Working Group 3.2
Education, Outreach and Careers

A Report to the National Committee for Astronomy
for the Australian Astronomy Decadal Plan 2016 – 2025

By Amanda Bauer, John O'Byrne and Working Group 3.2

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1. Introduction

Communicating our astronomical achievements to the broadest possible audience, and training our early career researchers to be prepared for the diverse array of challenges they will face during their careers, remain of vital importance to maintaining the high standards of success within the Australian astronomical community. From inspiring students, to promoting a science-literate public, to maximising the global impact of Australian astronomy research and technology, we summarise here the current state of Education, Outreach and Careers within astronomy and recommend actions toward progress from 2016 to 2025.

To gather information from the community across Australia we held four Town Hall meetings (in Sydney, Melbourne, Canberra and Perth in early 2014) and invited science educators, professional and amateur astronomers and curators of museums, planetaria, and observatories to participate.

The Working Group contributors were:
Amanda Bauer (WG3.2 co-chair, AAO), John O'Byrne (WG3.2 co-chair, Education coordinator, University of Sydney), Pete Wheeler (Outreach, Education & Communications Manager, ICRAR), Virginia Kilborn (Careers Coordinator, Swinburne University), Alan Duffy, Wiebke Ebeling, Christopher Fluke, Martin George, Duane Hamacher, Tanya Hill, Robert Hollow, Sarah Maddison, Quentin Parker, David Parkinson, Helen Sim, Andrew Walsh.

This document combines information from the previous Decadal Plan and Midterm Review, those Town Hall meetings, our own surveys and experiences. It is divided into 4 sections:

1. **Introduction and Executive Summary**
2. **School Education**
3. **Training and Careers**
4. **Outreach**

Note that data gathered from the survey of the Demographics Working Group 3.1 is generally NOT included here, but there is valuable statistical data relevant to this report in that survey.

1.1 Executive Summary

Below is a compilation of all the recommendations in this report. Those related to Education and Outreach should be referred to the ASA's Education and Public Outreach Chapter (EPOC) for further consideration and possible action. Recommendations related to Careers should be referred to the ASA's Early Career Researcher (ECR) and Women in Astronomy (WiA) chapters.

Education

E1 The ASA Education and Public Outreach Chapter (EPOC) is the most relevant community point-of-contact for continuing Curriculum engagement. EPOC should compile and maintain a list of astronomers and astronomy educators willing to liaise with state and national education authorities and science teacher associations.

E2 Encourage astronomers, both staff and students, to continue and increase their engagement with school teachers. Ensure that this is seen as a positive contribution, recognised at the organisational level by their employers.

E3 Explore one or more programs to support on-going teacher professional development in astronomy and seek substantial funding to support this.

E4 Explore the best way to provide easy access to the widest range of high quality resources for the teaching of astronomy. Determine whether this is best done through an Australian Astronomical Resource Centre or by engaging with or more international resource centres. Then implement and widely advertise this mode of access.

E5 Astronomy research organisations and existing astronomy providers should explore further collaborations and sharing of resources.

Extensive feedback received through the Town Hall meetings leading up to this report reveals that more interaction between professional astronomers and education and outreach providers (from teachers to amateur astronomy groups) is needed. **The biggest impact the professional astronomy community can have on the quality of school education overall is through contributing to teacher training (E3), in particular by leveraging existing programs. We recommend this as the highest priority Education recommendation.**

There was also considerable discussion and support in the Town hall meetings for the creation of a centralised database for educators, media, astronomy societies, outreach organisations and professionals (E4). Such a repository could include images and videos, a list of astronomers to contact when needed, as well as information relating to particular astronomical events. It would also highlight efforts already put in by museums, planetarium staff, observatories and astronomy societies that regularly produce these materials. A central repository would leverage individual efforts and reduce duplication of resource creation within the Australian community. However, this would require financial support for a dedicated core of staff to set up and maintain the necessary infrastructure, and it may be more sensible to explore engaging with existing international resource centres.

Careers

C1 Actively seek to promote an increase the number of female students entering studies at the PhD level within Australia.

C2 Postgraduate and ECR workshops should continue to be supported and promoted to ensure that young researchers receive training in “lateral skills”, and that their experience has broader relevance - for example, exposure to programming with languages in demand in industry (e.g. python rather than f77).

C3 Students and postdocs could be trained in the area of “Big data” which will be a potential growth area in astronomy (and industry) in the future and provide job opportunities.

C4 Industry training positions could be included as part of a PhD program – e.g. with a large software company doing database/data mining. This would provide valuable on-the-job skills, and would be suitable for some PhD students. (See WG 3.3 Report)

C5 Provide more career guidance and mentoring in order to retain those astrophysics researchers who will be leaders in the field.

C6 Provide the option to have postdocs ‘shadow’ a lecturer or other senior figure while they go about their usual day, to give an idea of where career progression would lead.

C7 Aim for longer post-doctoral positions – 3 year minimum, preferably 5 years where possible.

C8 When assessing a researcher’s portfolio, the broad range of skills they have should be considered – eg. software/instrument development, outreach, other service should be assessed along with the usual publication metrics.

C9 Promote fellowship schemes (e.g. Future Fellowships) as a vital option for mid-career researchers transitioning from post-doc to permanent positions.

C10 Promote an increased number of (non-tenured) “staff scientist” positions funded as an alternate mid-career path within academia. This would improve retention of highly skilled workers within the discipline, and would help mitigate the disparity between the current large number of postdocs and the small number of available mid-career positions.

C11 Train supervisors to have open discussions with students about potential career options.

C12 Create a contacts list of ex-astronomers who have entered the workforce and a database of opportunities for retraining such as the “Science to Data Science (S2DS)” workshops.

C13 Promote efforts to ensure genuine equity of access and opportunity in all positions within astronomy. For example, advertise positions as available part-time wherever possible to support career breaks.

C14 Establish general metrics to recognise and track ‘success’ in outreach and consider these in the evaluation of job applications, grant proposals, and time allocation proposals.

Discussion of Careers generated considerable debate in the Town Hall meetings and subsequent email input. This working group recognises the extensive development of career training workshops and programs that have been successfully introduced in response to the previous Decadal Plan, and encourages their continued support (C2). Yet, as most trained astronomers will not be able to gain a continuing, tenure-track academic position, **we also recommend that students receive more training in “transferable skills” and exposure to a variety of job opportunities outside the realm of academic research (C3,4,11,12).** This is perhaps the strongest set of recommendations in Careers.

For those working in astronomy, we recommend that longer postdoctoral positions should be offered where possible (C7) and promotion of mid-career opportunities (C9,10).

Efforts to ensure genuine equity of access and opportunity (notably for women) in all positions within astronomy should be a major goal for the coming decade (C13).

The recommendations include formal recognition and support of scientists for their involvement in outreach and science communication and software development activities at an organisational level (C8 and C14). This will improve the diversity of astronomers that are willing to dedicate time to interacting with students and educators and give credit for development efforts that take time and are necessary for data analysis and the production of high quality science results.

Outreach

O1 A national audit be undertaken of astronomy outreach programs, providers and resources, leading to the establishment of a publicly accessible repository and perhaps some national coordination.

O2 It is important that professional astronomy observatories and organisations have in-house education/outreach expertise. They should employ an “Outreach Officer” on staff. We emphasise the importance of public observatories, museums and science centres that offer astronomy content maintaining staff with astronomy training.

O3 The community in general and the ASA in particular should explore ways to build more links between the amateur and professional communities.

O4 The ASA should consider re-inventing the “seed funding” program as a way to build profile in the amateur community in particular. A modest program of several thousand dollars every 1 or 2 years may be sustainable. ASA’s EPOC may be the suitable body to run the program.

O5 A Working Group should be established for a fixed period of time that will create a short two-page set of Social Media Guidelines for individual Astronomers. This should also include a page of “what to avoid” and the pitfalls associated with using Social Media.

O6 In order to maximise the effectiveness of a social media strategy, it is recommended that a short Social Media and Science Communication training session be held in conjunction with the ASA meeting each year with more detailed workshops comprising part of the planned EPOC Education and Outreach Conference.

O7 Initiate an ASA Outreach Award for individuals for interact strongly with the public and schools.

O8 Establish EPOC acts as the point-of-contact for professional astronomers and astronomy educators willing to be contacted by media, education and other organisations.

O9 EPOC should run biennial workshops for the professional astronomy community and other interested parties on effective outreach and education practice.

O10 Promote research in indigenous astronomy to maintain our heritage and continued history of astronomical research.

The diversity of outreach activities, much of it conducted by people and organsations beyond the professional astronomy community, makes it difficult to adequately capture and describe. An ongoing effort to monitor and improve the efficiency of this activity may be warranted (O1).

The contribution of a vibrant amateur community to research, education and outreach is an extraordinary resource to astronomy, almost unique among the sciences, and its importance and local impact cannot be overstated. Building stronger links between the professional and amateur community (O3,4,7,8) can only be mutually beneficial.

The biggest change in outreach between this decadal planning period and the last is undoubtedly the growth of social media. While the professional community has some ‘stars’ in this area, improved skills throughout the community are clearly desirable (O5,6). It is impossible to say how this will develop over the coming decade but it is currently the major frontier for outreach.

2. School Education

Education in both Primary and Secondary Schools was clearly recognised by the community to be a critical issue, attracting a considerable portion of the discussion at the working group Town Hall meetings. It was also important in the previous report and featured in the following recommendations:

- That the professional astronomical community identify the need for, support and help develop effective on-going teacher professional development in astronomy.
- That the professional astronomical community be willing and proactive in contributing to future syllabus reviews and reforms within Australia

The mid-term review built on the second point, noting that the K-10 and senior national Science curriculum envisaged at that time included a significant amount of astronomy and space science, suggesting a role for astronomers in professional education for teachers.

In this sense the context of school education has changed significantly over the decade, with implementation underway for an Australian national curriculum for key subject areas including science. Much work has gone into this, but despite the recommendation above and the efforts of a few individuals, astronomers have had only a very small role in shaping the Australian curriculum in Science.

In another sense the context of school education has not changed so much since the previous review. There remains strong concern over the number of students studying science and mathematics at school. Taking science in the NSW HSC as an example, the proportion of students taking science is low and perhaps continuing to decline in the key areas of Physics and Chemistry.

	2007	**2010**	**2013**
Biology	14447	15849	16852
Chemistry	10287	10330	11032
Physics	9126	9359	9562
Senior Science	4210	4901	5441
Total Sciences	38070	40439	42887
Total HSC	62222	65146	66841

Table 1: Total number of students doing science subjects for the HSC

	2007	2010	2013
Biology	23	24	25
Chemistry	17	16	17
Physics	15	14	14
Senior Science	7	8	8

Table 2: Percentage of students doing science subjects for the HSC compared to the total number of HSC students

It is also noteworthy that the proportion of women doing physics remains low and is a matter of concern.

	2007	2010	2013
Biology	63	61	61
Chemistry	45	45	45
Physics	25	22	22
Senior Science	44	45	47

Table 3: Percentage of female students in each science subject for the HSC

Training of science teachers also remains a concern, with a continuing severe shortage of teachers with a solid background (e.g. a major) in Science (especially Physics) or Maths.

Both of these recommendations from the previous review were clearly relevant but rather non-specific. Astronomers ended up working in these areas without any evidence of a connection to the previous Decadal Planning process.

