomy @ Internet', is an online course written in Spanish, offered as an elective 'to all career students' in Honduras 'as part of their education' but particularly recommended for elementary and secondary school teachers, as well as to students and teachers elsewhere in Central and Latin America. The course 'represents an opportunity ... to be part of a scientifically literate generation, trained by professional astronomers'.

In 'The Epistemological Background of Our Strategies', *Mirel I. Birlan et al.* focused on the importance of identifying the fundamental concepts that astronomers wish to convey in educating the public. Only by being aware of 'the importance of the epistemological background' will astronomers succeed in 'defining the strategy of education in (through) astronomy', and in determining the role of astronomy should play as a required course within a general education curriculum, as it interacts with other scientific disciplines.

Turkey's response to the 2003 IAU Resolution, 'Towards a New Program in Astronomy Education in Secondary Schools in Turkey,' was presented by *Zeki Aslan*. Although before 1974, astronomy was taught on its own at the secondary level in Turkey, since then it has been incorporated into secondary-school physics courses as well as into elementary science and geography courses on the primary level. Most teachers on those levels, however, have had little formal preparation in astronomy, so that the teaching has not been 'very effective'. In addition, topics in astronomy 'are generally scheduled at the end of a particular course,' when there is little time left to devote to them. To remedy the situation, in 2005 the ITAK National Observatory (TUG) proposed to the Ministry of Education that a national meeting on 'teaching of astronomy and using astronomy to teach physics' be held for teachers of physics and astronomy teachers at the time of the 29 March 2006 total solar eclipse. The approximately 120 hand-picked schoolteachers and 10 schoolchildren 'had a beautiful sky to see the eclipse and to carry out ... experiments'. According to Aslan, the meeting, which involved 'astronomers and physicists from Turkish universities and educators from the Ministry of Education plus three educators from abroad', was 'very successful'. TUG subsequently submitted to the Ministry of Education a number of proposals, suggesting, among other things, that the Ministry of Education and TUG should collaborate in providing educational materials and in holding summer schools and in-service training for primary and secondary school teachers. Independently, in 2005 ME published a draft for a new primary-school science and technology course, in which astronomy topics, previously taught on the primary level as parts of other subjects and now presented under the rubric 'The Earth and the Universe', will make up nearly 10% of the entire course. A similar program for secondary schools is being prepared.

In 'Astronomy in the Russian Scientific-Educational Project', *Alexander V. Gusev* and *Irina Kitiashvili* decribed the International Center of the Sciences and Internet Technologies 'GeoNa' at Kazan University in the Republic of Tatarstan. Historically known as the home institution of mathematician Nikolai Lobachevsky, father of non-

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Euclidian geometry, Kazan University is now also the home of Center GeoNa ('Geometry of Nature'), 'a modern complex of conference halls including the Center for Internet Technologies, a 3D planetarium, … an active museum of natural sciences, an oceanarium, and a training complex …'. Through Center GeoNa, scientists and educators at Russian universities will be able to share their 'advanced achievements in science and information technologies' with foreign colleagues in 'scientific centers around the world'. In addition to hosting 'conferences, congresses, fundamental scientific research sessions' on lunar research, Center GeoNa also hopes to initiate a 'more intense program of exchange between scientific centers and organizations for a better knowledge and planning of their astronomical curricula and the introduction of the teaching of astronomy'.

Cecilia Scorza, on behalf of colleagues at ESO and the universities of Heidelberg and Leiden, presented 'Universe Awareness for Young Children' (UNAWE). This international program, 'motivated by the premises that access to the simple knowledge about the Universe is a birthright and that the formative ages of 4 to 10 years play an important role in the development of a human value system,' targets 'economically disadvantaged young children' in this age group and exposes them to 'the inspirational aspects of modern astronomy'. The program should be operational by 2009, the *International Year of Astronomy*, with goals including production of 'entertaining material in several languages and cultures,' organization of training courses for those who will present the program, and provision of a network for exchange of ideas and experiences. In 2006 pilot projects were carried out in Venezuela and Tunisia to examine UNAWE's feasibility. More information relating to UNAWE is available at `<http://www.UniverseAwareness.org/>`.

Ahmed A. Hady spoke about 'Education in Egypt and the Egyptian Response to Eclipses'. He began by summarizing the history of modern astronomy education at the university in Egypt, which began in 1936. The University of Cairo offers the bachelor of science degree in astronomy and physics, in astronomy, and in space science; a masters degree in astrophysics, in theoretical physics, and in space science; and a doctorate. Professional astronomical research is conducted at Cairo University and at Helwan Observatory in a variety of fields. Egyptian scientists participated in international observations of total solar eclipses in Egypt on 25 February 1952 and 29 March 2006. The more recent observations are being coordinated with the ESA/NASA *Solar and Heliospheric Observatory* (*SOHO*) and NASA's *Transition Region and Coronal Explorer* (*TRACE*) observations to show the magnetic structure of the corona.

Paul Baki described 'Spreading Astronomy Education Through Africa'. After explaining how different African societies 'practice astronomy largely for understanding and predicting the weather and climatic changes for seasons', he described 'some traditional tools that are used by some ethnic communities in East Africa to interpret astronomical phenomena for solving their local problems'. He noted that these communities 'combine the knowledge of plant and animal behavior changes together with sky knowledge to predict the weather and climate for the coming season'. Baki argued that from the African perspective, 'it seems that the best way to spread knowledge in astronomy is to begin by appreciating its cultural value'. He suggested incorporating the traditional practices into the standard astronomy curriculum, and predicted that by leading to environmental conservation and increased crop yields, as well as to an increase of tourism, such an approach would 'get recognition and possible funding from the various African governments'.

Located on the *Pampa Amarilla* in western Argentina, the Pierre Auger Cosmic Ray Observatory not only studies the highest energy particles in the universe but also participates, according to Beatriz Garcia, in 'a wide range of outreach efforts that link schools and the public with the Auger scientists and the science of cosmic rays, particle rays, particle physics, astrophysics, technologies'. In 'Education at the Pierre Auger Observatory:

The Cinema as a Tool in Science Education', Garcia described the use of educational videos for children between 6 and 11 and for general audiences, as well as the use of animation in science teaching and learning. She identified scientific outreach as a means of encouraging 'scientific vocations', particularly in countries where they are not accorded a high social status. Garcia asserted that 'if we want to help the student-public to think and be able to solve problems, the audio-visual language must be characterized by its originality and the search of new forms of expression that stimulate the imagination'.

The session concluded with *Mary Kay M. Hemenway*'s 'Freshman Seminars: Interdisciplinary Engagements in Astronomy'. To facilitate the transition of the diverse population of students entering the University of Texas at Austin to college academic and social life, the university offers freshman seminars limited to 15. Instructors invited to participate in the program may design the course of their choosing. The only stipulations are that students must complete a certain number of certain types of writing assignments, and must also attend 'sessions on time-management and using the library'; students whose seminars involve only two hours of class time each week must also attend an additional hour-long weekly event. Hemenway reported on two seminars rooted in astronomy. For a seminar focused on the life of Galileo, students modeled 'rotation and revolution of solar system objects with their own bodies'; experimented with lenses to master the concepts of focal length, field of view, and refracting telescopes; compared positions of Jovian satellites as Galileo drew them in *Sidereus Nuncius* with those calculated by the *Starry Night* computer program for the dates and location corresponding to Galileos depictions; and a dramatic reading of an English translation of Bertolt Brechts play 'Galileo'. These classroom activities were enriched by visits to the Blanton Museum of Art to view Italian art of the period, as a springboard to discussing the influence of religious struggles on contemporaneous artists; and to the Harry Ransom Center for humanities research, to expose students to original seminal works in the history of astronomy, including, among others, Ptolemy's *Almagest*, Copernicus's *De Revolutionibus*, and several by Galileo himself. A highlight of this seminar for many students is the mock trial 'in which Galileo has the benefit of something he lacked in reality-a defense team'. Students not assigned to either the prosecution or defense team participate in the judgment phase. A second seminar, 'Astronomy and the Humanities', students are exposed to science fiction, which they are asked to contrast with science facts known now and at the time of the writing; to poetry and literature with some astronomical connection; to a range of music with an astronomical theme; and to art work relating to astronomy. Hemenway concluded by noting that while the seminars' goal differs from that of introductory astronomy courses, Astronomy 101 instructors might do well to pick and choose from among the broad humanistic connections the seminars highlight to enrich the teaching of those standard academic offerings.