From the many issues discussed at the recent Town Hall meetings, the topics outlined below are highlighted as of particular interest or importance. From these we need to choose one or two specific and realistically achievable goals.

2.1 Curriculum change

The amount of astronomy contributing to science syllabi has been slowly increasing over the last two decades. Most students received their formal exposure to astronomical concepts in years 5 or 6 of primary school and at different times within years 7 to 10 of secondary school. Primary school content tends to focus the brief time available on basic concepts such as day and night, and basic awareness of stars and planets. In junior secondary school, astronomical concepts are taught within integrated science courses. In NSW, the curriculum included topics such as a description of the scale and content of the Universe, the Big Bang model, the lives of stars and the solar system. In practice the level of coverage varied greatly between schools and teachers.

In years 11 and 12, the curriculum coverage of astronomy varied greatly, ranging from essentially zero in some states up to one compulsory and one optional module out of eight in NSW physics. In the HSC year 12 course, about ¼ of physics students student took the Astrophysics option. Up until 2010, NSW also offered the "Cosmology Distinction Course" as a distance education subject to around 30 students who had accelerated their progress through other subjects.

The Australian Curriculum is being implemented now, with the F-10 Science Curriculum either already implemented or commencing implementation in all states. NSW was the last, in part due to its need for legislative requirements that allowed it to develop its own syllabus based on the Australian Curriculum. A commencement date for the senior science subjects is yet to be confirmed.

The curriculum changes will make it harder for K-10 teachers to ignore astronomy, suggesting a significant need and opportunity for effective training of teachers at the Primary level and in some states at the Secondary level. However, in the draft senior curriculum (years 11 and 12), the astronomy content is largely lost compared to what has been offered in NSW and Victoria. In that case, astronomy, as one of Australia's highest profile sciences, will not be featured to students making their career choices. This seems out of step with recommendation 11 in the *Inspiring Australia* report, noted in the Mid-term Review, that "a key focus of the national initiative should be raising awareness among young people of opportunities in science and research." As demonstrated by several innovative programs implemented since the last Decadal Plan, astronomy remains an excellent context for engaging students across scientific disciplines and exposing them to latest technologies.

This emphasises the need to remain engaged with national review of implementation of the Australian Curriculum and the state-level implementation. Interested astronomers should liaise with national and state-level curriculum authorities and science teacher associations. The community must be ready to provide input to any calls for curriculum submissions and identify astronomers willing to act on advisory bodies or examination boards.

Recommendation

E1 The ASA Education and Public Outreach Chapter (EPOC) is the most relevant community point-of-contact for continuing Curriculum engagement. EPOC should compile and maintain a list of astronomers and astronomy educators willing to liaise with state and national education authorities and science teacher associations.

2.2 Engaging with Teachers

Many teachers are reluctant to engage in astronomy, due to lack of much (or any) training in this content area and how to teach it. This is especially true for Primary teachers, many of whom are reluctant to engage in science generally, with astronomy often specifically identified as a challenge. However, it is also an opportunity, given the undoubted interest of the public, but especially children, in the sky. Astronomers need to engage with teachers – as many already do informally - while also recognising the constraints teachers face and their lack of relevant knowledge of the sciences. Equally, teachers need to recognise a professional astronomer's time constraints.

Perhaps the most obvious step is to encourage astronomers' participation in existing programs, notably Scientists and Mathematicians in Schools (SMiS). In 2014 there are only 16 ASA members registered with SMiS and only 11 actively participating, from an ASA membership of over 600. This program can become whatever the individual teachers and scientist make of it between themselves, with visits both ways and a wide range of other possible interactions depending on the resources available (e.g. portable planetaria, solar telescopes, etc.).

Another approach is the 'CAASTRO in the classroom' style program in which astronomy content tied to the curriculum is brought to regional and rural high-schools via video-conferencing. This program has been tested successfully in NSW and will so be going national with 1 FTE employed to run the program.

Sending resources (including people) into schools (incursion, as opposed to a school excursion) can be problematic because this type of incursion tends to be an *adjunct* to a teacher's program, used either as an introduction or final fun activity. Teachers often lack the confidence to follow-up. Resources will only be utilised effectively if matched with timely and relevant professional development.

Incursion visits are likely to be more relevant and effective when embedded in a school's program – e.g. when SMiS is used to create a close relationship between an astronomer and the teacher/school, perhaps with frequent with "digital" visits or email conversations, but perhaps only occasional face-to-face encounters.

Professional astronomers also need to recognise that amateur astronomers also play an active role interacting with local schools, most obviously with viewing nights.

As a community, we need to ensure that school (and outreach) activities are recognised as legitimate uses of an astronomer's time, with professional recognition at the organisational level, whether that be from supervisors evaluating an individual's performance review, through the hiring of someone specifically to engage in outreach (as the AAO has done) or similar measures.

Recommendation

E2 Encourage astronomers, both staff and students, to continue and increase their engagement with school teachers. Ensure that this is seen as a positive contribution, recognised at the organisational level by their employers.

2.3 Teacher Training

There is a widely perceived general lack of scientific literacy amongst many teachers, specifically with respect to astronomy and how to effectively teach astronomical concepts at a stage-relevant level in the classroom.

This is a particular challenge in primary schools where science is usually taught by the class teacher. Most primary teachers have little or no formal training in science beyond the units covered within their teaching degree, where little time is given to science. Often they were students who did little science or maths beyond year 10 themselves.

Science in the junior years high school (7-10) is taught as an integrated discipline rather than as separate subjects. The teacher therefore has to be competent across all of science when, although they may have a science degree, they probably only majored in one area such as biology but they are also asked to teach chemistry, geology and physics – and some astronomy. *Who's Teaching Science* (2005), released by the Australian Council of Deans of Science, suggests that ¾ of these teachers have a science degree, but the other ¼ have an Education degree with even less science content. Neither of these options is likely to include much knowledge of astronomy.

In the senior years of high school (11-12) astronomy is part of physics and in some earth and environmental science courses. Physics in particular is well known to suffer from a lack of qualified teachers, with *Who's Teaching Science* reporting that "nearly 43 per cent of senior school physics teachers lacked a physics major, and one in four had not studied the subject beyond first year."

With this background, the need to offer improved teacher training is apparent if we are to give our school students a useful background in astronomy (and science in general) – we need a "teach the teachers" approach. Teacher training for both pre-service and practicing teachers is the area in which we can have the biggest impact on formal school-level education. There are already many good resources available but, without awareness of them and training in how to use them, the quality of teaching and thus student engagement is likely to remain low.

Teacher feedback indicates that 'professionalisation' is key in attracting their interest - e.g. offering accredited Professional Development programs for both pre-service and practicing teachers, delivered by astronomers or education and outreach professionals.

Proposed actions:

- Wherever possible, engage with Education faculties in their teacher training. Programs underway such the "Opening Real Science" collaboration led by Macquarie University with six other universities, the AAO, CASS and Las Cumbres Observatory Global Telescope Network (LCOGTN) are working on two astronomy modules (out of a total of 8) aimed at skilling pre-service and practising teachers.
- Encourage formal and informal linkages between astronomy institutions with providers and accreditation agents of professional development (Australian Institute for Teaching School Leadership (AITSL) and its state-level equivalents). An example is the recent MOU between the Science Teachers' Association of NSW (STANSW) and CASS to accredit teacher workshops offered by CASS to fulfil requirements for teaching standards for the NSW Board of Studies, Teaching and Educational Standards (BOSTES).
- Other options might be Masters programs to give suitably qualified teachers a research experience by embedding them in departments. This may be difficult in a time of increasing university fees. Alternatively, a MOOC to train teachers in teaching astronomy might be feasible, but current experience with online training is not necessarily positive.
- Encourage or facilitate use of existing programs and actively support partnering with existing providers to contribute Australian materials and disseminate their existing ones. Example include global programs such as:
    - Universe Awareness (UNAWE http://unawe.org/) which provides examples of well-tested and developed resources, activity and pedagogy aimed at children 4-10 years old. Many of the resources and activities are ideal for requirements of new F-10 Australian Science Curriculum.
    - The Galileo Teacher Training Program (GTTP http://www.galileoteachers.org/) which is an International Astronomical Union (IAU) Cornerstone project providing teacher training accreditation and growing a community of educators. To date this program has been running at a modest level in Australia, primarily through CASS teacher workshops though there is great scope for expansion and partnership with other organisations.

  Expanding collaborations with these programs fulfils the remit of the Decadal Plan to engage with global partnerships and best practice and could be done so effectively via modest funding support.

The need for effective support of on-going teacher professional development in astronomy is not new. As noted earlier, it was identified by the Education working group for the previous Decadal Plan. As is apparent from the examples described above, some programs have been developed, but much remains to be done and international opportunities exist. There is considerable scope for reaching many more teachers if there is a higher level of funding and support. A serious effort in this area by the astronomical community requires funding as, for example, the Office of Learning & Teaching (OLT) has provided for the 'Opening Real Science' Program.

Recommendation

E3 Explore one or more programs to support on-going teacher professional development in astronomy and seek substantial funding to support this.

2.4 Teaching Resources

Several suggestions were made at the Working Group Town Hall meetings around the idea of providing new astronomical resources, such as short video presentations on various topics targeted at primary and secondary students. However, availability of resource material for astronomy has exploded in recent years, some of it provided by observatories as part of their own research or outreach. There was doubt about the utility of a separate effort to develop new resources and the cost in time and money. Resources most likely to have some value are those that offer Australian-centric content, but they are probably best produced by institutions already producing similar materials.

A simple example might be a new set of Australian images of the sky (2-D and 3-D) collated from the archives of AAO/RSAA/CASS/Swinburne etc. This might be a worthy successor to David Malin's photographic collections from the AAT and Schmidt telescopes. Producing a set of "Stock Images and Videos" made available through the new AAO website is a project currently underway through their Outreach Officer. The 'Opening Real Science' Program will produce several astronomy-based modules, becoming available through an online portal in 2016.

Existing resources are available through a variety of education portals. Whether the resources are good or whether teachers can find them and use them effectively is another question. Many are locked up in different repositories and ensuring they are known to teachers and can be readily accessed is the real issue. This relates back to the issues of Teacher Training (2.3) and a Resource Centre (2.5).

2.5 Australian Astronomical Resource Centre

There was considerable discussion at the Working Group Town Hall meetings about providing an Australian "clearing house" or repository for astronomical materials – images, simulations, lectures, opportunities for grants, contact details of astronomers/amateur societies/schools/museums etc. – in fact any materials that would be useful or of interest to teachers in particular, but also the public in general. This could act as a "one-stop shop" for resources relevant to Australian educators, astronomers and the public. It would be responsible for:

- accumulating resources, knowledge and experiences of what has and hasn't worked well in the past, especially in Australia
- integrating resources from international programs such as Galileo Teacher Training Program,

- advertising and making these resources available to teachers (and also anyone who wants them),
- asking for feedback about the resources and adjusting materials and strategies in response.

One model for such a service is *Uniserve Science* that served for some years as a national clearing house for science education materials, but which has now become part of the Institute for Science and Mathematics Innovation (IISME) at the University of Sydney.