5. Abstracts of oral contributions

5.1. *Main Objectives for this IAU Special Session on Innovation in Teaching and Learning Astronomy. By Rosa M. Ros (Spain) and Jay M. Pasachoff (USA)*

In the IAU resolution on the Value of Astronomy Education, passed by the IAU XXV General Assembly in 2003, it was recommended: to include astronomy in school curricula, to assist schoolteachers in their training and backup, and to inform teachers about available resources.

The aim of this Special Session 2 on 'Innovation in Teaching/Learning Astronomy' is to contribute to the implementation of these recommendations, introducing innovative

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points of view regarding methods of teaching and learning. Astronomers from all countries – developed or developing – will be equally interested.

Astronomy attracts many young people to education in important fields in science and technology. But in many countries, astronomy is not part of the standard curriculum, and teachers do not receive adequate education and support. Still, many scientific and educational societies and government agencies have produced materials and educational resources in astronomy for all educational levels. Technology is used in astronomy both for obtaining observations and for teaching. In any case, it is useful to take this special opportunity to learn about the situation in different countries, to exchange opinions, and to collect information in order to continue, over at least the next triennium, the activities related to promoting astronomy throughout the world.

In particular, we would like to invite all participants to explain their positive original experiences so they can be adapted for other regions. Everyone is invited to exchange their initiatives and to try to involve other countries in common projects. All of us are in the same boat.

5.2. *Learning astronomy by doing astronomy. By John R. Percy (Canada)*

In the modern science curriculum, students should learn science knowledge or 'facts'; they should develop science skills, strategies, and habits of mind; they should understand the applications of science to technology, society, and the environment; and they should cultivate appropriate attitudes toward science. While science knowledge may be taught through traditional lecture-and-textbook methods, theories of learning (and extensive experience) show that other aspects of the curriculum are best taught by doing science – not just hands-on activities, but 'minds-on' engagement. That means more than the usual 'cookbook' activities in which students use a predetermined procedure to achieve a predetermined result. The activities should be 'authentic'; they should mirror the actual scientific process.

In this presentation, I will describe several ways to include science processes within astronomy courses at the middle school, high school, and introductory university level. Among other things, I will discuss: topics that reflect cultural diversity and 'the nature of science'; strategies for developing science process skills through projects and other practical work; activities based on those developed and carried out by amateur astronomers; topics and activities suitable for technical-level courses (we refer to them as 'applied' in my province); projects for astronomy clubs and science fairs; and topics that expose students to astronomy research within lecture courses.

5.3. *Hands-on Universe – Europe. By Roger Ferlet (France)*

The EU-HOU project aims at re-awakening the interest for science through astronomy and new technologies, by challenging middle and high schools pupils. It relies on real observations acquired through an internet-based network of robotic optical and radio telescopes or with didactical tools such as Webcam. Pupils manipulate and measure images in the classroom environment, using the specifically designed software SalsaJ, within pedagogical trans-disciplinary resources constructed in close collaboration between researchers and teachers. Gathering eight European countries coordinated in France, EU-HOU is partly funded by the European Union. All its outputs are freely available on the Web, in English and the other languages involved. A European network of teachers is being developed through training sessions.

5.4. *Life of the Earth in the solar atmosphere. By Edvard V. Kononovich, Olga B. Smirnova, T.V. Matveychuk, G.V. Jakunina, and S.A. Krasotkin (Russia)*

The theory of stellar interior is a very stimulating tool of the physical and astrophysical curricula. To support the corresponding lecture courses, a practical work was proposed and elaborated upon in 1991 for advanced students of physics specializing in astrophysics at Moscow State University. The work is recommended for 5th year students and requires significant knowledge in theoretical astrophysics. The main purpose of the work is to calculate the evolutionary set of stellar models, including those for the Sun. The PC program is based on the B. Paczynski set of routines and supported by the Web interface. This allows working via Internet. The results of the work may be presented both in a table and graph form.

5.5. *A model of teaching astronomy to pre-service teachers that allows for creativity in communicating students' understanding of seasons. By W.R. MacIntyre (New Zealand)*

This paper details a model of teacher development for astronomy concepts that allows students to demonstrate their understanding of basic astronomy concepts as well as communicating that understanding in creative ways. Several key features of the model is the inclusion of starting from students' initial understanding about astronomical concepts, providing the time for students to assess their mental models with 3-D models, and individual student assessment of their astronomical understanding using 3-D models. It appears that the three features collectively provide an appropriate creative environment for students. Two students created two new 3-D models in order to communicate specific aspects of seasons – different solar inputs and varying lengths of day/night throughout the year. The students are interviewed highlighting the rationale for creating the new 3-D models. The uptake by other students, during the modelling assessment task, demonstrated their usefulness in communicating astronomical understanding of seasons. The model of teacher development illustrates how teacher educators can teach for astronomy understanding as well as allow for creative ways to communicate that understanding to others an essential disposition to being an effective astronomy educator in the classroom.

5.6. *How to teach, learning, doing and enjoying astronomy. By Rosa M. Ros (Spain)*

This contribution deals with the author's experience organising a summer school for European teachers over ten years and the parallels with the everyday school for students.

The main interests for teachers are similar to students. It is necessary to give them:

- answers to their questions;

- practical activities: learning by doing;

- study astronomy using different approaches: making models, cutting, drawings, playing in the playground and, in general, make them feel like actors in the teaching/learning process;

- astronomical activities can help teachers/students to teach/learn mathematics or physics in a more appropriate way to attract young people to science;

- simple and clear language. It is good to reduce the specialized language and try to play with the proximity to the student;

- methods which promote rationality, curiosity and creativity. All schools have a sky over their buildings, it must be used to observe and take measurements;

- a contextualized approach to astronomy. Do not present the concepts in an isolated way. The school must be connected with the place where students are living;

In summary, students should feel a positive passion related to some astronomical experiences; then they will add a positive connotation to astronomy.

This presentation will mix some concrete examples of all these ideas.

5.7. *Clickers: a new teaching tool of exceptional promise. By Douglas K. Duncan (USA)*

Wireless student response systems – 'clickers' – address two of the oldest and most fundamental challenges in teaching: how to engage students, and how to determine if they are learning what you are teaching. Clickers are relatively low cost and easy to use, and their use is spreading remarkably fast throughout the US, with many universities using thousands. Astronomy textbooks may be ordered with coupons for clickers in them.

The way the system works is that each student's clicker has buttons *a*, *b*, *c*, *d*, and *e*. Any time the instructor wants feedback, he or she asks a multiple choice question. Student responses go to a receiver that plugs into a computer (e.g., the instructor's) showing responses as a bar chart. The chart is often shown to the class via an LCD projector. Clickers give immediate feedback about what each student is thinking. The instructor can decide whether to proceed or to spend more time on a particular topic. Equally valuable, the student learns immediately whether he or she understands the concept the teacher is presenting, without waiting for a test or raising their hand to ask a question.

I will present extensive research data that show that when clickers are used well in large lecture classes, they increase the engagement of students and improve their learning by a significant amount. Students overwhelmingly like using clickers and believe they increase their learning. They also increase class attendance, typically by 20 %. Like any technology, it is possible to misuse clickers. Common mistakes made by new clicker users and how to avoid them will be described, as well as 'best clicker uses' such as peer instruction. (Peer instruction means that when the class answers are split, students have to debate with their neighbor who is right, rather than the instructor telling them.)

This presentation will feature a demonstration of the clickers, with one given to each person in attendance.

5.8. *Teaching the evolution of stellar and Milky Way concepts through the ages: a tool for the construction of a scientific culture using astrophysics. By Gilles Theureau (France)*

I will report on a two-semester experience at the Orlans University (France) of a course of history and epistemology of the concepts of stars and galaxies from Antiquity to early XXth century. The framework is a 'module d'ouverture' of the new Licence-Master-Doctorate reform of French University, i.e., a transversal course aiming at providing a scientific culture to a mixed set of students from various fields (law, languages, sport, physics, etc.). Due to the number of students and to their wide heterogeneity, the form chosen has been a 22 hours lecture distributed in 10 lessons plus one planetarium session. Special attention was made to regularly refer to and read through original historical texts. The final evaluation was centered on collecting reading notes and commentaries on an original (full) text book. The text was chosen among a list of various references covering the whole period of interest, each student or group presenting his own report.

5.9. *Educational opportunities in pre-Am collaboration. By Richard T. Fienberg (USA)*

While many backyard stargazers take up the hobby just for fun, many others are attracted to it because of their keen interest in learning more about the universe. The best way to learn science is to do science. Happily, the technology available to today's amateur astronomers – including computer-controlled telescopes, CCD cameras, powerful astronomical software, and the Internet – gives them the potential to make real contributions to scientific research and to help support local educational objectives.

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Meanwhile, professional astronomers are losing access to small telescopes as funding is shifted to larger projects, including survey programs that will soon discover countless interesting objects needing follow-up observations. Clearly the field is ripe with opportunities for amateurs, professionals, and educators to collaborate. Amateurs will benefit from mentoring by expert professionals, pros will benefit from observations and data processing by increasingly knowledgeable amateurs, and educators will benefit from a larger pool of skilled talent to help them carry out astronomy-education initiatives.

We will look at some successful pro-am collaborations that have already borne fruit and examine areas where the need and/or potential for new partnerships is especially large. In keeping with the theme of this special session, we will focus on how pro-am collaborations in astronomy can contribute to science education both inside and outside the classroom, not only for students of school age but also for adults who may not have enjoyed particularly good science education when they were younger. Because nighttime observations with sophisticated equipment are not always possible in formal educational settings, we will also mention other types of pro-am partnerships, including those involving remote observing, data mining, and/or distributed computing.

5.10. *Education efforts of the International Astronomical Union. By Jay M. Pasachoff (USA)*

I describe the education activities of the IAU, particularly the work of Commission 46 on Education and Development. We are most interested in education in schools and for general university education rather than for pre-professional training or graduate schools. We have over 75 National Liaisons, mostly from member countries of the IAU but some from nonmembers or regional groupings. We operate through 10 program groups, which are described at our website at <http://www.astronomyeducation.org>. We also organize Special Sessions at IAU General Assemblies, such as this Special Session 2 on Innovation in Teaching/Learning Astronomy Methods, organized by Rosa M. Ros and me, and Special Session 5 on Astronomy for the Developing World, organized by John B. Hearnshaw. A modified version of our Special Session from the 2003 IAU XXV General Assembly in Sydney was published as *Teaching and Learning Astronomy: Effective Strategies for Educators Worldwide* (Jay M. Pasachoff & John R. Percy, eds., 2005, Cambridge: CUP). Michèle Gerbaldi and Edward F. Guinan run the IAU International Schools for Young Astronomers. James C. White heads the IAU Program Group on Teaching Astronomy for Development. John B. Hearnshaw runs the IAU Program Group for the Worldwide Development of Astronomy. Charles R. Tolbert and John R. Percy run the IAU Exchange of Astronomers program with a limited number of grants for stays of over three months between astronomers in developing countries and established astronomical institutions. Barrie W. Jones, as vice-president, aided by Tracey J. Moore, runs the Newsletter and keeps track of the National Liaisons list. I run the Program group of Public Education at the Times of Solar Eclipses.

5.11. *Astronomy and culture. By Magda G. Stavinschi (Romania)*

Astronomy is, by definition, the sum of the material and spiritual values created by mankind and of the institutions necessary to communicate these values. Consequently, astronomy belongs to the culture of each society and its scientific progress does nothing but underline its role in culture. It is interesting that there is even a European society which bears this name 'Astronomy for Culture' (SEAC). Its main goal is 'the study of calendric and astronomical aspects of culture'. Owning ancient evidence of astronomical knowledge, dating from the dawn of the first millennium, Romania is interested in this topic. But astronomy has a much deeper role in culture and civilization. There are many

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aspects that deserve to be discussed. Examples? The progress of astronomy in a certain society, in connection with its evolution; the place held by astronomy in literature and, generally, in art; the role of the SF in the epoch of super-mediatization; astronomy and belief; astronomy and astrology in the modern society, and so forth. These are problems that can be of interest for IAU; but, the most important one could be her educational role, in the formation of the culture of the new generation, in the education of the population for the protection of our planet, and in the ensuring of a high level of spiritual development of the society in the present epoch.

5.12. *Light pollution a tool for astronomy education. By Margarita Metaxa (Greece)*

The problem of light pollution exists most everywhere and is still growing rapidly. The maintenance of dark skies at a prime astronomical location, and elsewhere as well, depends very much on the awareness of the public, and particularly with key decision makers responsible for developments, including lighting engineers. It is necessary to continually promote awareness of light pollution and its effects. Thus, the preservation of the astronomical environment is strongly connected and requires effective education. We will present the educational project that the newly formed Commission for the Prevention of Light Pollution, which the Hellenic Astronomical Society will support based on innovating teaching of astronomy. The framework of the project will be to collaborate through our National Pedagogical Institute with all possible school networks so to efficiently introduce the topic to schools and to relate it with our national curriculum. The help of astronomers and lighting engineers through the respective Commission will facilitate and provide the natural environment for this educational project. The duration will be two years, and through the project we expect the students-teachers to act as 'reporters' for this serious problem.

5.13. *Student gains in understanding the process of scientific research. By Travis A. Rector, Catherine A. Pilachowski, and Melina J. Young (USA)*

Research-Based Science Education is a method of instruction that models the processes of scientific inquiry and exploration used by scientists to discover new knowledge. It is 'research based' in the sense that students work together in self-guided, cooperative groups on a real research project. In other words, in order to learn science, students are given the opportunity to actually do science. Here we present the results of a study of undergraduate students that were given the opportunity to work on a research project underway to search for novae in Local Group galaxies. Students analyzed images obtained regularly from the WIYN 0.9 m telescope on Kitt Peak. Novae were found by blinking these images. Aperture photometry was used to generate light curves and measure decay rates. Students then explored individually chosen questions, such as comparing the location of novae in the galaxy and their rates of decay. Students then wrote research papers and gave oral presentations to the class. To assess their development in the understanding of science as a process, students completed pre- and post-concept maps on the topic of 'scientific research'. Each map was assessed for an understanding of the following ten concepts. Scientific research is: a process (i.e., a series of many steps over time); based upon prior knowledge or previous research; based on a hypothesis/question; uses experimentation; data collection; data representation (e.g., charts, tables and graphs); requires equipment; analysis/interpretation; generates results/conclusions; and results that link back to modify the initial hypothesis iteratively. Overall, students made significant gains on the concept maps, showing greater depth in the number of concepts and their relationships. On average, students increased the number of the ten understood concepts listed above from 2.8 before the class to 5.4 afterwards.