Such a resource centre must not duplicate existing efforts. We need to understand its context internationally and ask whether we need an Australian version. One of the lessons from the International Year of Astronomy (IYA) in 2009 was that the activities that reached the greatest number of people were those developed in conjunction with existing delivery networks. For example, *astroEDU* is a small but growing IAU-sponsored resource centre for educational activities. It is open-access, international and peer-reviewed. Australian input could be specifically linked to Australian Curriculum standards. Alternatively, the *NASA Wavelength* digital library is more extensive, but predominantly US-based.

Also, many of the Australian-developed education resources targeted at schools are already accessible through comprehensive sites such as *Scootle* https://www.scootle.edu.au/ec/p/home. Copyright and accessibility issues are also important here. Some materials developed by, for example the Australian Academy of Science (their *Science by Doing* program), are only accessible to Australian schools and not those in other countries.

An Australian Astronomical Resource Centre may be an expansion of an existing site such as the current Australian Astronomy portal or a totally new one. For such a site to be effective, well-supported and well-utilised it would require significant time and effort in the initial establishment then ongoing promotion and support to review and provide regular updates. This would likely require a significant percentage of a dedicated FTE as experience with other similar sites indicates that maintaining them via a volunteer effort is not effective. It would need to be based in an existing institution willing to provide the necessary infrastructure.

Recommendation
E4 Explore the best way to provide easy access to the widest range of high quality resources for the teaching of astronomy. Determine whether this is best done through an Australian Astronomical Resource Centre or by engaging with or more international resource centres. Then implement and widely advertise this mode of access.

2.6 Education: Museums, Planetaria and Public Observatories

[*see also Section 4 Outreach*]

Research suggests that an ‘out of school’ experience (an excursion) often has a long-lasting impact on students which is motivating, inspiring and memorable (Falk & Dierking 2013). Of course they offer the same opportunity for the general public. Museum visits are also reported to leverage positive attitudes towards lifelong learning (ibid).

These institutions already deliver a range of programs to schools with students of different demographics and ages. They are usually well aware of the latest school curricula and have access to good communication tools. Most have well developed online resources and teacher-training programs.

There is potential for astronomy research organisations to collaborate and share resources with existing astronomy providers (museums, planetaria, public observatories and astronomical societies). This could be an effective model by which to educate the broader population and provide formal learning experiences in astronomy that engage school children and the public in the past, present and future of Australian astronomy. The Mars Lab project developed between the University of New South Wales (The Australian Centre for Astrobiology), the University of Sydney (The Australian Centre for Field Robotics) and the Powerhouse Museum is an example and potential model for other such joint projects.

Recommendation
E5 Astronomy research organisations and existing astronomy providers should explore further collaborations and sharing of resources.

2.7 School Education - Case Studies

- **PULSE@Parkes** (http://www.atnf.csiro.au/outreach/education/pulseatparkes/) is an innovative program run by CSIRO Astronomy and Space Science in which high school students use the Parkes radio telescope remotely via the internet to observe pulsars then analyse their data. To date over 1,100 students from about 100 schools have controlled the telescope. Sessions have been run in several Australian states plus special sessions in England, Wales, the Netherlands and Japan for local students there. All the data obtained from the program is freely accessible online for both educational and scientific purposes. It can also be viewed in real time during observing sessions via online monitors and social media. A key part of the program is the ability for students to interact with professional astronomers and PhD students during the observing sessions. This has had a positive impact on students and been highlighted by participating teachers as promoting the student engagement with and interest in science. Some students have also utilised the data for open-ended student investigations and future developments will support this further. Considerable interest has also been shown by academics in South-East Asia and elsewhere in adapting materials for undergraduate education.

- **AstroTour** — For over a decade, Swinburne University of Technology has been helping to both educate and inspire a fascination in the Universe through its 3D AstroTour program (http://astronomy.swin.edu.au/outreach/?topic=astrotour). In the last five years alone (2009-2014), over 10,000 school students, Guides, Cubs, Scouts, Probus groups and members of the general public have been taken on virtual tours of the Universe in more than 300 AstroTour sessions. AstroTour guides include research staff and PhD students, who benefit from opportunities to develop their science communication skills by talking to diverse audiences of all ages. Swinburne Astronomy Productions, the team behind the 3D animated movies featured in all AstroTours, have taken Australia's astronomy outreach capabilities to an even larger level through their work on the internationally-successful IMAX documentary "Hidden Universe 3D". (See also Section 4.1 Planetaria)

- **Telescopes in Schools** (TiS - http://telescopesinschools.wordpress.com/) places research-grade telescopes into secondary schools in metropolitan Melbourne and regional Victoria and delivers training programs for using them. Started in 2012 by the Astrophysics Group at the University of Melbourne, TiS has set up telescopes in 10 schools, reached over 3000 students, held over 130 astronomy sessions and hosted its first Astrophotography Competition. Each TiS school is doing something different and interesting – as shown by the great photos and blogs posted by students, teachers and outreach participants on the project's website. Through hands-on experiences and getting to know professional astronomers, TiS inspires students to aspire to further education and science.

- The **Space to Grow (S2G) project** was launched in 2009 and funded by an ARC Linkage grant to Macquarie University. It was designed to help address the serious problem of poor student engagement and retention of science material using the proven hook of astronomy. The project innovatively combined rural and city schools, astronomers and technology-focused educational researchers in a novel learning and teaching program. Year 9/10-12 students have the opportunity to control powerful $30M research-grade, robotically operated telescopes via the internet while directing educational research to an area of natural interest and engagement to students – astronomy, see: http://physics.mq.edu.au/astronomy/space2grow/ for further details. A key outcome was the generation of authentic science, and the publication of 3 astronomy refereed journal papers in PASA with astronomers, teachers and their students as bona-fide co-authors. This project directly inspired the new 2013 $2.3million OLT "Opening Real Science" program, also led by Macquarie University, and including the AAO, CASS and LCOGT as partners along with 6 partner universities. This program aims to reach up to 50% of all pre-service teachers in NSW. It expands the S2G ethos of using authentic science in the classroom to cover the national curriculum across other branches of science and with mathematics but this time more focused on pre-service teachers. The idea is to transform the way the teachers themselves engage with and deliver the national curriculum science via the S2G authentic science approach.

- The **Mars Lab** (http://www.themarslab.org) project developed between the University of New South Wales (The Australian Centre for Astrobiology), the University of Sydney's Australian Centre for Field Robotics) and the Powerhouse Museum. The Mars Lab is a

Mars Yard, or re-creation of the Martian surface and robotics lab established within Sydney's Powerhouse Museum. It engages high school students in the search for life on Mars, and the technologies which enable that search. A core feature of the Mars Lab is the development and testing of rovers on the Mars Yard for astrobiological research. Students undertake scientific missions and experiments in-line with the Australian Curriculum. The rovers themselves, as well as a range of sophisticated on-board instruments, are operated remotely via the National Broadband Network from within the school classroom or "Mission Control Room". Spanning all areas of STEM (Science, Technology, Engineering and Mathematics), these real world science experiences, along with the live interactions between young people, scientists and engineers, represent a platform upon which students develop understandings, pose their own questions and drive their own learning.

- The **Victorian Space Science Education Centre** (VSSEC) in Melbourne (https://www.vssec.vic.edu.au/) runs extensive astronomy-related programs in an innovative setting. VSSEC applies the latest educational research to develop effective programs for both students and teachers. VSSEC's programs support dedicated subject and cross-curricula domains. The programs are delivered in context and highlight career and study paths. Programs predominantly support secondary school learning however VSSEC also offers a range of outreach programs for primary students and events to engage the general public. To maintain the highest level of excellence in both pedagogy and science content VSSEC established an advisory board consisting of representatives from academia, education and the government.

2.8 Some feedback from Teachers

- From Rob Farr, Head of Science at Brigidine College St Ives and author of several science textbooks:

"The connections that students can make to the real world through the study of astronomy make lasting impressions like no other field of science. The sheer mind-boggling concepts that astronomy presents forces students, perhaps for the first time, to consider their place in the universe and exposes them to questions where answers are sill be sought. For so many, this ignites their inquiring mind and can be the catalyst for developing abstract thought processes. As a teaching area, it is one where hands-on activities and first-hand experiences are readily at hand, connecting the world of the student to the world of real science.

The PULSE@Parkes program, developed and coordinated by Rob Hollow, has been an excellent example of a program that has bridged the world of the school student to that of real science with real purpose. Each year, every student has provided very positive feedback about their experience with some making comments many years afterwards. A number have recounted how this has led to them pursuing a career in science and how the PULSE@Parkes experienced remained at the forefront of their memories of school as they followed their career paths."

- From Gary Tilley (Seaforth PS):

"Firstly, I REALLY wanted to pat the astronomers on the back for their great efforts in helping me at my school…. Of all the scientists I have worked with, astronomers have been the most available and encouraging. That speaks volumes to the dedication of astronomers."

- Value and Impact of S2G

"Space to Grow has had a marked impact. My students have increased their ability in using a wide range of computer programs, such as MS Excel, Photoshop, Fits Liberator and Aperture Photometry Tool. I have seen a dramatic improvement in the student's enthusiasm for Science. My Year 7-10 students now actively ask deep and meaningful questions using a wide range of online resources. They are also motivated to attend the sessions, and see value in Scientific research.

Many of my students now talk about careers in Science and I have had many interviews with parents expressing their gratitude for engaging their child's interest in Science.

In summary, Space to Grow has been a worthwhile and challenging program which has received praise from students, parents and the wider community. It is indeed a valuable vehicle for ensuring our students look at Science as a viable career choice."

3. Training and Careers

In Australia, about 70 students each year from 2009 to 2013 have commenced PhD programs in astronomy and astrophysics. Australian institutions also expose some 3000 students per year to undergraduate astronomy courses. In *Nature*, Sir David King states that "*One measure of a nation's knowledge base is its output of PhD students*" (*Nature* 2004, 430, 311-316).

3.1 Statistics

3.1.1 Undergraduate

Undergraduate courses in astronomy-related disciplines are offered in approximately 13 Australian Universities. Of these, two offer their courses either online or through other distributed teaching method such as video conferencing to separate campuses.

Several institutions across Australia provide a range of opportunities for undergraduate students to take part in short term research programs with astronomers. These include AAO, the University of Sydney, CSIRO, the Australian Gemini office, UWA, Swinburne, UNSW, Macquarie University, ANU-RSAA, and ICRAR. These programs attract undergraduate students from Australia and around the world.

Programs such as PULSE@Parkes have the potential to be adapted to the needs of regional partners for undergraduate education. The program has already toured Japan once and will be doing so again in late 2014 through funding from the Australia-Japan Foundation. China is keen to use it to engage both high school and university students in hands-on observing and data analysis for student investigations. Other current or planned programs and facilities in Australia could be valuable to partner institutions in the region, particularly given our relatively high number of advanced telescopes plus computing facilities and clear, dark or quiet skies compared with other countries.

3.1.2 Postgraduate Coursework

Postgraduate coursework degrees offer an opportunity for science educators, people working in astronomy-related fields and amateur astronomers to take their interest in astronomy onto a more advanced basis. Three institutes offer these programs via online/distance education to a total of over 250 students per year, about half of these internationally. The online Masters program at Swinburne University is best known.