5.14. *Effects of collaborative learning on students' achievements in introductory astronomy.*
By Myung-Hyun Rhee, S.-W. Kim, E.-J. Kim, J. Kim (Republic of Korea)

For the last few years, we have performed various Collaborative Learning (CL) sessions in the classes of the Introductory Astronomy course for non-science majors at Yonsei University, Seoul, Korea. We present some results from these experiments, mainly focusing on the effects of Collaborative Learning (CL) on university students' Communication Apprehension (CA), Class Satisfaction and Academic Achievement.

The main results we found are as follows:

(1) The amount of CA reduction is proportional to the number of CL sessions; the amount of CA reduction of the nine CL students was much higher than that of the zero CL (control group), two CL and five CL students.

(2) The amount of CA reduction was greater with the higher CA students.

(3) CA reduction effect was intact after a half year later.

(4) Academic Achievement of the nine CL students was higher than that of the two CL, five CL and control group students.

(5) Students' Class Satisfaction also showed more or less the same results with Academic Achievement.

5.15. *Worldwide on-line distance learning university astronomy. By Stewart P.S. Eyres, B.J.M. Hassal, I. Butchart, and Gordon E. Bromage (United Kingdom)*

The University of Central Lancashire operates a suite of distance learning courses in Astronomy, available both on-line and via CD-ROM. The courses are available worldwide, and emphasize flexibility of study. To this end, students can study anything from a single module (1/6th of a full year at degree level) all the way up to an entire degree entirely by distance learning. Study rates vary from one to four modules each year, and students can move on to Level 2 modules (equivalent to second year level in a UK degree) before completing the full set of Level 1 modules. Over 1000 awards have been made to date. The core syllabus is Astronomy and Cosmology at Level 1, alongside skills in literature research, using computers, and basic observing. We also offer a basic history of European astronomy. At Level 2, we look at the astrophysics of the Sun, the stars, and galaxies including the Milky Way. By Level 3, students are expected to engage in a large individual project, and a collaborative investigation with other students, alongside high-level courses in cosmology, relativity, extreme states of matter and the origins of the elements, life and astronomical objects. While many students are retired people looking to exercise their brains, keen amateurs or professionals with disposable incomes, a significant fraction are teachers seeking to improve their subject knowledge or high school students gaining an edge in the UK University entrance competition. Via our involvement with SALT, we offer our courses to members of previously disadvantaged communities. This leads to an incredibly diverse and lively student body.

5.16. *Edible astronomy demonstrations. By Donald A. Lubowich (USA)*

By using astronomy demonstrations with edible ingredients, I have been able to increase student interest and knowledge of astronomical concepts. This approach has been successful with all age groups from elementary school through college students. I will present some of the edible demonstrations I have created including using popcorn to simulate radioactivity; using chocolate, nuts, and marshmallows to illustrate density and differentiation during the formation of the planets; and making big-bang brownies or chocolate-chip cookies to illustrate the expansion of the universe. Sometimes the students eat the results of the astronomical demonstrations. These demonstrations are an effective teaching tool and the students remember these demonstrations after they are presented.

5.17. *Amateur astronomers as public outreach partners. By Michael A. Bennett (USA)*

Amateur astronomers involved in public outreach represent a huge, largely untapped source of energy and enthusiasm to help astronomers reach the general public. Even though many astronomy educators already work with amateur astronomers, the potential educational impact of amateur astronomers as public outreach ambassadors remains largely unrealized.

Surveys and other work by the ASP in the US show that more than 20 % of astronomy club members routinely participate in public engagement and educational events, such as public star parties, classroom visits, work with youth and community groups, etc. Amateur astronomers who participate in public outreach events are knowledgeable about astronomy and passionate about sharing their hobby with other people. They are very willing to work with astronomers and astronomy educators. They want useful materials, support, and training. In the USA, the ASP operates 'The Night Sky Network', (funded by NASA). We have developed specialized materials and training, tested by and used by amateur astronomers. This project works with nearly 200 local astronomy clubs in 50 states to help them conduct more effective public outreach events. It has resulted in nearly 3,600 outreach events (reaching nearly 300,000 people) in just two years. In this presentation we examine key success factors, lessons learned, and suggest how astronomers outside the US can recruit and work with 'outreach amateur astronomers' in their own countries.

5.18. *Does the Sun rotate around the Earth or roes the Earth rotate around the Sun? – An important aspect of science education. By Syuzo Isobe (Japan)*

Sciences are continuously developing. This is a good situation for the sciences, but when one tries to teach scientific results, it is hard to decide which levels of science should be taught in schools. The point to evaluate is not only the quality of scientific accuracy, but also the method with which school students of different scientific abilities study scientific results. In astronomy, an important question, which is 'Does the Sun rotate around the Earth or does the Earth rotate around the Sun?' can be used to evaluate student abilities. Scientifically, it is obvious that the latter choice is the better answer, but it is not so obvious for the lower-grade students and also for the lower-ability students even in the higher grades. If one sees daily the sky without scientific knowledge, one has an impression of 'the Sun rotates around the Earth,' and for his rest of his life he will not see any problem. If one wants to be a scientist, though, he should know that 'the Earth rotates around the Sun' before reaching university level. If he will become a physical scientist, he should understand that it is not correct to say 'the Earth rotates around the Sun,' but he should know that the Earth rotates around the center of gravity of the solar system. A similar type of question is 'has the Earth the shape of a sphere, or a pear, or a geoid?'

There are many teachers with varying ranges of students who do not understand the proper level of science instruction. When students of lower capacity are instructed to understand concepts with the higher degrees of sophistication, they can easily lose their interest in the sciences. This happens in many countries, especially in Japan, where there are many different types of people with different jobs. We, as educators, should appreciate that the students can be interested in any given scientific idea, no matter what level of sophistication it is.

5.19. *Using sounds and sonifications for astronomy outreach. By Fernando J. Ballesteros (Spain)*

It is well known that good astronomy pictures play a great role in astronomy outreach, triggering curiosity and interest, as in the case of *HST* pictures. But this same aim can also be obtained by means of sounds. Here I present the use of astronomy-related sounds and data sonifications to be used for astronomy outreach. Examples of these sounds are the case of the *Cassini* probe passing through Saturn's rings, radio signals from pulsars, black holes, aurorae, or signals from space missions, among many others. These are sounds that people, usually, will never hear and are a good tool for provoking an interest when teaching astronomy. In our case, sounds are successfully used in a weekend science-spreading program of the Spanish National Broadcast RNE, called 'The sounds of science'. But teachers can also make use of them in the classroom easily, as sounds only require a simple cassette player

5.20. *Teaching astronomy and the crisis in science education. By Nicholas R. Lomb, T.M. Stevenson, M.W.B. Anderson, and G.G. Wyatt (Australia)*

In Australia, as in many other countries, the fraction of high school students voluntarily choosing to study the core sciences such as physics and chemistry has dropped in recent decades. There seems to be a number of reasons for this worrying trend, including the perception that they are difficult subjects that lack relevance to the lives of the students. Family influence to choose courses that are believed to be more likely to lead to highly paid careers is also a major factor.