3.1.3 Postgraduate Research

Postgraduate research-based training is offered in 16 Australian Universities. In addition to this, national facilities such as the CSIRO-ATNF and the Anglo-Australian Observatory (AAO) both contribute strongly to the training of professional astronomers through their co-supervision programs.

The number of Astronomy PhDs granted has risen dramatically in recent years:

Years	Astronomy PhDs granted	average per annum
1990 - 1994	108	21.6
2000 - 2004	83	16.6
2009 - 2013	164	32.8

The recent increase in degrees per annum also follows an increasing trend in total number of PhD (MSc and Honours) students enrolled in university programs:

Year	number of PhD students
2005	157
2010	237
2014	326

In 2014, the 326 PhD students were accompanied by 28 MSc students and 47 Honours students (including MSc in place of Honours at the University of Melbourne).

Over the past five years, the number of students commencing a PhD in Australia each year has remained consistent:

Year	number of PhD students commencing
2009	66
2010	75
2011	63
2012	69
2013	69

Of the students commencing PhD programs over the last 5 years, 59% have been Australian and 41% have been from overseas. This has increased from the 29% of admitted overseas students reported in the previous Decadal Plan.

Gender ratios of graduate level students in Australia have increased over the current decadal period and this reflects a worldwide trend of increasing numbers of women in astronomy and astrophysics programs. From 1990 - 1994, the male to female postgraduate student ratio was 85:15. In the period of 2000 - 2004 the ratio changed dramatically to 63:37. The male to female ratios seen in the US in 2002/2003 was 67:33 and remained similar by 2013 at 65:35. [see also 3.3.5 Equity and Access]

Recommendation

C1 Actively seek to promote an increase the number of female students entering studies at the PhD level within Australia.

3.2 Postgraduate Career Training

In OECD (i.e. developed) countries the number of PhDs earned each year grew by almost 40% in the decade 1998 to 2008, a rate far above that required to replace senior academic staff retiring or leaving the field ("The PhD Factory", 2011 Nature, 472, p 276). The reality is that the vast majority of ECRs should prepare for a career outside of academia.

A major success in response to the previous decadal plan has been the inclusion of training programs within the astronomical community to prepare students with skills for astronomy careers, including Early Career Researcher (ECR) training and ANITA courses. Below, we will describe programs that have been initiated and recommend continued support for such training programs. We also highlight the importance of training aimed at careers *beyond* academic research.

3.2.1 Graduate Training Workshops

The Australian National Institute for Theoretical Astrophysics (ANITA) became a Chapter of the ASA in 2006. ANITA now runs two meetings under the auspices of the ASA, serving primarily to educate graduate students: (1) the Summer School in Theoretical Astrophysics and (2) the Astroinformatics School, which alternate year by year. Although originally funded by the surplus from the 2003 IAU General Assembly, the ASA intends to continue funding these meetings, supplemented with sponsorship from other Australian astronomical institutions. These are in addition to the ASA's long-running Harley Wood Winter Schools for postgraduate students.

Separate chapters of the ASA also run two other regular workshops that serve students or early career researchers. The Women in Astronomy Chapter of the ASA runs a workshop each year to acknowledge and address issues of diversity throughout the astronomical community. The Early Career Researcher Chapter has initiated a workshop offered every other year to address topics relating to career progression for the future leaders of the astronomical community (primarily postdocs and junior faculty). This workshop has proved incredibly beneficial for training and mentoring purposes and is an excellent opportunity for those specifically focused on continuing academic careers in astronomy.

More technical workshops are also available, such as the CSIRO's radio astronomy schools and the AusGO optical data reduction workshops.

Astrophysics PhD students typically finish their studies having gained substantial problem solving and statistical skills, which are of value to a wide array of employers. Supervisors and universities should help students to recognise their skill sets, and ensure they are prepared for future careers, not just in astronomy.

Recommendations

C2 Postgraduate and ECR workshops should continue to be supported and promoted to ensure that young researchers receive training in "lateral skills", and that their experience has broader relevance - for example, exposure to programming with languages in demand in industry (e.g. python rather than f77).

C3 Students and postdocs could be trained in the area of "Big data" which will be a potential growth area in astronomy (and industry) in the future and provide job opportunities.

C4 Industry training positions could be included as part of a PhD program – e.g. with a large software company doing database/data mining. This would provide valuable on-the-job skills, and would be suitable for some PhD students. (See WG 3.3 Report)

3.2.2 Mentoring

Mentoring benefits both mentor and mentee at any stage in one's career. Mentoring opportunities within the astronomical community have increased in recent years, for example through workshops provided by the ASA's Early Career Researcher chapter. In addition, recent annual ASA Scientific Meetings have featured a "speed meet a mentor" session (hosted by the Women in Astronomy chapter), to spark relationships beyond students' host institutions.

Part of mentoring may be "shadowing" of an academic, since it has been suggested that many postdocs may not realise just what a change in career lifestyle becoming a lecturer (or similar) involves, relative to being a postdoc.

Mentoring Case Study

CAASTRO has made it a priority that young researchers receive a world-class mentoring experience. At the core of these activities is the CAASTRO-wide mentoring program launched in 2012. Each of the ~150 members of CAASTRO, spread throughout Australia, is paired with a mentor, a mentee, or both.

Each pairing is chosen so that the two people have similar broad interests, but are from different institutions or research collaborations—the aim is to provide an additional layer of advice on top of whatever mentoring an individual is receiving from their supervisor and immediate research group. Mentors and mentees begin the program through an online interactive mentoring guide, and then are asked to meet 3–4 times per year (once in person, other times by phone/video), where they discuss research progress, work-life balance, career opportunities, or any other topics they feel appropriate. Pairings are evaluated on an annual basis, through which an independent administrator receives confidential feedback and re-pairs people if needed.

Feedback from participants so far has been extremely positive, with young researchers commenting that they've never had a real mentor before and that it was good to know that there was always someone looking out for them. One early-career researcher has even credited his success in landing a permanent position to the advice he received from his CAASTRO mentor on applications and interviews.

Recommendations

C5 Provide more career guidance and mentoring in order to retain those astrophysics researchers who will be leaders in the field.

C6 Provide the option to have postdocs 'shadow' a lecturer or other senior figure while they go about their usual day, to give an idea of where career progression would lead.

3.3 Career Path

Of course the primary goal of training PhD students is to see them through to successful careers contributing to humanity's understanding of the cosmos and the Universe we live in through successful Australian research campaigns and technology development. But the number of permanent astrophysics research positions available imply that not all trained PhD students will ever become lecturers or professors. Supervisors should be open to this discussion during a student's PhD, to acknowledge a range of possibilities and exposure to alternate career paths.

3.3.1 Dissatisfaction and worry over future career prospects

Many junior astronomers feel dissatisfied, as they wish to continue on with their chosen astrophysics careers, but worry that there is no guarantee of career progression or permanent employment down the track. It goes without saying that some will leave Australia to seek work overseas, but many overseas researchers will also come to Australia, given its international standing as a location for high quality research. The relative numbers for each career stage will remain approximately the same in the foreseeable future.

A major issue in Australian astronomy is that there are currently a large number of "young" post-docs due to the 34 fellowships funded through the Australian Research Council's Super Science Initiative. This one-time Super Science Fellowship scheme will be completed by 2016, leaving a legacy of early career researchers in a particularly difficult position for finding long-term positions in research academia in Australia.

3.3.2 Postdocs as workforce for future intellectual economy

There is a need for astrophysics-trained researchers who decide to leave the academic field. Highly educated individuals such as these will form the basis of the intellectual economy that Australia has to grow. To quote Ian Chubb (the Chief Scientist of Australia) in his National Press Club keynote address in March 2014 *"In the US, it is suggested that 60 per cent of the workforce in 2020 will require skills held by only 20 per cent of the current workforce"*. Australia needs people with the skills astrophysics graduates possess to drive the transition from a manufacturing economy to an intellectual one, as will have to happen with all OECD countries.

3.3.3 Options and support for transitioning and retaining postdocs

As a community we need to support our students and postdocs. Longer postdocs are a preferred option, with a 3 year minimum but optimally 5 years. For a 3 year position, post-docs typically need to search for a position after 1 year in their current job which can be detrimental to their research and career prospects.

Universities should foster an environment where a wide range of career choices and opportunities are available to postgraduate students. We should discourage the idea that only success in astrophysics counts - an astrophysics PhD can lead to fulfilling careers in many areas. Previous astrophysics graduates have careers in industry, finance, computer science, and medical research just to name a few.
Create contacts list for alumni for ex-astronomers who have entered the workforce
Database to track opportunities for retraining such as The Insight Fellowship and the "Science to Data Science (S2DS)" workshops.

Another career track for postdocs transitioning into the mid-career stage that could be explored are "staff scientist" positions that are not tenure-track, but could be ongoing (contingent upon funding). This provides at least one option for some postdocs to make use of their astronomy-specific training within an academic setting. Given the broad knowledge and advanced training of those who would fill such positions, this is a particularly attractive option if the overall number of postdocs in astronomy decreases, either due to a smaller number of longer-term (i.e. 5-year) postdocs receiving funding, or due to earlier transitions to alternate careers (e.g., immediately after the PhD stage rather than after 1-2 subsequent postdoc terms).

3.3.4 Training for Supervisors

As supervisors of PhD students and managers of postdocs, senior people also have a duty to make their charges aware of the potential for career variation. Information and training should be made available for all supervisors to become aware of the career resources and direction available to their students and postdocs. The "Science to Data Science (S2DS)" workshops, for example, aim to train analytical PhD graduates in the commercial tools and techniques needed to be hired into commercial data science roles.

Supervisors should have open discussions with students about potential career options. Students should be encouraged to follow the employment path that suits them best – whether that is within, or outside of, astronomy.

3.3.5 Equity and Access

The issues associated with women in Astronomy have been higlighted in recent years with the formation of the Women in Astronomy Chapter of the ASA. Despite the name, the chapter has interests in equity of opportunity and access for all groups. Annual workshops highlight the issues and necessary actions to an increasing cross-section of the astronomical community.

Many actions are well known, for example jobs that can be offered as part time should be advertised as such in order to support people returning to the field from career breaks for whatever reason. Often such breaks are for family reasons and particularly affect women, however they might also be to explore *non-astronomy,* career-related work experience opportunities. Breaks should be stigma-free and should not count against a candidate during job selections.

CAASTRO has been pro-active in recent years in setting an example on these issues. Recently the Women in Astronomy chapter has launched its Pleiades Awards (http://asawomeninastronomy.org/the-pleiades-awards/) to recognise orgnaisations employing astronomers that take active steps to advance the careers of women through focused programs and strive for sustained improvement in providing opportunities for women.

Recommendations

C7 Aim for longer post-doctoral positions – 3 year minimum, preferably 5 years if possible.

C8 When assessing a researcher's portfolio, the broad range of skills they have should be considered – eg. software/instrument development, outreach, other service should be assessed along with the usual publication metrics.

C9 Promote fellowship schemes (e.g. Future Fellowships) as a vital option for mid-career researchers transitioning from post-doc to permanent positions.

C10 Promote an increased number of (non-tenured) "staff scientist" positions funded as an alternate mid-career path within academia. This would improve retention of highly skilled workers within the discipline, and would mitigate to at least some degree the disparity between the current large number of postdocs and the small number of available mid-career positions.

C11 Train supervisors to have open discussions with students about potential career options.