Astronomy has a broad public appeal and escapes much of the negative feelings associated with most other scientific fields. Anecdotally and logically, this allows astronomy to be used as a tool to stimulate students' scientific interest. While this is most evident at college level in the USA and at Australian universities, informal education centres can play an important role. Investment in public facilities and the provision of resources for astronomy outreach can be highly beneficial by engaging the imagination of the public. We will discuss activities offered at Sydney Observatory where public attendance have more than doubled in the last decade. These include a regular schools program and preliminary results from a survey of teachers' experiences and attitudes to their class visit will be given.

5.21. *Astronomy for all as part of a general education. By John E.F. Baruch, D.G. Hedges, J. Machell, C.J. Tallon, and K. Norris (United Kingdom)*

This paper evaluates a new initiative in support of the aim of Commission 46 of the IAU to develop and improve astronomy education at all levels throughout the world. This paper describes a free facility to support education programmes which include basic astronomy and are delivered to students who have access to the internet on `<www.telescope.org/>`.

This paper discusses the role of robotic telescopes in supporting both students and their teachers and shows that, although robotic telescopes have been around for some time, almost all of them are designed to cater to an elite, a tiny percentage, group of students. These telescopes are generally not true autonomous robots but remotely driven telescopes. This paper shows how truly autonomous robots offer the possibility of delivering a learning experience for all students in their general education. The experience of the Bradford Robotic telescope is discussed. This telescope is on track to deliver the initial levels of astronomy education to all school students in the UK.

The problems of delivering a web-based education programme to very large numbers of students are discussed. Traditionally innovative astronomy programmes have been delivered through enthusiastic teachers with considerable expertise in IT and astronomy.

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This paper looks at the problems of delivering such a programme with teachers who have little confidence working with IT and little knowledge of basic astronomy and discusses practical solutions. The facility is available free of charge and it is intended to continue to be so.

5.22. *A status report from the IAU Division XII Working Group on Communicating Astronomy with the Public. By Dennis R. Crabtree (Canada), E. Ian Robson (UK), and Lars Lindberg Christensen (Germany)*

This Division XII Working Group was created in 2004 following a conference entitled 'Communicating Astronomy to the Public' held at the US National Academy of Sciences in Washington, DC, in early October, 2003. The Working Group's Mission Statement is as follows:

Mission statement:

To encourage and enable a much larger fraction of the astronomical community to take an active role in explaining what we do (and why) to our fellow citizens.

To act as an international, impartial coordinating entity that furthers the recognition of outreach and public communication on all levels in astronomy.

To encourage international collaborations on outreach and public communication.

To endorse standards, best practices and requirements for public communication.

This paper will report on the achievements and progress made since the working group's formation and present our plans for the next three years.

5.23. *Outreach using media. By Julieta Fierro (Mexico)*

Outreach is the best way to carry out informal astronomy education during a person's life. Astronomy is such an attractive and evolving discipline that people of all age levels are usually attracted to it in spite of feeling threatened by the apparent difficulty of science. During my presentation I shall address the importance of astronomical popularization. I shall mention fundraising for its diffusion employing radio and television programs. Simple demonstrations will also be included. I will also remind members of Commission 46 that 2009 might become the *Year of Astronomy* and mass media are an ideal way for publicizing astronomical outreach projects.

5.24. *Hands-on science communication. By Lars Lindberg Christensen (Germany)*

Many of the most important questions studied in science touch on fundamental issues with a great popular appeal, such as: How was the world created? How did life arise? Are we alone? How does it all end?

Communication of science to the public is important and will play an even greater role in the coming years. The communication of achieved results is more and more often seen as a natural and mandatory activity to inform the public, attract funding, and attract science students. In some countries, university statutes are even being rewritten in these years to include communication with the public as the third mandatory function besides research and education.

A number of interesting 'lessons learned' from the daily work at the Education and Outreach (EPO) office of the European Space Agency's Hubble Space Telescope will be presented. The topics include conventional as well as unconventional issues such as:

* How does the flow of communication from scientist to public work, which actors are involved, and which pitfalls are present in their interaction? How can possible problems be avoided?

* What are the criteria that determine whether press releases 'make it' or not?

* How can a commercial approach benefit an EPO office?

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* What is the right skills base in a modern EPO office?
* How can modern technology be used to communicate science more efficiently?

5.25. *Critical evaluation of the New Hall of Astronomy for the Science Museum.*
By Silvia Torres-Peimbert (Mexico)

In December 2004, a new astronomy exhibit was opened at 'Universum', the Science Museum at the University of Mexico. The displays are presented in several sections: (*i*) Sun, stars and matter between the stars; (*ii*) clusters, galaxies and the universe as a whole; and (*iii*) the tools of astronomers.

The main concept is not limited to the description of each component, but also incorporates the idea that all components, including the universe, are subject to continuous evolution. In addition, a representation of the vastness of space, a timeline from the Big Bang to the present epoch, and some video clips from local astronomers are included. As a complement to the exhibit, a section on the history of astronomy is also included. We are now in the process of assessing the impact of the different elements of this exhibit among the visitors. The results of this evaluation will be presented.

5.26. *Revitalizing astronomy teaching through research on student understanding.*
By Timothy F. Slater (USA)

Over the years, considerable rhetoric exists which instructional strategies induce the largest conceptual and attitude gains in non-science majoring, undergraduate university students. To determine the effectiveness of lecture-based approaches in astronomy and astrobiology, we found that student scores on a 68-item pre-test/post-test concept inventory showed a statistically significant increase from 30 % to 52 % correct. In contrast, students evaluated after the use of Lecture-Tutorials for Introductory Astronomy increased to 72 %. The Lecture-Tutorials for Introductory Astronomy are intended for use during lecture by small student groups and compliment existing courses with conventional lectures. Based on extensive research on student understanding, Lecture-Tutorials for Introductory Astronomy offer professors an effective, learner-centered, classroom-ready alternative to lecture that does not require any outside equipment or drastic course revision for implementation. Each 15-minute Lecture-Tutorial for Introductory Astronomy poses a carefully crafted sequence of conceptually challenging, Socratic-dialogue driven questions, along with graphs and data tables, all designed to encourage students to reason critically about difficult concepts in astronomy and astrobiology.

5.27. *ESO's astronomy education programme.*
By Douglas P.I. Pierce-Price, Henri Boffin, and Claus Madsen (Germany)

ESO, the European Organisation for Astronomical Research in the Southern Hemisphere, has operated a programme of astronomy education for some years, with a dedicated Educational Office established in 2001. We organise a range of activities, which we will highlight and discuss in this presentation. Many are run in collaboration with the European Association for Astronomy Education (EAAE), such as the 'Catch a Star!' competition for schools, now in its fourth year.

A new endeavour is the ALMA Interdisciplinary Teaching Project (ITP). In conjunction with the EAAE, we are creating a set of interdisciplinary teaching materials based around the Atacama Large Millimeter Array project. The unprecedented astronomical observations planned with ALMA, as well as the uniqueness of its site high in the Atacama Desert, offer excellent opportunities for interdisciplinary teaching that also encompass physics, engineering, earth sciences, life sciences, and culture.

Another ongoing project in which ESO takes part is the 'Science on Stage' European science education festival, organised by the EIROforum – the group of seven major European Intergovernmental Research Organisations, of which ESO is a member. This is part of the European Science Teaching Initiative, along with Science in School, a newly launched European journal for science educators.

Overviews of these projects will be given, including results and lessons learnt. We will also discuss possibilities for a future European Astronomy Day project, as a new initiative for European-wide public education.