C12 Create a contacts list of ex-astronomers who have entered the workforce and a database of opportunities for retraining such as the "Science to Data Science (S2DS)" workshops.

C13 Promote efforts to ensure genuine equity of access and opportunity in all positions within astronomy. For example, advertise positions as available part-time wherever possible to support career breaks.

3.4 Recognition of Science Communication / Outreach

That research is important goes without saying, but so too is the communication of that research; a potential Nobel Prize winning discovery won't win any prizes or aid society if it goes no further than the researcher.

The ability to convey this science to other researchers through conferences, seminars and publications is well established in astronomy as these efforts appear in CVs. Less apparent are efforts to convey the science to the ultimate boss of all publicly funded institutions, the taxpayer and their representatives, the ministers in charge of science.

By promoting awareness of science and highlighting the benefits of a scientifically literate and engaged community, researchers aid the entire field by raising its status, which is particularly valuable at times of limited government budgets. However, currently this effort is not tracked and hence is seen as an opportunity cost, in which the scientist has spent their potential research time aiding the field at the expense of their own research career. This is particularly important for the early career researcher with a limited publication record, yet it is precisely these postdocs and PhD students who undertake the bulk of outreach activities in Australia. We suggest several steps that can be taken to address this issue.

3.4.1 Establish general metrics to track 'success' in outreach

By formally recognising outreach efforts and their inclusion in professional development reviews we can ensure that early career researchers are bolstering their CVs as well as encourage more senior staff to participate in these activities. While we don't advocate one metric over another (delivery methods rapidly change online for example) it is crucial that universities and funding bodies work towards developing general targets that can apply to a range of desired goals without being prescriptive as to the method.

3.4.2 Consideration of outreach efforts and plans in grant applications

To encourage senior staff to undertake outreach themselves, or recognise the value of staff engaging in it, the evaluation of grant proposals should include both outreach efforts to date as well as detailed plans in the future if the grant is successful.

3.4.3 Proposal evaluation after the award

Sustained outreach efforts can be encouraged by requiring researchers to account for their ongoing outreach efforts as part of the standard update reports of their grant. Also consider that "outreach" may also include formal "education" initiatives. Recognition should be given to the idea that astronomers do not necessarily have to deliver the outreach or education themselves but could collaborate/assist other professional, e.g. teachers or science communicators in developing or delivering programs.

3.4.4 Time Allocation Committees to consider outreach statements

Time Allocation Committees such as ATAC and ASTAC, for example, already encourage applicants to detail outreach efforts with potential data that they plan to acquire through tax-payer funded telescopes and supercomputers. We suggest the significance of this section should increase and be seen as standard in all allocation committees to encourage the transfer of data (as well as results) from the scientific field to the public domain as quickly and understandably as possible.

Every researcher engaged in outreach activities will encounter a scientist or funding committee who, whether explicitly or implicitly, does not value these efforts. To change this attitude is a long battle but it begins by making the activity a part of a process for assessing access to publicly-funded facilities.

Recommendations

C14 Establish general metrics to recognise and track ‘success’ in outreach and consider these in the evaluation of job applications and grant or time allocation proposals.

4. Outreach

Astronomy is fortunate that the public has such a strong interest in astronomical science, astronomical events and night sky phenomena. However, this opportunity also carries a responsibility for the astronomical community to ensure public accessibility of timely, relevant and accurate information to engage their interest. As well as imparting specific knowledge of astronomy, these efforts also improve the scientific literacy of the community and can encourage positive attitudes towards science.

The Australian community is well served by outreach programs delivered around the country by individual researchers and educators in universities, research organisations, science centres and planetaria. Astronomy also has the unique resource of dedicated amateur astronomy societies, with members who are passionate about their hobby and eager to share their awareness with others. It is widely recognised that improved information sharing and broader collaborations between professional, amateurs and public facilities is highly desirable to increase the reach and impact of astronomy outreach across Australia.

The community of professional astronomers can also benefit from the experience of working with public museums, science centres, planetaria and amateur astronomy groups. Such partnerships provide an avenue for researchers to communicate their research to a broad audience and offer opportunities to hone their communication skills. More than ever, research astronomers need to connect with the public to build broad support for science funding and ensure the vitality of Australian astronomy into the future.

In this section we describe some current programs and statistics and recent developments. The attempt to gather this information emphasises how widespread and diverse the efforts in astronomical outreach in Australia are. Getting a better picture may be better handled as an ongoing effort, perhaps managed by EPOC and/or a current outreach and education provider, in the same way that demographic data is routinely gathered by the Women in Astronomy chapter. To succeed this initiative would require a national coordinator tasked with overseeing the delivery of the project, with the support of representatives in each state. It would lead to the establishment of a publicly accessible repository containing the details of programs, providers and resources.

Recommendation

O1 A national audit be undertaken of astronomy outreach programs, providers and resources, leading to the establishment of a publicly accessible repository and perhaps some national coordination.

4.1 Planetaria

Planetaria across Australia are form a small but vibrant community under the auspices of the Australasian Planetarium Society (APS), which also includes planetaria across New Zealand and the Australasian region and is an affiliation of the International Planetarium Society (IPS), the global association for planetarium professionals.

Established in 1998, APS has grown in the past decade to promote the exchange of ideas, information and experiences within the planetarium industry. The Society meets annually, shares developments through the APS website and blog, and provides a forum for representing the Australasian region on an international scale.

A highlight for the Society was the hosting in 2006 of the 18th International Planetarium Society Conference held in Melbourne which was the first time that the IPS had gathered in the southern hemisphere and provided the opportunity to showcase both the Australian planetarium and Australian astronomical communities.

The APS consists of 14 institutional members, five international commercial members and a number of individual members. A survey was distributed to the APS in June-July 2014 which generated five responses. These were from the Sir Thomas Brisbane Planetarium, Horizon: the Planetarium, Melbourne Planetarium at Scienceworks, Queen Victoria Museum and Art Gallery Planetarium and Sydney Observatory. The following extensive report incorporates data collected from this survey and from APS member reports produced annually as part of the APS annual conference.

4.1.1 Attendance

Fixed planetaria in Australia are quite diverse with a great variation in size, funding models and organisational set-up. Table 4 describes the fixed planetarium facilities across Australia, including their annual attendance figures. It is noted that for three of the planetaria – Wollongong Science Centre & Planetarium, Sydney Observatory and Bendigo Planetarium – the attendance figure reflects the total attendance across their facility rather than planetarium audiences alone, since the planetarium is not a separately ticketed venue.

State	Planetarium	Funding model	Seating Capacity	Average number of shows daily	Annual Attendance (2004-2005)[1]	Annual Attendance (2011/2012)	Annual Attendance (2012/2013)
WA	Horizon: the Planetarium, situated within Scitech, Perth	government and corporate sponsorship, particularly lotterywest	180	4 - 5	60,000	100,000 (+7,500 portable space dome)	97,500 (+13,000 portable space dome)

VIC	Melbourne Planetarium, situated within Scienceworks, Museum Victoria	state government	155	5	110,000	136,000	135,000
QLD	Sir Thomas Brisbane Planetarium, Brisbane	local council	133	4-6	57,000[2]	59,000	58,000
NSW	Wollongong Science Centre and Planetarium	government and sponsorship	70		47,000[2]		
SA	Adelaide Planetarium, University of South Australia, Mawson Lakes	university	45		6,500	--	14,500
TAS	Queen Victoria Museum and Art Gallery Planetarium, Launceston	state government	39	2	5,000	7,000	6,500
NSW	Sydney Observatory	state government	20	3-5		179,000[2]	182,000[2]
VIC	Bendigo Planetarium, situated within the Bendigo Science and Technology Centre	state government	18	2	50,000[2]		

1. Taken from previous Decadal Plan
2. Figures represent entire facility which includes the planetarium

Table 4: Annual Attendance at Australian Planetaria

The International Year of Astronomy (IYA) in 2009 appeared to boost visitor numbers to planetaria, but it is difficult to separate the contribution of IYA from other factors, such as changes in advertising practices, changes in programming, or upgrades to facilities. As an example, visits to Scienceworks (site of Melbourne Planetarium) rose almost 50% around this time, but mainly because of the Star Wars Exhibition that opened in June 2009!

For the majority of planetaria, the attendance is dominated by family audiences, representing approximately two-thirds of the totals. The remainder consists primarily of school groups, who are offered programs that are usually either targeted to meet individual schools' requirements or deliberately aligned to the national curriculum. Exceptions to these numbers are the Queen Victoria Museum and Art Gallery Planetarium, which has a roughly 50-50 split between families and education groups, and Sydney Observatory which attracts 42% of tourists, the highest percentage for any planetarium. It is fitting that Sydney Observatory is on the UNESCO/IAU Heritage of Astronomy portal.

In addition, there are an unknown number of portable planetarium providers that spend the majority of their effort serving school communities, with the added convenience of being able to take the planetarium into the school environment.

Even though a large portion of the visitation for fixed planetaria is due to family and schools audiences, many facilities have also introduced specific programs tailored for adults such as Scitech's "After dark", Sir Thomas Brisbane Planetarium's "Saturday Night Live" and Scienceworks' "Big Kids Night Out" and "Discover the Night Sky" sessions.

4.1.2 Planetarium Shows

The core business of planetaria is planetarium shows - either pre-recorded or live presentations. All Australian planetaria place a strong emphasis on incorporating a live night sky segment in their planetarium sessions. It is clearly a strength of the planetarium and highly valued to give audiences the wherewithal to navigate the night sky. It is also an opportunity for many planetaria to introduce Australian indigenous night sky teachings.

Importantly, the past decade has seen a major change to the technology of planetaria with the introduction of fulldome projection. For the first time, this has enabled planetaria to easily share content across facilities and in response, the industry for producing and licensing planetarium shows has undergone a rapid growth. Planetaria can purchase new planetarium productions at reasonable costs and provide audiences with a wide variety of programs (both astronomy and non-astronomy) that can be regularly changed to capture repeat visitation.

Australia's three major planetarium facilities – Horizon Planetarium (Scitech, Perth), Melbourne Planetarium (Scienceworks) and Sir Thomas Brisbane Planetarium - were the first to switch to the new technology throughout 2005 and since then all fixed planetaria and many portable ones have acquired the funding to upgrade to the new technology.

In 2013, as a sign of the ongoing success of fulldome projection, the Sir Thomas Brisbane Planetarium, Melbourne Planetarium and Horizon Planetarium once again upgraded their equipment, to renew the technology of their systems. In addition, Sydney Observatory introduced a new fulldome system and upgraded their modest planetarium facilities in April 2013.

A further advantage of this new technology is that it ensures planetaria provide a high-quality cinematic experience, as is now expected by a digital-savvy audience. A limitation of the technology is that it requires continual upgrades to remain technologically up-to-date. Melbourne Planetarium has successfully secured ongoing funding to support the changing nature of technology and allow for planned equipment upgrades every 3-4 years. It is hoped that this model may be adopted by other Australian planetaria to sustain their viability.

Melbourne Planetarium is the only Australian planetarium with an established in-house production facility and has recently released its seventh fulldome production for international licensing. Its productions are now screened within Australia and across 50 planetaria world-wide including New Zealand, USA, Canada, Europe, Argentina, India, Turkey and South Korea. Other astronomy-related planetarium productions produced in Australia include: 'DARK' produced by Peter Morse and Paul Bourke from University of Western Australia in collaboration with Scitech and ICRAR, and 'Heart of the Sun' produced by Australian IMAX director/producer John Weiley. Both of these productions have also been successfully distributed internationally.

4.1.3 Collaborations with astronomy researchers

The Planetarium community is highly supportive of collaborating with astronomy researchers and being a conduit for researchers to engage with the public. However, it is an area which could be improved and developed.

Most planetaria are opportunistic in regards to hosting public lectures by Australian or visiting international research astronomers. The exceptions are Sydney Observatory, which has an annual program established with the AAO and Horizon: the planetarium, which hosts events with research astronomers at least four times a year.

Horizon planetarium is also one of the three main supporters of Astronomy WA, which brings together local universities and astronomy organisations including ICRAR and CAASTRO, amateur astronomy groups, government departments and public museums. The collaboration aims to use astronomy to raise the profile of science with the people of Western Australia. The major public engagement program of the collaborative is the annual Astronomy WA Astrofest, which attracts over 3,000 people each year and sets a great example for other states to follow.

The Melbourne Planetarium is currently working with astronomers to bring astronomical research to the public via two different forums. It has formed a partnership with CAASTRO to create a planetarium show based on CAASTRO research for delivery in 2015. This production and additional support material will be made available to all planetaria across Australia and New Zealand under a no-cost licensing arrangement and using the network of the APS.

Secondly, the Melbourne Planetarium has collaborated with astronomers from the GAMA survey team to incorporate all major Australian astronomical datasets – 2dF, 6dF, GAMA and WiggleZ – into the planetarium system. This presents a perfect opportunity for conveying the depth of Australian astronomy research to the public. This data visualisation was highly acclaimed at the 2014 International Planetarium Society Conference in Beijing and will soon be rolled out to planetaria world-wide.

Sydney Observatory's unique position as an astronomy heritage site has enabled it to undertake academic research in the history and heritage of astronomy in Australia, particularly with a focus on New South Wales.

The Adelaide Planetarium takes part in the annual Southern Hemisphere Summer Space program conducted by the University of South Australia. Students of the program spend an evening at the planetarium and are joined by special guests such as Australian-born astronaut Dr Andy Thomas and Italian astronaut Paolo Nespoli.

Lastly, planetaria are also fortunate to gain a new source of content provider with the European Southern Observatory (ESO) now creating fulldome content that is freely available to planetaria. These new resources, along with access to embargoed press results through the ESO Science Outreach Network, are a valuable resource for Australian planetaria to provide current and up-to-date astronomy information to the public. It complements the public outreach work that has been done by NASA for several decades.

4.1.4 Other activities

Apart from planetarium shows and research collaborations, planetaria are also involved in a wide range of outreach activities including astronomy courses, public astronomy nights, teacher orientations, sleepovers, star parties and dinners. Most planetaria have close links with local amateur astronomical societies and provide meeting spaces or coordinate events in partnership with the amateur astronomers. Some of the most successful activities are centred around 'events', with the transit of Venus in 2012 being a notable recent example at most facilities.

Australian planetaria are also highly effective at engaging local and national media with regular contributions including: writing articles and feature columns for newspapers and astronomy magazines; participating in regular radio spots; conducting radio and television interviews; and alerting the media to upcoming astronomical events.

The most common types of publications produced by planetaria include teachers' packs, information sheets on astronomical topics and night sky notes, the majority of which are published online. Planetaria also handle public enquiries on a daily basis, with the majority received by email and coming from interested adults with general questions about night sky phenomena, purchasing a telescope or astronomy in general.

All planetaria have an online presence with a web site, electronic newsletter or blog that is often shared with their host science centre. The major change in online offerings in recent years has been the growth in social media, with most centres now offering Facebook or twitter.

Sydney Observatory has certainly led the field in regards to its social media outreach with a well-established blog and twitter feed and a forum for reporting meteor sightings called “Lights in the sky”. It has also had great success with live-streaming of astronomical events such as eclipses and occultations, and in particular over 1 million people world-wide viewed its coverage of the 2012 Transit of Venus.

4.1.5 The role of Planetaria in society

With the wealth of astronomy information now freely accessible by the general public, the role of planetaria has shifted somewhat. Rather than being the sole public information provider, planetaria now create social opportunities for the public to engage with science. They have the unique ability to regularly offer memorable astronomical experiences to a broad sector of the population. This is more efficient than spasmodic outreaches to schools and community groups which often come about due to the generosity and networks of an individual astronomer.

Planetaria need to be an accurate source of astronomy information and it’s by forming collaborations and working with the astronomical research community that Australian planetaria can be sure to provide the best and most up-to-date content while also motivating public support for astronomy research.

4.2 Observatories and their Visitors’ Centres

These facilities fall into three classes. Some are visitors' centres associated with major astronomical facilities (the Exploratory at Siding Spring, Parkes, Narrabri, and Tidbinbilla). Others are publicly owned facilities existing primarily to educate the public, host school events, and give the public the opportunity to observe the sky using small optical telescopes (e.g. Ballarat Observatory, Perth Observatory, Sydney Observatory) . In addition, a small number of private observatories from the ASA’s Designated Observatory list responded to the survey. Some of these amateur observatories also engage in education and community outreach.

The Table below shows the attendance figures reported for observatories and visitors' centres in Australia. The International Year of Astronomy in 2009 (see 4.4.1) generated a boost in visitor numbers. Sydney Observatory received 182,000 visitors in calendar year 2009 — a big increase on the usual number for preceding years of around 140,000.

The visitors’ centres attached to professional observatories predominantly attract tourists, from families to seniors. They provide displays, exhibitions and audio-visual theatres but their main attraction is to allow people to get up-close to professional telescopes.

Like the planetarium community, observatories have taken advantage of new and more affordable technologies. For instance, several locations have been operating 3-D theatres or presenting 3D astronomy content in partnership with Swinburne University of Technology (CSIRO Parkes Observatory, Sydney Observatory, Ballarat Municipal Observatory & Museum, the Grote Reber Museum, the University of Western Sydney and the ANU at Mt Stromlo Observatory).

In contrast, the Narrabri Visitors' Centre is now unstaffed but open during normal business hours due to funding cuts to CSIRO. The Mt Stromlo Visitors' Centre remains closed since the 2003 bush fires (but a café has been open and will undergo refurbishment in 2015). Publicly funded observatories not associated with national facilities are now a rarity. In 2013 the state-government-funded Perth Observatory closed its research programs but the Observatory continues to offer tours and educational programs.

Sydney Observatory continues to offer night and day astronomy tours and educational programs on its listed heritage site. These include telescope viewing, a digital planetarium and museum. A new accessible dome, modern telescope and restored astrograph will open early 2015. There is a plan to increase education and tourism attendances to coincide with the staged opening of Barangaroo. The Sydney and Perth observatories produce annual sky guides, and many observatories produce fact sheets. Most facilities have dedicated school programmes, and provide worksheets and information on the facility itself.

Other small observatories are typically run by individuals and centre around giving visitors the opportunity to view astronomical objects for themselves.

	2004-2005 year	2013 calendar year
Parkes Radio Telescope	120,000	85,000
Australia Telescope Compact Array (Narrabri)	11,000	12,500
Canberra Deep Space Communication Complex (Tidbinbilla)	70,000	68,000
Siding Spring Exploratory	19,000	
Sydney Observatory	135,000	182,000
Perth Observatory	9,000	
University of Southern Queensland	2,100	450
Macquarie University Observatory	2,200	700

Table 5: Annual Attendance at Australian Observatories and Visitors' Centres
[more data is available in the Demographics Survey]

Recommendation

O2 It is important that professional astronomy observatories and organisations have in-house education/outreach expertise. They should employ an “Outreach Officer” on staff. Also, we emphasise the importance of public observatories, museums and science centres that offer astronomy content maintaining staff with astronomy training.

Case Study - Sydney Observatory

Sydney Observatory is an astronomy heritage site, public observatory and museum. Its main purpose is education in contemporary astronomy and the collection and preservation of Australian astronomical heritage, particularly that associated with New South Wales. In recent times the communication of astronomical events and a broad range of related themes has attracted significant audiences on-site (180,000 per annum in 2012-13), through outreach, online and via the popular media. The popular Australasian Sky Guide is in its 24th year of publication.

Sydney Observatory has a sustainable, curriculum-based and well-established education service delivered by expert astronomy communicators to schools and the public. This is through guided telescope tours, the 3D Space Theatre programs developed by Swinburne University, a Digital ‘Sydney Planetarium’, publications, exhibitions and smartphone Apps. As part of the Museum of Applied Arts and Sciences (MAAS), Sydney Observatory is one of three venues, with an exhibition, collections management and a touring exhibitions service.

Live streaming astronomical events, an active social media and content rich astronomy-based website and blog are capabilities. A new dome is currently under construction, which will be fitted with a DFM 40cm telescope and an articulated eyepiece suitable for use by people with disabilities.

Sydney Observatory offers University students training in public outreach and employs ~30 undergraduate, postgraduate and doctoral students as casual astronomy guides. It also conducts an active work experience program for ~150 Year 10 school students per annum and supports the Public Education Foundation, the Starlight Foundation (training Captain Starlight) and schools across NSW. Sydney Observatory offers opportunities for affiliated societies to meet and to host guest lectures and events. It assists other organisations with outreach.

4.3 Astronomical Societies

There are at least 50 known astronomical societies or clubs in Australia (see http://astronomy.org.au/amateur/amateur-societies/australia/). The contribution of a vibrant amateur community to research, education and outreach cannot be overstated.

Each astronomical society is a local group where amateur astronomers and other interested members of the public the public can come together to share their passion and learn astronomy.

Events organised specifically for society members include regular meetings and access to dark sky sites, as well as astronomy courses and lectures by professional astronomers.

Some of the members conduct valuable astronomical research projects, as recognised by the biennial Berenice and Arthur Page Medal awarded by the ASA. This award is presented at the biennial National Australian Convention of Amateur Astronomers (NACAA).

Survey responses were received from a subset of these societies. Membership numbers, where given, ranged from about 20 to about 1000. Based on the responses received, a reasonable figure for the total membership of amateur societies in Australia would be in the vicinity of 4000.

Many societies also run successful and valuable public programs and events. These are often organised to take advantage of specific astronomical phenomena such as the Transit of Venus or Opposition of Mars. However, they also include regular visits to schools to provide students with easy access to telescope observations. Typical survey responses showed public outreach attendance figures of a few hundred per year. The Ballarat Astronomical Society in Victoria quotes annual attendance figures at the Ballarat Observatory as over 3000, while the Port Macquarie Astronomical Society in NSW has about 3500 visitors per year at its observatory. Based on the surveys received, an estimate for all such public outreach attendances would be in the region of 20,000.

Club newsletters dominate publications produced by astronomical societies, although in some cases other publications are made more widely available. One example is the Astronomical Society of Victoria's Yearbook, containing details of astronomical phenomena.

Many societies have websites and it is often through these that enquiries relating to astronomical phenomena are directed. The societies are also very good at working with media and in particular have formed strong relationships with local newspapers and/or radio programs.

One comment made throughout the Working Group Town Hall meetings concerned the lack of interaction between amateur societies and the ASA despite the good links between some individuals in both communities and the regular talks by professionals to some astronomical societies.