5.28. *Astronomy remote observing research projects of USA high school students. By Mary Ann Kadooka (HI, USA)*

In order to address the challenging climate for promoting astronomy education in the high schools, we have used astronomy projects to give students authentic research experiences in order to encourage their pursuit of science and technology careers. Initially, we conducted teacher workshops to develop a cadre of teachers who have been instrumental in recruiting students to work on projects. Once identified, these students have been motivated to conduct astronomy research projects with appropriate guidance. Some have worked on these projects during non-school hours and others through a research course. The goal has been for students to meet the objectives of inquiry-based learning, a major US National Science Standard. Case studies will be described using event-based learning with the NASA Deep Impact mission. Hawaii students became active participants investigating comet properties through the NASA *Deep Impact* mission. The Deep Impact Education and Public Outreach group developed materials which were used by our students. After learning how to use image processing software, these students obtained Comet 9P/Tempel 1 images in real time from the remote observing Faulkes Telescope North located on Haleakala, Maui, for their projects. Besides conducting event-based projects which are time critical, Oregon students have worked on galaxies and sunspots projects. For variable star research, they used images obtained from the remote observing offline mode of Lowell Telescope, located in Flagstaff, Arizona. Essential to these projects has been consistent follow-up required for honing skills in observing, image processing, analysis, and communication of project results through Science Fair entries. Key to our success has been the network of professional and amateur astronomers and educators collaborating in a multiplicity of ways to mentor our students. This work-in-progress and process will be shared on how to inspire students to pursue careers in science and technology with these projects.

5.29. *Global network of autonomous observatories dedicated to student research. By Richard Gelderman (USA)*

We will demonstrate operation of one or more meter-class telescopes devoted to student-initiated astronomical research projects. For multiple decades, astronomers have promised each other the development of global networks of telescopes. For the last decade, without ever fulfilling the initial promise, we have upped the ante and promised global networks of robotic telescopes. Sometimes the network is to be composed of 20- to 40-cm aperture telescopes; other times the network will include meter-class telescopes. Sometimes the network is exclusive to a select, small group of users; other times the dream is open to any interested parties. Western Kentucky University, the Hands-On Universe project, and NASA's Kepler mission have achieved the first components of a network of telescopes established for educational programs. We will discuss the process used by teachers and students to make use of a substantial fraction of the network's observing time, and to access most of the archived data. Examples of student projects will be shared, along with immediate plans for expanding the network.

5.30. *Remote telescopes in education: an australian study.*
By David H. McKinnon, and L. Danaia (Australia)

In 2004, the Australian Federal Department of Education, Science and Training funded a study into the impact of using remote telescopes in education in four educational jurisdictions: The Australian Capital Territory, New South Wales, Queensland, and Victoria. A total of 101 science teachers and 2033 students in grades 7 - 9 provided pre-intervention data. Students were assessed on their astronomical knowledge, alternative conceptions held, and ability to explain astronomical phenomena. They also provided information about the ways in which science is taught and their attitudes towards the subject. Teachers provided information about the ways in which they teach science. Students (N = 1463) and teachers (N = 35), provided the same data after the intervention was completed. The return rate for students and teachers was 71 % and 34 % respectively. This represents the largest study undertaken involving the use of remote telescopes in education. The intervention comprised a set of educational materials developed at Charles Sturt University (CSU) and access to the CSU Remote Telescope housed at the Bathurst Campus, NSW. Outcomes showed that students had increased their astronomical knowledge significantly.

5.31. *Visualizing large astronomical data holdings.*
By Carol A. Christian, A. Connolly, A. Conti, N. Gaffney, S. Krughoff, B. McClendon, A. Moore, and R. Scranton (USA)

Scientific visualization involves the presentation of interactive or animated digital images for interpretation of potentially huge quantities of observed or simulated data. Astronomy visualization has been a tool used to convey astrophysical concepts and the data obtained to probe the cosmos. With the emergence of large astrophysical data archives, improvements in computational power and new technologies for the desktop, visualization of astronomical data is being considered as a new tool for exploration of data archives with a goal to enhance education and public understanding of science.

We will present results of some exploratory work in the use of visualization technologies from the perspective of education and outreach. These tools are also being developed to facilitate scientists2019 use of such large data repositories as well.

5.32. *Stellar evolution for students of Moscow University.*
By Edvard V. Kononovich (Russia)

Theory of stellar interior is a very stimulating tool of the physical and astrophysical curricula. To support the corresponding lecture courses, a practical work was proposed and elaborated upon in 1991 for advanced students of the physics department who specialized in astrophysics at Moscow State University. The work is recommended for 5th year students and requires significant knowledge of theoretical astrophysics. The main purpose of the work is to calculate the evolutionary set of stellar models, including those for the Sun. The PC program is based on the B. Paczynski set of routines and supported by the WEB interface. This allows working via Internet. The results of the work may be presented both in table and graph forms.

5.33. *Astronomy for everybody: an approach from the CASAO.*
By Maria C. Pineda de Carias (Honduras)

Astronomy is a science that attracts the attention of all ages of people from a variety of views and interests. At the Central America Suyapa Astronomical Observatory of

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the National Autonomous University of Honduras (CASAO/NAUH), the formal general course of Introduction to Astronomy (AN-111) for all-careers students and the regular courses for a Master in Astronomy and Astrophysics students, three different academic outreach programs have become of importance, after less than a decade of experience. A 'Visiting the CASAO/NAUH Program' is aimed at elementary and secondary schools, where astronomers three times per week present to groups from fifteen up to one hundred students and their teachers. Conferences on selected topics of astronomy, illustrated with real sky and astronomical objects and images, give the opportunity to observe the sun, the moon and planets using a small telescope. They explain how astronomers today perform their observations and, also, how the Mayas that inhabited Central America did their observations during their time. The 'Astronomical Nights Program', intended for the general public, children, youth and adults who attend on Friday nights at the Astronomical Observatory, learn about astronomical bodies' properties, the sky of the week, and the differences in making observations using small telescopes and with a naked eye. 'Intro_Astro@Internet' is an online course program designed for school teachers and is also used by college and university students of Central America willing to learn more systematically on their own using new technologies about the sky, the solar system, the stars, and the universe. In this paper we present a complete description of these programs and the ways they are currently developed at CASAO/NAUH, and a discussion of how these programs contribute to the implementation of the IAU Resolution on the Value of Astronomy Education.

5.34. *The epistemological background of our strategies.* *By Mirel I. Birlan (France), Gheorghe Vass, and Constantin Teleanu (Romania)*

The major objectives of the long-term strategy in promoting a scientific discipline into the education sphere may be the following:
- A permanent presence of the discipline inside the general education;
- A good harmonisation with other disciplines (at least the scientific ones); and
- A maximal efficiency of its presence as a required discipline.

Before any practical approaches (social, administrative, or any other), it is required (necessary) that the promoters of any discipline formulate and underline its cognitive and formative contribution. This can be done only by starting with the epistemological statute of the discipline and its pedagogical implications.

Defining the epistemological statute, as well as the requirements of an optimal communication among the options concerning the orientation (re-orientation) of educational strategies, brings forth the necessity of analysing some fundamental concepts, with epistemological characters.

Even if it seems to be known by everyone, usually the concepts are not taken into account with their real importance. The fundamental concept we refer to herein constitute a real 'conceptual network' who, *volens-nolens*, is the epistemological background for any strategy of education relative to science.

Being conscious of the importance of the epistemological background will permit the modification of the beginning and the references used in defining the strategy of education in (through) astronomy.