Recommendations

O3 The community in general and the ASA in particular should explore ways to build more links between the amateur and professional communities.

4.4 Interactions with the Professional Community

4.4.1 IYA 2009

At an international level, IYA was coordinated by a small Secretariat attached to the IAU. Australian IYA activities, however, were planned and funded through the Australian National

Node which was the AAO. An Australian Advisory Group advised on the general strategy for running the Year, including possible sources of funding. Throughout 2009, IYA was coordinated by Helen Sim with assistance from members of a small Working Group. “Science in Public”, a Melbourne-based consultancy, was hired to assist with planning IYA and to seek funding.

The major Australian funding for IYA came from the then Department of Innovation, Industry, Science and Research, since the global financial crisis of 2008-9 led to a tightening of the purse strings across both the public and private sectors, and other expected sources of funding evaporated. This changed the nature of the funding arrangements from an open, competitive process to funding a number of specific projects. The ASA was able to provide “seed funding” for a number of outreach proposals submitted by the community.

The specific aims of the Year in Australia were to:

- Raise awareness of Australia's contributions, strengths and role in astronomy.
- Use astronomy to encourage people, particularly young people, to engage with the natural world and deepen their understanding of it through education.
- Promote understanding of how science is done, using astronomy as an appealing example.
- Promote appreciation of the scientific and technological skills that enable discovery in astronomy and are themselves driven by its challenges.

Key points list to arise from IYA:

- Around 600 IYA events were run in Australia.
- Education projects and materials were the “products” most likely to have a successful “afterlife” following IYA.
- The (international) projects that have continued after IYA have been those supported by passionate individuals.
- Projects that use existing delivery networks are the most effective way to reach large numbers of people.
- Organisers of future International Years or similar undertakings should provide standard evaluation tools to volunteer event organisers.

Case study: ‘Astronomy WA Astrofest’

As Australia’s biggest astronomy event, the Astronomy WA Astrofest in Perth, is an excellent example of what can be achieved when the astronomical community comes together.

Astrofest has been wowing thousands of members of Perth’s public with WA’s beautiful night sky annually since 2009. Astrofest involves every astronomy organisation in Perth for an evening of astronomically themed education and family fun.

Telescopes look at distant objects, and stalls from local astronomy organisations provide information and activities for visiting families. Space domes (inflatable planetaria) and engaging science shows entertain children, while talks from local astronomers highlight local science. Visitors also have the opportunity to learn more about the Square Kilometre Array radio telescope and can create their own Lego radio antenna.

Astronomy WA is a highly effective collective of university astronomy departments, local observatories, amateur astronomy clubs, interested primary and secondary teachers, the local planetarium and any other astronomy related business in Western Australia. Meeting quarterly, the Astronomy WA group ensures the astronomy community in WA is strong, connected and sharing the research going on in Western Australia with the public.

Astrofest is an Astronomy WA event coordinated by the International Centre for Radio Astronomy Research (ICRAR, a joint venture of Curtin University and the University Western Australia) with organisational support from Scitech, WA's science museum, the Astronomical Group of WA, an amateur astronomy club, and many others.

Over 12 organisations and 80 staff and volunteers are involved in making Astrofest a success each year, and the 4,000+ people that attend the event are always impressed - over 98% of them ask for another Astrofest every year!

A diverse cross section of the Perth community attends Astrofest, with over 70% of attendees having not attended an Astrofest before. The age groups represented span fairly evenly from children, through to older adults. Astrofest also has great impact within the community, both in inspiring interest in astronomy and science, but also in communicating the major projects that are underway in Australia:

- 89% of attendees said that Astrofest was a good way to learn about astronomy,
- 88% said they felt more inspired about astronomy after Astrofest,
- 86% said they were more interested in astronomy after Astrofest,
- 82% said Astrofest made them want to find out more about astronomy,
- 66% said that Astrofest has made them feel more confident about astronomy, and
- 60% said that Astrofest had changed the way they thought about astronomy.

Since the first Astrofest in 2009, smaller regional events in Carnarvon, Mount Magnet and the Murchison have also started, supported by the Perth Astrofest team, and another offshoot event inspired by Perth's will be held in Sydney in 2015.

4.4.3 Seed funding program

Although the IAU General Assembly in 2003 and the IYA in 2009 saw increased communication and cooperation between the professional and amateur communities, generally there is a lack of awareness among amateurs of the ASA in particular.

One way to address this suggested in the Town Hall meetings is to re-invent the "seed funding" program the ASA ran during IYA. In that program the ASA provided $8000 to facilitate astronomy outreach activities in the general community. 58 applications were received asking for a total of about $78,500 - i.e. the program was oversubscribed by a factor of ten! The proposals were assessed by a small panel against the following criteria:

- reaching a new audience
- reaching outside the cities
- wide public reach
- making an event/activity viable that may not be otherwise
- encouraging people to continue an involvement in astronomy

- kick-starting an event/activity that will become sustainable by establishing a program that may then continue from other funding streams/income

Recommendation

O4 The ASA should consider re-inventing the “seed funding” program as a way to build profile in the amateur community in particular. A modest program of several thousand dollars every 1 or 2 years may be sustainable. ASA’s EPOC may be the suitable body to run the program.

4.4.4 Citizen Science

In recent times, great strides have been made towards the advancement of instrumentation and computing power. Following the footsteps of particle physics, observational astronomy in Australia is moving towards large all-sky surveys using these next generation instruments (e.g. the Australian Square Kilometer Array Pathfinder, ASKAP and Taipan etc). A direct consequence of these next generation projects/surveys is the emergence of "big data" science.

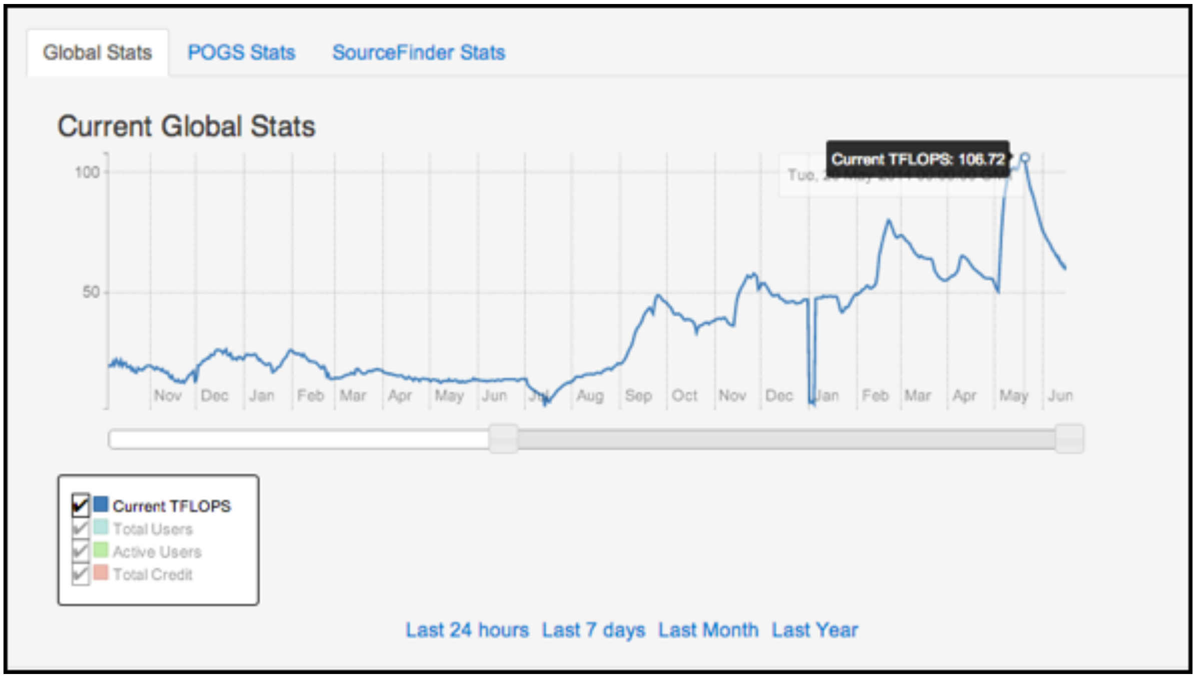
Case Study 1:
theSkyNet – people powered computing for astronomical research

On September 13th, 2011 theSkyNet officially launched. In a little over 24 hours 3,000 people from around the world signed up, and within a week 50,000 had visited the website. Today more than 30,000 computers located in 112 countries have helped theSkyNet’s processing power peak within 10 TFLOPS of the 500th best supercomputer in the world.

TheSkyNet is an ambitious distributed computing initiative raising the public profile of astronomical research while simultaneously creating a research grade data processing resource for science.

TheSkyNet works on the principal that lots of small contributions, in this case computing resources, can add up to a significant resource for science. Members of theSkyNet donate their spare computing power to be combined into a distributed supercomputer that processes raw astronomy data before returning the data products for analysis.

Astronomy is a data intensive activity and as our engineers and scientists design, develop and switch on the next generation of radio telescopes, the supercomputing resources needed to extract science from this deluge of data are in increasingly high demand. TheSkyNet is designed to compliment these resources by allowing projects that lend themselves to a distributed computing processing environment to be catered for without the need for a dedicated supercomputer.



The User Experience

TheSkyNet 'experience' has been carefully constructed to appeal to those that are attracted to an engaging, colourful, interactive, modern and communal online experience. Using gaming strategies to influence positive behaviour is a great motivator, especially when it comes to the online community. Projects like SETI@home ask the online community to donate spare computing power rewarding their users with a screen saver, but as the online communities habits and expectations change and more projects compete for 'donors', it's important to find new ways to attract and retain users.

In the case of theSkyNet the "game" is about processing as much data as possible, as an individual and as part of a group (known as an alliance). Data processed and time connected to theSkyNet translates into credits for users and a ranking against others. The more machines you have contributing to your account or the more members you have in your alliance, the higher your ranking.

From the citizen science community theSkyNet receives CPU processing power for astronomical research and maybe an advocate that attracts new members. In return, the users can earn rewards, join or create alliances, meet and interact with other like-minded individuals, spruik their achievements to peers and perform tasks that increase prestige amongst this online community.

Research

TheSkyNet Pan-STARRS1 Optical Galaxy Survey (POGS) is one of the research projects currently utilising theSkyNet platform.

The project combines the spectral coverage of GALEX, Pan-STARRS1, and WISE to generate a multi-wavelength UV-optical-NIR galaxy atlas for the nearby Universe. From this, the project will calculate physical parameters such as star formation rate, stellar mass of the galaxy, dust attenuation, and total dust mass of a galaxy, on a pixel-by-pixel basis using spectral energy distribution fitting techniques. Once completed this will be the largest and most comprehensive database of its kind in the world.

TheSkyNet 'POGS' project utilises the distributed computing system BOINC (see Vinsen, K., Thilker, D. 2013 in *Astronomy and Computing*). The Berkeley Open Infrastructure for Network Computing (BOINC) was originally developed for the SETI@home project and has since been rebuilt into a generic framework for all kinds of distributed computing projects. BOINC has allowed theSkyNet team to develop the POGS project quickly and efficiently. As an added bonus BOINC allows POGS to tap into an extensive community of over 200,000 active volunteers.