5.35. *Towards a new program in astronomy education in secondary schools in Turkey.* *By Zeki Aslan and Zeynel Tunca (Turkey)*

It has been of great concern for Turkish astronomers that the teaching of astronomy, which is a part of the physics course in secondary schools, is not very effective, or not taught at all, mainly because the majority of the physics teachers have had no formal

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education in astronomy. Knowing this, TUBITAK National Observatory (TUG) proposed to the Ministry of Education in 2005 that a national meeting for physics and astronomy teachers be held during the opportune time of the total solar eclipse of 29 March, 2006, with the subject matter 'teaching of astronomy and using astronomy to teach physics'. The meeting, with participation of teachers from all over Turkey, has been very successful. The speakers were astronomers and physicists from Turkish universities and educators from the Ministry, plus three educators from abroad. A text containing minutes of the meeting has been submitted to the Ministry of Education. The details and their relevance to the 2003 IAU Resolution and the role TUG has undertaken will be presented.

5.36. *Astronomy in the Russian scientific-educational project KazanGeoNa2010. By Alexander V. Gusev and Irina Kitiashvili (Russia)*

The European Union promotes the Sixth Framework Programme. One of the goals of the EU Programme is opening national research and training programs. A special role in the history of the Kazan University was played by the great mathematician Nikolai Lobachevsky – the founder of non-Euclidean geometry (1826). Historically, the thousand-year old city of Kazan and the two-hundred-year old Kazan University carry out the role of the scientific, organizational, and cultural educational center of the Volga region. For the continued successful development of educational and scientific-educational activity of the Russian Federation, Kazan (in the Republic of Tatarstan) was offered the national project: the International Center of the Sciences and Internet Technologies 'GeoNa'. Geometry of Nature - GeoNa - wisdom, enthusiasm, pride, grandeur. This is a modern complex of conference halls including the Center for Internet Technologies, a 3D Planetarium - development of the Moon, PhysicsLand, an active museum of natural sciences, an oceanarium, and a training complex 'Spheres of Knowledge'. Center GeoNa promotes the direct and effective channel of cooperation with scientific centers around the world. GeoNa will host conferences, congresses, fundamental scientific research sessions of the Moon and planets, and scientific-educational actions: presentation of the international scientific programs on lunar research and modern lunar databases. A more intense program of exchange between scientific centers and organizations for a better knowledge and planning of their astronomical curricula and the introduction of the teaching of astronomy are proposed. Center GeoNa will enable scientists and teachers of the Russian universities with advanced achievements in science and information technologies to join together to establish scientific communications with foreign colleagues in the sphere of the high technology and educational projects with world scientific centers.

5.37. *Universe awareness for young children. By Cecilia Scorza, George K. Miley, Carolina Ödman, and Claus Madsen (the Netherlands, Germany)*

Universe Awareness (UNAWE) is an international programme that will expose economically disadvantaged young children aged between 4 and 10 years to the inspirational aspects of modern astronomy. The programme is motivated by the premise that access to simple knowledge about the universe is a basic birthright of everybody. These formative ages are crucial in the development of a human value system. This is also the age range in which children can learn to develop a 'feeling' for the vastness of the universe. Exposing young children to such material is likely to broaden their minds and stimulate their world-view. The goals of Universe Awareness are in accordance with two of the United Nations Millennium goals, endorsed by all 191 UN member states, namely (*i*) the achievement of universal primary education and (*ii*) the promotion of gender equality in schools.

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We propose to commence Universe Awareness with a pilot project that will target disadvantaged regions in about 4 European countries (possibly Spain, France, Germany and The Netherlands) and several non-EU countries (possibly Chile, Colombia, India, Tunisia, South Africa and Venezuela). There will be two distinct elements in the development of the UNAWE program: (*i*) Creation and production of suitable UNAWE material and delivery techniques, (*ii*) Training of educators who will coordinate UNAWE in each of the target countries. In addition to the programme, an international network of astronomy outreach will be organised.

We present the first results of a pilot project developed in Venezuela, where 670 children from different social environments, their teachers and members of an indigenous tribe called Yekuana from the Amazon region took part in a wonderful astronomical and cultural exchange that is now being promoted by the Venezuelan ministry of Education at the national level.

5.38. *Education in Egypt and Egyptian response to solar eclipses. By Ahmed A. Hady (Egypt)*

Astronomy and space science education started in Egypt at the university level since 1939 at the Department of Astronomy and Meteorology, Cairo University. Undergraduate and graduate education in Egypt will be discussed in this work. About 15 students yearly obtain their PhD degrees in Astronomy from the Egyptian universities. Seven international groups under my supervision have done the total solar eclipse observations that took place on 29 March, 2006, in El-Saloum (Egypt). The results of observations and photos will be discussed. An Egyptian-French group have done the total solar eclipse observations that took place on 25 February, 1952, in Khartoum by using a Worthington Camera. The research groups of astrophysics in Cairo University and Helwan Observatory are interested in the fields of solar physics, binary stars, celestial mechanics, interstellar matter and galaxies. Most of the researches have been published in national scientific journals, and some of them were published in international journals.

5.39. *Spreading astronomy education through Africa. By Paul Baki (Kenya)*

Although astronomy has been an important vehicle for effectively passing a wide range of scientific knowledge, teaching the basic skills of scientific reasoning, and for communicating the excitement of science to the public, its inclusion in the teaching curricula of most institutions of higher learning in Africa is rare. This is partly due to the fact that astronomy appears to be only good at fascinating people but not providing paid jobs. It is also due to the lack of trained instructors, teaching materials, and a clear vision of the role of astronomy and basic space science within the broader context of education in the physical and applied sciences. In this paper we survey some of the problems bedeviling the spread of astronomy in Africa and discuss some interdisciplinary traditional weather indicators. These indicators have been used over the years to monitor the appearance of constellations. For example, the Orions are closely intertwined with cultures of some ethnic African societies and could be incorporated in the standard astronomy curriculum as away of making the subject more 'home grown' and to be able to reach out to the wider populace in popularizing astronomy and basic sciences. We also discuss some of the other measures that ought to be taken to effectively create an enabling environment for sustainable teaching and spread of astronomy through Africa.

5.40. *Education at the Pierre Auger Observatory: the cinema as a tool in science education. By Beatriz Garcia and C. Raschia (Argentina)*

The Auger collaboration's broad mission in education, outreach and public relations is coordinated in a separate task. Its goals are to encourage and support a wide range of outreach efforts that link schools and the public with the Auger scientists and the science of cosmic rays, particle physics, astrophysics in general, and associated technologies. This report focuses on recent activities and future initiatives and, especially, on a very recent professional production of two educative videos for children between 6 and 11 years: 'Messengers of Space' (18 min), and for general audiences: 'An Adventure of the Mind' (20 min). The use of new resources, as 2D- and 3D-animation, to teach and learn in sciences is also discussed.

5.41. *Freshman seminars: interdisciplinary engagements in astronomy. By Mary Kay M. Hemenway (USA)*

The Freshman Seminar program at the University of Texas is designed to allow groups of fifteen students an engaging introduction to the university. The seminars introduce students to the resources of the university and allow them to identify interesting subjects for further research or future careers. An emphasis on oral and written communication by the students provides these first-year students a transition to college-level writing and thinking. Seminar activities include field trips to an art museum, a research library, and the Humanities Research Center rare book collection. This paper will report on two seminars, each fifteen weeks in length. In 'The Galileo Scandal', students examine Galileo's struggle with the church (including a mock trial). They perform activities that connect his use of the telescope and observations to astronomical concepts. In 'Astronomy and the Humanities', students analyze various forms of human expression that have astronomical connections (art, drama, literature, music, poetry, and science fiction); they perform hands-on activities to reinforce the related astronomy concepts. Evaluation of the seminars indicates student engagement and improvement in communication skills. Many of the activities could be used independently to engage students enrolled in standard introductory astronomy classes.