Within the POGS project each volunteer's involvement is tracked on a per pixel per galaxy basis. With this data the website is able to display a list of galaxies that an individual user has worked on. Clicking on a galaxy reveals even more data, as we are able to show each user exactly which part of the galaxy they have been working on.

At its heart theSkyNet is about everyday computer users participating in a collaborative science themed effort, with each doing a little so that the sum of the parts adds up to a powerful tool for science.

Case Study 2:
The Radio Galaxy Zoo

Despite the great leap in computing power and algorithms, present-day automated computer algorithms for pattern recognition still pales in comparison to the human eye-brain combination for tasks such as classification of shapes; picking out filaments of low signal-to-noise features etc. Therefore until such computer algorithms become readily available, there is still need in the earlier years of the upcoming decade to accommodate alternative methods of data analysis such as citizen science via online environments such as the Zooniverse.

We can expect 70 million sources from the upcoming EMU (radio all-sky survey using ASKAP) survey. Unfortunately current algorithms will fail to match these radio sources with their host galaxies for approximately 10% of the sources. We are currently testing the feasibility of using the Zooniverse method to identify host galaxies via the Radio Galaxy Zoo project (radio.galaxyzoo.org). The Radio Galaxy Zoo project uses archival datasets from the FIRST and ATLAS surveys. Astronomers from several Australian institutes are actively involved in Radio Galaxy Zoo, with both Principal Investigators Australian-based.

The Zooniverse (www.zooniverse.org) is an online environment where public education/outreach actually contributes towards new science discoveries and publications.

Currently, the Zooniverse has an army of over 1 million volunteers spread across 22 projects. According to ADS, 43 refereed papers (with over 1300 citations) have resulted from the Galaxy Zoo project alone. It should be noted that the Galaxy Zoo project was only launched in 2007 (based on a survey which started in 2000) after the main slew of survey science papers were published by the SDSS team.

Such projects will also generate a vast amount of data for training and informing the development of the next generation machine learning algorithms. For example, Banerji et al. (2010) used the Galaxy Zoo dataset as a training set for an artificial neural network programmed to classify optical galaxy morphologies.

To maximise the scientific return on the large surveys that the Australian community is set to pursue in the coming years, we should acknowledge that citizen science has an excellent scientific role beyond public outreach/education and deserves the support of the community. The specific needs of these projects are not so much in processing but reliable/stable server hosting space where up and downloads of data dumps are possible.

Citizen science is obviously a valuable resource for both formal and informal education. The Zooniverse projects match closely with the three strands in the new Australian Curriculum in Science - Science Understanding, Science Inquiry Skills and Science as a Human Endeavour - particularly for the astronomy components in Years 5, 7 and 10 plus senior Physics.

4.4.5 Light pollution

Another area where the professional astronomy community has a particular common interest with the amateur community is in the impact of Light Pollution. The ASA maintains a list of 'Designated Observatories' (see http://asa.astronomy.org.au/observatories.html), indicating observatories (mainly amateur) that are deemed worthy of protection from obtrusive lighting because of their contributions to astronomy in research, education or community outreach. This list is related to Australian Standard AS4282 on "The Control of the Obtrusive Effects of Outdoor Lighting" that provides guidelines for planning authorities to ameliorate the effects of light pollution in the vicinity of observatories.

Standards Australia is the organisation that formulates, publishes and distributes documents covering a vast range subjects, of which lighting is one of particular interest to optical astronomers. It should be noted that *Standards Australia* is only one of the sources of documents used by planning bodies, including local government (councils etc), State and Federal governments. Councils develop their own Development Control Plans (or similarly titled documents) which can range from simple plans through to major and influential pieces of local legislation. The State Planning department often co-ordinates local government activities as well as producing over-riding plans. A good example of the latter is the Orana Regional Environmental Plan No.1, which was designed to protect the night skies around the Siding Spring Observatory. Federal Government plans include those issued by the Civil Aviation Safety Authority.

In NSW, the Department of Planning and Environment is the peak agency responsible for planning legislation, including regulations governing outdoor lighting. The Dark Skies Committee at Siding Spring Observatory works closely with both the Department and Standards Australia to maintain sky conditions in the face of major resource-extraction proposals in the district, including coal-mines and gas wells. At the time of writing, the State's planning regulations are in a state of flux, with new policies set to be introduced. The Orana Regional Environmental Plan will be repealed during the course of this Decadal Plan, and it is important to ensure that appropriate legislation is enacted to safeguard the night skies of Siding Spring.

A further challenge to dark-sky preservation is rapidly-changing lighting technology, in particular with the widespread adoption of energy-efficient LEDs for outdoor lighting of all kinds. This technology is advantageous in that it gives lighting designers more directional control over the emergent flux, but has the drawback of having a relatively high blue content, with colour temperatures often in excess of 4000K. This leads to more damaging horizontal scatter of upward light-spill.

All optical astronomers, both professional and amateur have an interest in good standards. The ASA has representation on some *Standards Australia* committees, while a few other astronomers are engaged at other planning levels.

4.5 Social Media

Every researcher should be encouraged to engage in social media activities, if interested, however appropriate training for individual researchers is required to maximise these efforts.

As a growing body of Social Media channels is available (current examples include Twitter, facebook, Instagram, LinkedIn, etc.), astronomers and organizations must be actively strategic in how they choose to communicate their science and research. The key is to develop a science communication strategy that combines conventional media (TV, radio, newspapers, magazines) with new media to reach the broadest possible audience without overlapping the effort of developing content and material.

All Social Media should be focussed on activities that provide an honest portrayal of research and outreach programs, in addition to astronomy in general. The key aspects of this approach are a thorough review of internal resources (personnel to maintain channels, likely frequency of news, technical knowledge for contents creation, funds if required) and the design of a long-term feasible Social Media communication plan.

Social Media is an evolving platform which will encompass new tools, apps, and websites over the coming decade. Flexibility in adapting to changing sources of communication should be practiced by astronomy organisations and individual professionals. Regular training of astronomers interested in engaging in social media is desirable to maximise its effectiveness.

In addition, training sessions will allow individuals to share information on what works and does not work.

Recommendations

O5 A Working Group should be established for a fixed period of time that will create a short two-page set of Social Media Guidelines for individual Astronomers. This should also include a page of "what to avoid" and the pitfalls associated with using Social Media.

O6 In order to maximise the effectiveness of a social media strategy, it is recommended that a short Social Media training session be held in conjunction with the ASA meeting each year with more detailed workshops comprising part of the planned EPOC Education and Outreach Conference.

Case Study: Pint in the Sky (PiSky)

PiSky is a mid-length (~10min) youtube video featuring Dr Katie Mack and Dr Alan Duffy discussing big astronomical themes in a relaxed setting, in this case, the pub! Currently 12 PiSky videos have been created that have been viewed over 17,000 times (with hundreds of 'likes').

The concept for a fun conversational piece on astronomical themes that could change how science was viewed (i.e. no white-lab coats and a 'cooler' setting) came from a CAASTRO organised outreach workshop in 2012. The format of the show features two people chatting about astronomy, starting with an explanation of a science result at a level that everyone could understand, but then rapidly ramp it up to research-level discussion.

An innovative approach to PiSky was to have viewers tweet questions that they would like to see answered. A third of the videos have featured these viewer suggestions but the success of this element of the show relies on more rapid turn-around of videos.

While PiSky is a fun and successful outreach platform it has proven to have fairly onerous post-production editing and content overlays (including the sourcing of such visuals etc). As with all outreach efforts, the success of the show depends on volunteer's time, in this case Alan and Katie, and for PiSky to continue to grow some funding may be required to hire a dedicated part-time producer.

4.6 Calendar of Events

The ASA already maintains a calendar of events for professional astronomers at http://asa.astronomy.org.au/calendar.html. This needs to be more widely publicised and used.

A larger calendar for the broader astronomical community is a more difficult undertaking, facing similar resource issues to a national repository of teaching resources (2.5). Such a calendar was available as part of IYA. It will only be useful if it is well-maintained and publicised. It would rely on organisations and individuals voluntarily submitting events and supporting the calendar and would also require ongoing administration. A host location/organisation would need to be identified and funded.

4.7 Role of EPOC

The ASA's Education and Public Outreach Chapter (EPOC) is currently reviewing and refining its role, goals and activities. It has the potential to support some or many of the outreach and education recommendations of the Decadal Plan but is heavily reliant on the good will and support of individual chapter members and support of the ASA. It plans to grow its profile to the professional community and via an increased online profile through an improved ASA website and social media to the wider public. This means that it may serve as the main point-of-contact for the public and community seeking astronomy education and outreach advice and materials. If it is to go further and be responsible for delivery of specific programs this would require additional support and funding. EPOC could also provide lists of experts in different areas of astronomy and astronomy education.

Another potential role is maintaining records of education and outreach groups, programs and events nationally. Again, the extent to which this is achievable and successful will depend upon the level of support and commitment by individuals and organisations.

Recommendation

O7 Initiate an ASA Outreach Award for individuals for interact strongly with the public and schools.

O8 Establish EPOC acts as the point-of-contact for professional astronomers and astronomy educators willing to be contacted by media, education and other organisations.

O9 EPOC should run biennial workshops for the professional astronomy community and other interested parties on effective outreach and education practice.

4.8 Aboriginal Astronomy and Astronomy Heritage

Astronomical heritage in Australia began more than 50,000 years ago when seafaring people navigated the sea from southeast Asia to Sahul (New Guinea and Australia), bringing their knowledge and traditions to the newfound South Land. Over the following millennia, Indigenous Australians continued to develop complex knowledge systems about the stars that were used for navigation, calendars, law, and social structure.

Captain James Cook sailed to the east coast of Australia after observing the Transit of Venus in 1769, but the history of Western astronomy in Australia really began in 1788 when the First Fleet landed at Sydney Cove. Lt William Dawes, the fleet’s First astronomer, established an observatory near the harbor at the place we now call Dawes Point. He also befriended a local Aboriginal woman named Patyegarang and recorded the local Dharug language and traditions, including names of celestial bodies, from his observatory. Since that time, the study of astrophysics and Indigenous astronomy has rapidly grown.

The history and heritage of astronomy forms an essential context within which to educate the public about past, contemporary, and future astronomy in a scientific and cultural context. It is an important component of the nations history and culture – before and after colonisation – to educate the public and preserve Australia's rich astronomical heritage. Currently there are two sites of astronomical heritage listed on the National Heritage database for astronomy: the remains of Parramatta Observatory and Mt Stromlo Observatory. There are plans to nominate Aboriginal heritage sites linked to astronomy. New astronomical facilities, such as the site of the SKA, are built on Aboriginal land. It is thus essential to maintain collaborations with Indigenous Australians for the mutual benefit of Indigenous culture and the future of astrophysical research.

The UNESCO/IAU Portal to the Heritage of Astronomy, and associated paper (Cotte & Ruggles 2010) provides a framework for astronomical heritage, which would be appropriate for Australia to adopt. This includes sites of cultural (Indigenous) astronomy, colonial astronomy, radio astronomy and sites 'strongly connected with the history of modern astronomy' (ibid.). The importance of 'cultural landscape' to astronomy is also embodied by this study.

Recommendation

O10 Promote research in indigenous astronomy to maintain our heritage and continued history of astronomical research.