6. List of posters

Approximately 60 posters were presented by participants from over 20 countries. The titles of the poster papers, their authors names, and the countries of their affiliation follow:

- An educational CD-ROM based on the making of Guide Star Catalog II, *R.L. Smart*, Italy
- An astronomer in the classroom: Observatoire de Paris' partnership between teachers and astronomers, *A. Doressundiram, C. Barban*, France
- An effective distance mode of teaching astronomy, *V.B. Bhatia*, India
- Astrobiology and extrasolar planets - a new lecture course at Potsdam University, *S.A. Franck, W. von Bloh, Ch. Bounama*, Germany
- `<Astronomia.pl>` portal as a partner for projects aimed at students or public, *K. Czart, J. Pomierny*, Poland
- Astronomical black holes as an exciting tool and object for teaching relativistic physics, *V. Karas*, Czech Republic
- Astronomy and space sciences in Portugal: communication & education, *P. Russo, A. Pedrosa, M. Barrosa*, Portugal

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• Astronomy education in the Republic of Macedonia, *O. Galbova, G. Apostolovska*, Macedonia

• Astronomy education in Ukraine, the school surriculum, and a lecture course at Kyiv Planetarium, *N.S. Kovalenko, K.I. Churyumov*, Ukraine

• Astronomy education with movement and music, *C.A. Morrow*, US

• Astronomy in the laboratory, *B. Suzuki*, Japan

• Astronomy in the training of teachers and the tole of practical rationality in sky observation, *P.S. Bretones, M. Compiani*, Brazil

• Astronomy, the Australian school curriculum, and the role of the Sir Thomas Brisbane Planetarium, *A. Axam, M. Rigby, W. Orchiston*, Australia

• Challenges of astronomy: classification of eclipses, *Sonja Vidojevic*, Serbia

• Cosmic deuterium and social networking software, *J.M. Pasachoff, D.A. Lubowich, T.-A. Suer, T. Glaisyer*, USA

• Cosmology and globalization, *D.K. Perkins*, USA

• Crayoncolored planets: using childrens drawings as guides for improving astronomy Teaching, *A.B. De Mello, E.A.M. Gonzalez, B.C.G. De Lima, D.H. Epitácio Pereira, R.V. De Nader*, Brazil

• Critical evaluation of the New Hall of Astronomy for the Science Museum at the University of Mexico, *S. Torres-Peimbert, C. Doddoli*, Mexico

• Daytime utilization of a University Observatory for laboratory instruction, *J.R. Mattox*, USA

• e-SpaceCam : development of a remote cooperative observation system for telescopes with P2P (Peer-to-Peer) agent network using location, *T. Okamoto*, Japan

• Education and public outreach for eGY: virtual observatories that connect teachers with authentic science data, *P.A. Fox*, USA

• Education at the Pierre Auger Observatory: The cinema as a tool in science education, *B. Garcia, C. Raschia*, Argentina

• Educational opportunities in pro-am collaboration, *R.T. Fienberg, R.E. Stencel*, USA

• Elementary astronomy, *J. Fierro Gossman*, Mexico

• Experiences in the Sky Classroom, *A.T. Gallego*, Spain

• Gemini Observatory outreach, *A. Garcia*, Chile

• Gemini Observatory's innovative education and outreach for 2006 and beyond, *J. Harvey*, USA

• History of the teaching of astronomy in serbian schools, *Sonja Vidojevic, S. Segan*, Serbia

• History of Ukrainian culture and science in astronomical toponymy, *I.B. Vavilova*, Ukraine

• Identification and support of outstanding astronomy students, *A.D. Stoev, E.S. Bozhurova*, Bulgaria

• Image subtraction using a space-varying convolution kernel, *J.P. Miller, C.R. Pennypacker, G.L. White*, USA

• Light pollution: a tool for astronomy education, *M. Metaxa*, Greece

• Malargüe light pollution: a study carried out by measuring real cases, *B. Garcia, A. Risi, M. Santander, A. Cicero, A. Pattini, M.A. Cantón, L. Córica, C. Martínez, M. Endrizzi, L. Ferrón*, Argentina

• Making and using astronomical fairy-tales on DVD in planetarium, *V.G. Goncharova*, Russia

• Modern facilities in astronomy education, *H.A. Harutyunian, A.M. Mickaelian*, Armenia

- News from the cosmos: daily astronomical news web page in Spanish, *A. Ortiz*, Spain
- Outreach activities of the National Astronomical Observatory of Japan, *T. Ono, J. Watanabe, H. Agata*, Japan
- Physics education: a significant backbone of sustainable development in developing countries, *A.R. Akin*
- Podcast, blogs, and new media outreach techniques, *A. Price, P. Gay, T. Searle*, USA
- Popularization of astronomy through cooperation between students and educators in Japan: the TENPLA project (1), *M. Hiramatsu*, Japan; (2) *K. Kamegai*, Japan
- Reproduction of William Herschel's metallic mirror telescope, *N. Okamura, S. Hirabayashi, A. Isida, A. Komori, M. Nishitani*, Japan
- Research thinking development by teaching archaeo-astronomy, *P.V. Muglova, A.D. Stoeva*, Bulgaria
- Role of creative competitions and mass media in the astronomy education of school students, *E.Yu. Aleshkina*, Russia
- Sendai Astronomical Observatory: its renewal and history as an observatory for the general public, *J. Watanabe*, Japan
- Simple, joyful, instructive: make a unique telescope of your own and explore the Universe, *Y. Hanaoka*, Japan
- 'Solar System: Practical Exercises' and 'Astronomy: Practical Works' for secondary scholars, *A. Tomic*, Serbia
- Star Week: a successful campaign in Japan, *J. Watanabe*, Japan
- Successful innovative methods in introducing astronomy courses, *T.K.C. Chatterjee*, Mexico
- The 2005 annular eclipse: a classroom activity at EPLA, *H. Filgaira*, Spain
- The Armagh Observatory human orrery, *M.E. Bailey, D.J. Asher, A.A. Christou*, Northern Ireland, UK
- The constellations of the zodiac: astronomy for low vision and blind people, *B. Garcia, A. Cicero, M. Farrando, P. Bruno*, Argentina
- The distance-learning part-time masters and doctoral internet programs in astronomy at James Cook University, Australia, *G.L. White, A. Hons, W. Orchiston, D. Blank*, Australia
- The first two years of the Latin-American Journal of Astronomy Education (RELEA), *P.S. Bretones, L.C. Jafelice, J.E. Horvath*, Brazil
- The Pomona College undergraduate 1-meter telescope, astronomy laboratory, and remote observing program, *B.E. Penprase*, USA
- The recent globe at night initiative involving schoolchildren and families from 96 countries, *C.E. Walker*, USA
- The Universe: helping to promote sstronomy, *R.M. Ros, F.J. Moldón*, Spain
- Use of modern technologies in improving astronomy education in Tanzania, *N. Jiwaji*, Tanzania
- Visualization of the astronomy domain: a mapping strategy in teaching and learning astronomy, *S. Gulyaev*, New Zealand
- Weaving the cosmic web: frontiers of astronomy education on the internet, *D.K. Perkins*, USA
- What mathematics is hidden behind the astronomical clock of Prague? *M. Krizek, A. Solcová, L. Somer*, Czech Republic
- With weekly astronomy tips against the weekly papers' astrology humbug, *G.A. Szécsényi-Nagy*, Hungary

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Summarizer: Naomi Pasachoff. Assistants: Javier Moldon and Madeline Kennedy.

Epilogue

A book based on the proceedings of this Special Session will be published by Cambridge University Press, editors Jay M. Pasachoff, Rosa M. Ros, and Naomi Pasachoff. Its publication will be announced at `<http://www.astronomyeducation.org>`.

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